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MONASH UNIVERSITY
THESIS ACCEPTED IN SATISFACTION OF THE
REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PSYCHOLOGY

ON.....3 June 2003.....

.....[redacted].....

Sec. Research Graduate School Committee

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Addendum

p. xii – delete Abstract and replace with the following: "This thesis investigated aspects of attention and motor function in children with Attention Deficit/ Hyperactivity Disorder (ADHD), combined type. The performance of unmedicated ADHD, medicated ADHD, and normal children was investigated on a task that required participants to respond to targets and ignore distractors. Unmedicated ADHD children when compared to controls showed slow and inaccurate responding. Slow responding reflected problems with movement preparation but not movement execution. Inaccurate responding reflected problems with response inhibition, selective attention, impulsive responding and difficulties maintaining vigilance. Set-shifting difficulties were also evident, in the form of higher distractibility errors (responses to distractors). Compared to controls, medicated ADHD children were not significantly slower in their responses. However, medicated ADHD children did make significantly more impulsive responses than controls. Perceptual biases were also investigated in normal children and children with ADHD, using various chimeric stimuli in free-viewing conditions. Leftward biases were found for normal children with no effects of age. Contrary to expectations, leftward biases were also found for ADHD children. Finally, in a bimanual coordination task it was found that compared to controls, ADHD children were significantly more variable in both velocity and coordination, and less accurate in coordination, when making simple in-phase bimanual movements. Similarly, ADHD children were also more variable in velocity and coordination, when executing complex out-of-phase bimanual movements. In summary, the results of this thesis indicate problems of attention, inhibition, set-shifting, and motor functioning in children with ADHD. Although results are preliminary, they suggest that some of these difficulties may be absent in ADHD children taking stimulant medication."

p. 24 – on the bottom of the page insert the following paragraph: "It must be taken into consideration that the above-mentioned studies, and those reviewed in Table 1, have a number of methodological problems that may help explain inconsistencies between them, and that limit generalization of their findings. These methodological limitations include small sample size (e.g. Hynd et al., 1993; Giedd et al., 1994; Baumgardner et al., 1996; Mataro et al., 1997; Filipek et al., 1997; Semrud-Clikeman et al., 2000; Lou et al., 1989; Zametkin et al., 1993; Vaidya et al., 1998; Schweitzer et al., 2000), inclusion of participants that are not medication naive (so that any effects may be caused by medication use; e.g. Castellanos et al. 1994,1996; Filipek et al. 1997; Zametkin et al. 1993; Schweitzer et al, 2000), inclusion of participants that have been used in other studies (e.g. Castellanos et al., 1996; Casey, Castellanos et al., 1997; Berquin et al., 1998; Semrud-Clikeman et al., 2000), and inclusion of individuals with comorbid diagnoses (e.g. Hynd et al., 1993; Castellanos et al., 1994, 1996; Casey, Castellanos et al., 1997, Berquin et al., 1998, Lou et al., 1989)."

p. 33 – at the end of the second paragraph, which ends with the words "...planned initiative." insert: "The supervisory attention system was later proposed (Stuss, Shallice, Alexander, & Picton, 1995) to function under four circumstances: when there is no known solution to the task at hand; when weakly activated schemata (schemata are routine programs for the control of overlearned skills) are evoked; when specific selection among schemata is necessary; and when inappropriate schemata must be inhibited. Further, rather than constituting a unitary process, the supervisory system was considered to consist of a number of component processes. These supervisory system processes were proposed to be involved in tasks that require sustained attention, concentrating attention, sharing attention, suppressing attention, switching attention, preparatory attention and setting attention (see Stuss et al., 1995 for a review)."

p. 34 – after the first paragraph, insert the following paragraph: "Another model of attention, formulated by Mirsky and colleagues (Mirsky, Fantie, & Tatman, 1995; Mirsky, 1996), stipulates that attention can be divided into five distinct functions: *focus/execute, sustain, shift, encode* and *stabilize*. In this model, *focus* refers to the capacity to concentrate on a specific task and to screen out distracting stimuli. When attempting to identify neuropsychological tests that measured this capacity, the authors were unable to separate focusing from the requirement of rapid responding, which resulted in use of the term *focus/execute*. The superior temporal gyrus, inferior parietal cortex, and the corpus striatum were identified as being involved in this function. *Sustaining* attention refers to the ability to stay on task in a vigilant manner for a reasonable interval, and involves rostral midbrain structures. *Shifting* attention is defined as being able to efficiently shift focus from one aspect of a stimulus to another, and involves the dorsolateral prefrontal cortex and the anterior cingulate gyrus. *Encoding* refers to the ability to hold information in mind for a brief period while performing some action or cognitive operation on it, and involves limbic system structures including the hippocampus and amygdala. Finally, the *stability* or reliability of attentional effort is proposed to depend on midline-thalamic and brain-stem structures. Upon testing ADHD children with a battery of neuropsychological tests that were thought to measure these functions, the authors concluded that children with ADHD are impaired in the focus/execute, shift, sustain, and stabilize aspects of attention (Mirsky, Pascualvaca, Duncan, & French, 1999).

p. 63 – before the last paragraph, insert the following paragraph: "It has been consistently found that stimulant medication reduces overall motor activity, reduces the latency of motor responses (reaction time), and decreases the variability of responding (variability in reaction time) in children with ADHD (Zahn, Rapoport, & Thompson, 1980; Douglas, Barr, Amin, O'Neill, & Britton, 1988) and in normal children (Zahn et al., 1980; Rapoport et al., 1978). However, the effects of stimulant medication on other aspects of motor functioning are not so clear. Lerer and Lerer (1976) observed that after 60 days of methylphenidate therapy, more than 70% of ADHD children showed an improvement in soft neurological signs, whereas none of the children receiving placebo did. A study by McMahon and Greenberg (1977), however, found a high degree of variability in neurological signs in ADHD children, which was not significantly affected by stimulant drug treatment. Balance (Wade, 1976) and handwriting (Lerer, Lerer, & Artner, 1977) of ADHD children has also been found to improve with administration of stimulant medication. However some other aspects of fine motor coordination, such as figure drawings, have not been observed to improve in ADHD children on stimulants (Greenberg, Deem, & McMahon, 1972)."

p. 68 – Delete the last paragraph and replace with the following paragraph: "In one study various aspects of attention and motor functioning were investigated in normal children, unmedicated ADHD children, and medicated ADHD children. The paradigm employed had the potential to quantify a variety of problems in a single, novel task. It measured the ability to inhibit distracting stimuli and the ability to inhibit a response, impulsive responding, inattentiveness or vigilance, motor performance, set-shifting and spatial biases. Spatial biases or perceptual asymmetries were further investigated in normal right-handed children and children with ADHD, through the use of various chimeric stimuli in free-viewing conditions. Finally, motor performance in children with ADHD was explored further, using a bimanual coordination task that required participants to produce simple symmetrical bimanual movements and complex asymmetrical bimanual movements at both slow and fast speeds."

p. 72 – following the first sentence under the Participants section, insert: "Normal children were not screened for ADHD but explanatory statements used in recruitment of normal children stated that: "We are seeking children aged 7 – 12 years of age, who have normal (or corrected to normal) vision, and who have not had any serious head injuries (involving loss of consciousness), or other disease or trauma affecting the brain. It is most important that your child has not previously had a diagnosis of ADHD, or any other childhood condition involving the brain." Further, the parents and teachers of normal children filled out a behavioural rating scale on inattentive and hyperactive-impulsive behaviour. Although this is not diagnostic in itself, none of the normal children acting as controls scored lower than one standard deviation below the mean."

p. 72 – on line 10 of the *Participants* section, insert: "These clinicians also made subgroup and comorbidity diagnoses. In the public paediatric outpatient unit children were assessed by a multi-discipline team, consisting of a psychologist, psychiatrist, speech therapist and occupational therapist."

p. 73 – at end of the first paragraph, insert: "Unfortunately it was not possible to select the medicated and non-medicated groups randomly because testing children off their typical doses of medication required parental consent. This opens the possibility that the medicated group of children could have differed from those tested off medication, e.g., by showing more severe symptoms."

p. 78 – on line 2, paragraph 1, insert: "Unfortunately, it was impractical given the intended scope of this thesis, and the limited resources available, to obtain information on socio-economic status. Therefore, normal children and ADHD children could not be matched on this variable. However, normal children were recruited through public rather than private schools to minimize any differences due to potentially higher socio-economic status of the control group."

p. 79 – under the *Demographic data* section, line 5, insert: "None of the controls fell in the clinical range (two or more standard deviations below the mean, or standard scores of 0-4) on the ADDES."

p. 80 – line 4 in the last paragraph, delete "19 ms" and replace with "119 ms".

p. 81 – In Table 3 insert the following ranges of ADDES scores:
Under *ADDES – School version. Mean overall percentile ranking.* For unmedicated ADHD children insert: "range = 11-55". For controls, insert: "range = 51-100". Under *ADDES – Home version. Mean overall percentile ranking.* For unmedicated ADHD children insert: "range = 0-31". For controls, insert: "range = 19-100". Under *ADDES – Home version. Mean inattentive ratings.* For unmedicated ADHD children insert: "range = 0-8". For controls, insert: "range = 7-14". Under *ADDES – Home version. Mean hyperactive-impulsive ratings.* For unmedicated ADHD children insert: "range = 0-9". For controls, insert: "range = 8-14". Under *ADDES – School version. Mean inattentive ratings.* For unmedicated ADHD children insert: "range = 5-11". For controls, insert: "range = 9-14". Under *ADDES – School version. Mean hyperactive-impulsive ratings.* For unmedicated ADHD children insert: "range = 5-12". For controls, insert: "range = 11-15".

p. 82 – delete Figure 2 and replace with the following Figure 2:

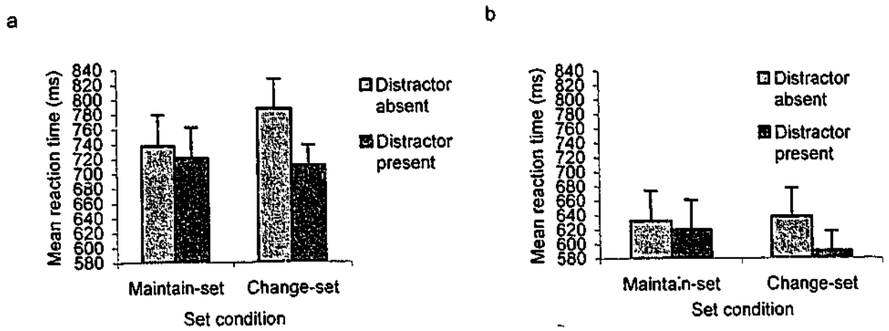

Figure 2: Mean reaction time (with standard error bars) for a) unmedicated ADHD children and b) control children in the no-reach task when distractor is present and absent, in maintain-set and change-set conditions.

p. 87 – before the section on Proportional errors, insert the following section:

Effect sizes

An overview of effect sizes (partial eta squared) for the main effects and significant interactions is presented in Table 3b. These effect sizes indicate the percentage of the total variation of the dependent variable that can be accounted for by the main effect/interaction (Cramer, 1994). In terms of interpreting these effect sizes, Cohen (1969) characterizes $\eta^2 = .01$ as small, $\eta^2 = .06$ as medium, and $\eta^2 = .14$ as a large effect size. Therefore, most of the effect sizes for the significant results can be considered as large.

Table 3b: Significance of ANOVA results (sig. = significant, ns. = not significant) and effect sizes (η_p^2) for main effects and significant interactions for the data in Experiment 1.

Variables	group	set	dist.	reach	target	dist. x set	dist.x group	set x group	target x group
Data									
Reaction time data in the reach task.	sig. $\eta_p^2 =$ 0.29	ns. $\eta_p^2 =$ 0.00	sig. $\eta_p^2 =$ 0.36	n/a	n/a	-	-	-	n/a
Movement time data in the reach task.	ns. $\eta_p^2 =$ 0.01	sig. $\eta_p^2 =$ 0.22	sig. $\eta_p^2 =$ 0.23	n/a	n/a	-	-	-	n/a
Reaction time data in the no-reach task.	sig. $\eta_p^2 =$ 0.20	ns. $\eta_p^2 =$ 0.00	sig. $\eta_p^2 =$ 0.36	n/a	n/a	sig. $\eta_p^2 =$ 0.34	-	-	n/a
Inattentive error data in the reach task.	sig. $\eta_p^2 =$ 0.30	sig. $\eta_p^2 =$ 0.21	ns. $\eta_p^2 =$ 0.05	n/a	n/a	-	-	-	n/a
Inattentive error data in the no-reach task.	sig. $\eta_p^2 =$ 0.34	sig. $\eta_p^2 =$ 0.16	sig. $\eta_p^2 =$ 0.41	n/a	n/a	sig. $\eta_p^2 =$ 0.26	sig. $\eta_p^2 =$ 0.17	-	n/a
Impulsive error data.	sig. $\eta_p^2 =$ 0.18	ns. $\eta_p^2 =$ 0.00	n/a	ns. $\eta_p^2 =$ 0.01	n/a	n/a	n/a	-	n/a
Distractibility error data in the reach task.	sig. $\eta_p^2 =$ 0.39	sig. $\eta_p^2 =$ 0.25	n/a	n/a	sig. $\eta_p^2 =$ 0.62	n/a	n/a	ns./ trend $\eta_p^2 =$ 0.12	sig. $\eta_p^2 =$ 0.25
Distractibility error data in the no-reach task.	sig. $\eta_p^2 =$ 0.20	sig. $\eta_p^2 =$ 0.21	n/a	n/a	n/a	n/a	n/a	sig. $\eta_p^2 =$ 0.18	n/a

n/a refers to variables that are not applicable to the analysis of those particular data. Dist refers to the variable distractor.

p. 89 – under the *Demographic data* section, line 5, insert: "None of the controls fell in the clinical range (two or more standard deviations below the mean, or standard scores of 0 - 4) on the ADDES."

p. 89 – delete *Section 3.4.8*

p. 90 – In Table 4 insert the following ranges of ADDES scores:
Under *ADDES – School version. Mean overall percentile ranking.* For medicated ADHD children, insert: "range = 1-84". For controls, insert: "range = 63-100". Under *ADDES – Home version. Mean overall percentile ranking.* For medicated ADHD children, insert: "range = 0-8". For controls, insert: "range = 27-100". Under *ADDES – Home version. Mean inattentive ratings.* For medicated ADHD children, insert: "range = 1-3". For controls, insert: "range = 8-14". Under *ADDES – Home version. Mean hyperactive-impulsive ratings.* For medicated ADHD children, insert: "range = 0-5". For controls, insert: "range = 8-14". Under *ADDES – School version. Mean inattentive ratings.* For medicated ADHD children, insert: "range = 1-12". For controls, insert: "range = 11-14". Under *ADDES – School version. Mean hyperactive-impulsive ratings.* For medicated ADHD children, insert: "range = 0-13". For controls, insert: "range = 11-14".

p. 91 – on line 2 delete "2.742" and replace with "4.451".

p. 94 – delete Figure 3 and replace with the following Figure 3:

a b

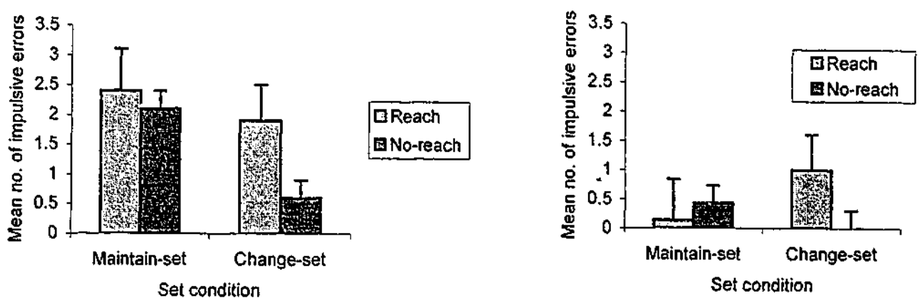

Figure 3: Mean number of impulsive errors (with standard error bars) made by a) medicated ADHD children and b) controls in reach and no-reach conditions, for maintain and change-set conditions.

p. 95 – delete Figure 4 and replace with the following Figure 4:

a b

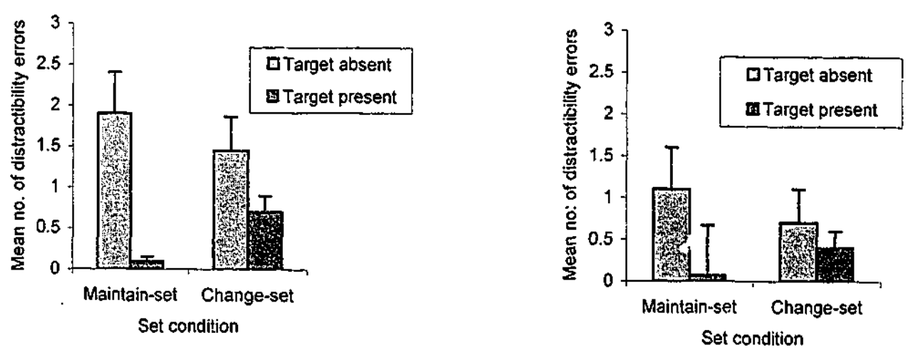

Figure 4: Mean number of distractibility errors (with standard error bars) made by a) medicated ADHD and b) control children for the reach task in the maintain and change-set conditions, in the absence and presence of a target.

p. 96 – delete Section 3.5.7, and prior to the section on Proportional errors, insert the following section:

Effect sizes

An overview of effect sizes (partial eta squared) for the main effects and significant interactions for Experiment 2 is presented in Table 4b. According to Cohen (1969) $\eta^2 = .01$ is a small effect, $\eta^2 = .06$ is a medium effect, and $\eta^2 = .14$ is a large effect. As can be seen from Table 4b, only very large effect sizes reached significance, which is expected from the small sample size in this Experiment.

Table 4b: Significance of ANOVA results (sig. = significant, ns. = not significant) and effect sizes (η_p^2) for all main effects and significant interactions for the data for Experiment 2.

Variables Data	group	set	dist	reach	target	dist x set	dist x group	set x group	set x reach	set x target
Reaction time data in the reach task.	ns. $\eta_p^2 =$ 0.07	ns. $\eta_p^2 =$ 0.19	ns. $\eta_p^2 =$ 0.25	n/a	n/a	-	-	ns./ trend $\eta_p^2 =$ 0.27	n/a	n/a
Movement time data in the reach task.	ns./ trend $\eta_p^2 =$ 0.26	ns. $\eta_p^2 =$ 0.12	ns. $\eta_p^2 =$ 0.08	n/a	n/a	-	-	sig. $\eta_p^2 =$ 0.39	n/a	n/a
Reaction time data in the no-reach task.	ns. $\eta_p^2 =$ 0.04	ns. $\eta_p^2 =$ 0.02	ns. $\eta_p^2 =$ 0.21	n/a	n/a	-	-	-	n/a	n/a
Inattentive error data in the reach task.	ns. $\eta_p^2 =$ 0.07	ns. $\eta_p^2 =$ 0.13	ns. $\eta_p^2 =$ 0.01	n/a	n/a	-	-	-	n/a	n/a
Inattentive error data in the no-reach task.	ns. $\eta_p^2 =$ 0.08	sig. $\eta_p^2 =$ 0.42	sig. $\eta_p^2 =$ 0.38	n/a	n/a	sig. $\eta_p^2 =$ 0.41	ns./ trend $\eta_p^2 =$ 0.27	-	n/a	n/a
Impulsive error data.	sig. $\eta_p^2 =$ 0.46	ns. $\eta_p^2 =$ 0.12	n/a	ns. $\eta_p^2 =$ 0.17	n/a	n/a	n/a	-	sig. $\eta_p^2 =$ 0.35	n/a
Distractibility error data in the reach task.	ns. $\eta_p^2 =$ 0.12	ns. $\eta_p^2 =$ 0.01	n/a	n/a	sig. $\eta_p^2 =$ 0.48	n/a	n/a	-	n/a	sig. $\eta_p^2 =$ 0.42
Distractibility error data in the no-reach task.	ns./ trend $\eta_p^2 =$ 0.25	ns. $\eta_p^2 =$ 0.01	n/a	n/a	n/a	n/a	n/a	-	n/a	n/a

n/a refers to variables that are not applicable to the analysis of those particular data. Dist refers to the variable distractor.

p. 97 – At the end of paragraph 3, insert: "Nevertheless, any comparisons between medicated and unmedicated ADHD children throughout this discussion are purely qualitative and must therefore be interpreted with due care."

p. 99 – At the end of line 2, insert: "As pointed out previously, these results are only preliminary and require replication in systematic studies of medication."

p. 99 – on line 17 of paragraph two, delete the sentence: "A case study outlining findings for two inattentive type ADHD children is reported in Experiment 5."

p. 102 – on line 11 delete the sentence: "Again, medication appeared to resolve this difficulty." Replace with: "Again, medication appeared to resolve this difficulty, although the design of this study prevents any firm conclusions about the effects of medication to be made."

p. 103 – under the *Demographic data* section, line 8, insert: "None of the children fell in the clinical range (two or more standard deviations below the mean, or standard scores of 0 - 4) on the ADDES."

p. 104 – In Table 5 insert the following ranges of ADDES scores:
Under *ADDES – School version. Mean overall percentile ranking.* For 7-8 year-old children, insert:"range = 25-100". For 9-10 year-old children, insert: "range = 10-95". For 11-12 year-old children, insert: "range = 55-100".
Under *ADDES – Home version. Mean overall percentile ranking.* For 7-8 year-old children insert: "range = 28-81". For 9-10 year-old children, insert: "range = 19-95". For 11-12 year-old children, insert: "range = 30-100".

p. 115 – prior to the section on Proportional errors, insert the following section:

Effect sizes

An overview of effect sizes (partial eta squared) for the main effects and significant interactions for Experiment 2 is presented in Table 5b. As can be seen from the table, most of the significant results reflected large effect sizes (> $\eta^2 = .14$; Cohen, 1969).

Table 5b: Significance of ANOVA results (sig. = significant, ns. = not significant) and effect sizes (η_p^2) for all main effects and significant interactions for the data for Experiment 3.

Variables / Data	group	set	dist	reach	tar-get	dist x set	dist x group	set x dist x group	set x group	group x target
Reaction time data in the reach task.	sig. $\eta_p^2 =$ 0.45	ns. $\eta_p =$ 0.05	sig. $\eta_p^2 =$ 0.33	n/a	n/a	-	-	-	-	n/a
Movement time data in the reach task.	ns. $\eta_p^2 =$ 0.10	sig. $\eta_p^2 =$ 0.29	sig. $\eta_p^2 =$ 0.47	n/a	n/a	sig. $\eta_p^2 =$ 0.16	sig. $\eta_p^2 =$ 0.25	-	-	n/a
Reaction time data in the no-reach task.	sig. $\eta_p^2 =$ 0.35	ns. $\eta_p^2 =$ 0.02	sig. $\eta_p^2 =$ 0.20	n/a	n/a	sig. $\eta_p^2 =$ 0.45	-	sig. $\eta_p^2 =$ 0.21	-	n/a
Inattentive error data in the reach task.	sig. $\eta_p^2 =$ 0.46	ns./ trend $\eta_p^2 =$ 0.10	ns. $\eta_p^2 =$ 0.07	n/a	n/a	sig. $\eta_p^2 =$ 0.23	-	sig. $\eta_p^2 =$ 0.51	-	n/a
Inattentive error data in the no-reach task.	sig. $\eta_p^2 =$ 0.45	sig. $\eta_p^2 =$ 0.26	sig. $\eta_p^2 =$ 0.35	n/a	n/a	sig. $\eta_p^2 =$ 0.24	sig. $\eta_p^2 =$ 0.39	sig. $\eta_p^2 =$ 0.35	sig. $\eta_p^2 =$ 0.30	n/a
Impulsive error data.	sig. $\eta_p^2 =$ 0.37	sig. $\eta_p^2 =$ 0.13	n/a	ns. $\eta_p^2 =$ 0.02	n/a	n/a	n/a	-	-	n/a
Distractibility error data in the reach task.	sig. $\eta_p^2 =$ 0.46	sig. $\eta_p^2 =$ 0.10	n/a	n/a	sig. $\eta_p^2 =$ 0.74	n/a	n/a	-	sig. $\eta_p^2 =$ 0.15	sig. $\eta_p^2 =$ 0.43
Distractibility error data in the no-reach task.	sig. $\eta_p^2 =$ 0.37	sig. $\eta_p^2 =$ 0.14	n/a	n/a	n/a	n/a	n/a	-	sig. $\eta_p^2 =$ 0.38	n/a

n/a refers to variables that are not applicable to the analysis of those particular data. Dist refers to the variable distractor.

p. 123 – Experiments 4 and 5 (pages 123-133) are withdrawn.

p. 134 – Chapter 4 (pages 134-150) is withdrawn.

p. 163 – delete line 4 of the *Participants* section, which reads: "Diagnoses were made by experienced clinicians in accordance with DSM-IV diagnostic criteria (American Psychiatric Association, 1994)." Replace with: "Diagnoses (including ADHD subgroup and comorbidity diagnoses) were made by experienced clinicians in accordance with DSM-IV diagnostic criteria (American Psychiatric Association, 1994)."

p. 173 – line 6 of paragraph 2, delete the sentence: "In Experiment 13 the effect of stimulant medication on the performance of in-phase and out-of-phase movements was explored in a child with ADHD, using an off-on-on-off single-subject design."

p. 173 – on line 12 of the *Participants* section, insert: "These children were diagnosed with the combined type of ADHD (and comorbid disorders) by experienced clinicians in accordance with DSM-IV criteria (American Psychiatric Association, 1984)."

p. 173 – under the *Participants section,* on line 13 insert: "The control children were not screened for ADHD; however, the Explanatory Statement used in recruitment emphasised that it was important that these children did not have a diagnosis of ADHD, or any other childhood condition. Further, the parents and teachers of control children filled out a behavioural rating scale on inattentive and hyperactive-impulsive behaviour. Although this is not diagnostic in itself, none of the controls scored lower than one standard deviation below the mean."

p. 174 – on line 8, insert: "None of the controls fell in the clinical range (two or more standard deviations below the mean, or standard scores of 0-4) on the ADDES."

p. 175 – In Table 12 insert the following ranges of ADDES scores:
Under *ADDES – Home version. Mean inattentive ratings.* For ADHD children, insert: "range = 0-7". For controls, insert: "range = 8-14". Under *ADDES – Home version. Mean hyperactive-impulsive ratings.* For ADHD children, insert: "range = 0-7". For controls, insert: "range = 9-14". Under *ADDES – Home version. Mean overall percentile ranking.* For ADHD children, insert: "range = 0-11". For controls, insert: "range = 44-95". Under *ADDES – School version. Mean inattentive ratings.* For ADHD children, insert: "range = 1-12". For controls, insert: "range = 8-13". Under *ADDES – School version. Mean hyperactive-impulsive ratings.* For ADHD children insert: "range = 2-13". For controls, insert: "range = 9-13". Under *ADDES – School version. Mean overall percentile ranking.* For ADHD children insert: "range = 1-84". For controls, insert: "range = 44-100".

p. 191 – Experiment 13 (pages 191-201) is withdrawn.

p. 202 – in paragraph 1, line 12 insert: "Although some ADHD children were tested on medication and others off medication, it must be taken into consideration throughout this discussion that the experimental design did not allow the performances of unmedicated and medicated ADHD children to be compared directly, and that any comparisons are purely qualitative."

p. 202 – delete paragraph two, and replace with: "Briefly, this thesis investigated the performance of unmedicated ADHD, medicated ADHD and normal children on a task that required participants to respond to targets and ignore distractors. This paradigm allowed quantification of problems of impulsivity, achieving and sustaining an alert state (vigilance), ability to inhibit responses to distracting stimuli, set-shifting, atypical spatial biases and motor performance. Spatial biases or perceptual asymmetries were further investigated in normal right-handed children and children with ADHD, through the use of various chimeric stimuli in free-viewing conditions. Finally, motor performance in children with ADHD was explored further, using a bimanual coordination task that required participants to produce simple symmetrical bimanual movements and complex asymmetrical bimanual movements at both slow and fast speeds. A summary of the overall results obtained from the various experimental tasks is provided in Table 14."

p. 203 – delete Section 7.1.

p. 204 – on line 1 of Section 7.2 delete: "Experiments 1-5"; and replace with: "Experiments 1-3".

p. 204 – on line 7 of paragraph 3 please delete the word: "observed"; and replace with the word: "apparent".

p. 205 – delete the first sentence of paragraph 3.

p. 206 – delete the last two sentences of the first paragraph and delete the second paragraph.

p. 207 – on line 12 of Section 7.3, delete the word: "are", and replace with the words: "appear to be".

p. 207 – on line 9 of Section 7.4 delete the words: "in Experiments 10 and 11 (Chapter 5)".

p. 209 – delete the first paragraph of section 7.5 and replace with: "Motor impairments in ADHD were investigated in terms of reaction time and movement execution times of simple unimanual movements, as well as in terms of the ability to perform simple and complex bimanual movements."

p. 209 – on line 11 of the second paragraph, delete the rest of the paragraph starting from the sentence: "Results of the single-subject study..." Replace with: "Further, the group of medicated ADHD children (Experiment 2) showed normal movement preparation and a trend for faster movement execution than controls. While this finding needs to be replicated in a more systematic and extensive study of the effects of medication on motor performance in ADHD, the results suggest that stimulant medication may improve the processes of motor preparation, and possibly also motor execution."

p. 210 – delete the first sentence of paragraph 2 and replace with the following sentence: "The investigation of simple bimanual movements involved turning two wheels in a way that hand-movements were symmetrical, whilst complex bimanual movements consisted of asymmetrical hand-movements."

p. 211 – delete the last sentence of the first paragraph and replace with the following sentence: "It would be of great interest to determine whether children with the inattentive type of ADHD have similar deficits in bimanual coordination as those with the combined type, and whether improvements are evident with the administration of stimulant medication."

p. 211 – delete the second paragraph, and prior to the Summary section, please insert the following section:

Limitations of the Current Research

There are a number of potential methodological limitations of the current research that must be considered. The heterogeneity of ADHD must be taken into consideration, which limits the generalizability of findings from studies with smaller sample sizes to the general ADHD population. It is noteworthy, for example, that in the current research the ADHD children had mean IQ scores around 100. This may not be a representative sample of ADHD children, because samples of ADHD children in other studies have had reported IQs at the lower (e.g. Oosterlaan & Sergeant, 1998; Barnett et al., 2001) and the higher end of the normal IQ range (e.g. Seidman, Biederman, Faraone, Weber, & Ouellette, 1997; Schachar, Logan, Wachsmuth, & Chajezyk, 1988; Biederman et al., 1998). These differences in IQs between studies may reflect the heterogeneity of the ADHD population. Further, the majority of ADHD children used in the current experiments had comorbid diagnoses. It is possible that differences in comorbid disorders may be responsible for inconsistent findings between studies (such as the current findings relating to spatial biases), which again limit the generalizability of findings to the larger ADHD population. Future studies may seek to replicate the present experiments, taking into account comorbid diagnoses. Another factor, which may have confounded results, is stimulant medication; the present research could not access medication-naive children.

The present research was compromised to some extent by the limited resources available. For example, ADHD children and controls could not be matched on socio-economic status, and normal children could not be screened for ADHD by an experienced clinician. Further, ADHD children could not be randomly assigned to medicated and non-medicated groups because this was dependent on parental consent, and whether the child was taking stimulant medication in the first place. Consequently, it is possible there were differences in the severity of ADHD symptoms between the medicated and unmedicated groups of ADHD children. As the effect of stimulant medication was not studied systematically, any results pertaining to medication must be treated as preliminary. It should also be recognised that medication effects are difficult to judge when child and researcher are not blind to medication status. These methodological issues do not allow results of unmedicated and medicated ADHD children to be compared directly. Any such comparisons made in this thesis are therefore qualitative, and should be treated as suggestive only.

p. 211 – delete Summary section and replace with the following summary:

A variety of tasks showed no support for an anomalous right-visual-field spatial bias that has previously been interpreted in terms of greater right hemisphere impairment in ADHD. The results of the present research indicate that the performance of ADHD children is characterised by both slow and inaccurate responding. Inaccurate responding appears to reflect problems with response inhibition, selective attention, impulsive premature responding, set-shifting, and difficulties in achieving and maintaining an alert state. There is some suggestion that these deficits may be state- rather than trait-markers, because they appear to be absent in ADHD children taking stimulant medication. Impulsive responding was, however, a significant problem for medicated ADHD children. Although results are necessarily preliminary, and require further research to systematically test the effects of stimulant medication, they suggest that some aspects of slow and inaccurate responding may be absent with the use of stimulant medication.

Slow responding in ADHD reflects problems with the cognitive processes associated with *preparation* for a simple unimanual movement, rather than with problems in the *execution* of a unimanual movement. However, ADHD children were also found to have difficulties in executing simple and complex bimanual movements. Further research is necessary to ascertain whether aspects of bimanual-coordination are affected by stimulant medication, and whether these persist into adulthood.

p. 213 – in Table 14 delete the sections pertaining to Experiments 4, 5, and 13.
p. 364 – delete Appendix I: Analyses for Experiment 4
p. 365 – delete Appendix J: Analyses for Studies 6-9
p. 389 – delete Appendix K: Student self-evaluation scale
p. 430 – delete Appendix Q: Counterbalancing for the bimanual coordination task in Experiment 13.
p. 431 – delete Appendix R: Analyses for Experiment 13.
p. 436 – delete references: Achenbach (1991) and Achenbach, McConaughy, and Howell (1987).
p. 436 – delete references: Adams, Kelley, and McCarthy (1997) and Alexander (2000)

p. 439 – delete reference for Biederman, Faraone, Milberger, and Doyle (1992).

p. 439 – on line 15 insert: "Biederman, J., Faraone, S., Taylor, A., Sienna, M., Williamson, S., & Fine, C. (1998). Diagnostic continuity between child and adolescent ADHD: Findings from a longitudinal clinical sample. *Journal of the American Academy of Child and Adolescent Psychiatry, 37*(3), 305-313."

p. 440 – delete the reference for Bussing, Schuhmann, Belin, Widawski, and Perwien (1998).

p. 441 – at the end of the page insert: "Cohen, J. (1969). *Statistical Power Analysis for the Behavioural Sciences.* New York: Academic Press."

p. 442 – on line 21 insert: "Cramer, D. (1994). *Introducing statistics for social research.* London: Routledge."

p. 443 – on line 26 insert: "Douglas, V. I., Barr, R. G., Amin, K., O'Neill, M. E., & Britton, B. G. (1988). Dosage effects and individual responsivity to methylphenidate in attention deficit disorder. *Journal of Child Psychology and Psychiatry, 29*(4), 453-475."

p. 445 – delete reference for Fischer, Barkley, Fletcher, and Smallish (1993).
p. 447 – delete reference for Graham, Lee, Morling, and Russo (u.d.).

p. 447 – on line 3 insert: "Greenberg, L. M., Deem, M. A., & McMahon, S. (1972). Effects of dextroamphetamine, chlorpromazine, and hydroxyzine on behavior and performance in hyperactive children. *American Journal of Psychiatry, 129*(5), 533-539."

p. 448 – delete reference for Hope, Adams, Reynolds, Powers, Perez, and Kelley (1999).
p. 449 – delete reference for Jensen, Mrazek, Knapp, Steinberg, Pfeffer, Schowalter, and Shapiro (1997)

p. 451 – on line 27 insert: "Lerer, R. J., & Lerer, M. P. (1976). The effects of methylphenidate on the soft neurological signs of hyperactive children. *Pediatrics, 57*(4), 521-525." and: "Lerer, R. J., Lerer, M. P., & Artner, J. (1977). The effects of methylphenidate on the handwriting of children with minimal brain dysfunction. *The Journal of Pediatrics, 91*(1), 127-132."

p. 454 – delete reference for Mandal, Olmi, and Wilczynski (1999).
p. 455 – delete reference for McDougal (1999).
p. 456 – delete reference for Mitsis, McKay, Schulz, Newcorn, and Halperin (1999).

p. 456 – on line 27 insert: "Mirsky, A. F. (1996). Disorders of attention. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, Memory, and Executive Function* (pp. 71-95). Baltimore: Paul Brookes Publishing." and: "Mirsky, A. F., Fantie, B. D., & Tatman, J. E. (1995). Assessment of attention across the lifespan. In R. L. Mapou & J. Spector (Eds.), *Clinical Neuropsychological Assessment. A cognitive approach.* (pp. 17-48). New York: Plenum Press." and: "Mirsky, A. F., Pascualvaca, D. M., Duncan, C. C., & French, L. M. (1999). A model of attention and its relation to ADHD. *Mental Retardation and Developmental Disabilities Research Reviews,5*,169-176."

p. 458 – delete reference for Pennington (2001).
p. 460 – delete references: Reynolds and Kamphaus (1992), and Robin and Vandermay (1996).
p. 463 – delete reference for Slomkowski, Klein, and Mannuzza (1995).

p.464 – on line 28 insert: "Stuss, D. T., Alexander, M. P., & Picton, T.W. (1995). A multidisciplinary approach to anterior attentional funtions. In Grafman & K. J. Holyoak & F. Boller (Eds.), *Structure and Functions of the Human Prefrontal Cortex. Annals of the New York Academy of Sciences.* (Vol. 769, pp. 191-211). New York: The New York Academy of Sciences."

p. 468 – on line 4 insert: "Wade, M. G. (1976). Effects of methylphenidate on motor skill acquisition of hyperactive children. *Journal of Learning Disabilities, 9*(7), 443-447."

p. 469 – on line 7 insert: "Zahn,T., Rapoport, J. L., & Thompson, C. L. (1980). Autonomic and behavioral effects of dextroamphetamine and placebo in normal and hyperactive prepubertal boys. *Journal of Abnormal Child Psychology, 8*(2), 145-160."

Studies of Attention and Motor Function in Children with Attention Deficit/ Hyperactivity Disorder (ADHD)

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This thesis is submitted in partial fulfilment
of the requirements for the Degree of
Doctor of Psychology (Clinical)

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An excerpt of *Die Geschichte vom Zappel-Philipp* (the story of fidgety Philip) from Heinrich Hoffmann's (1808-1894) popular German story-book, *Der Struwwelpeter*:

"Ob der Philipp heute still
Wohl bei Tische sitzen will?"
Also sprach in ernstem Ton
Der Papa zu seinem Sohn,
Und die Mutter blickte stumm
Auf dem ganzen Tisch herum.
Doch der Philipp hörte nicht,
Was zu ihm der Vater spricht.
Er gaukelt
Und schaukelt,
Er trappelt
Und zappelt
Auf dem Stuhle hin und her.
"Philipp, das mißfällt mir sehr!"

Seht, ihr Lieben Kinder, seht,
Wie's dem Philipp weiter geht!
Oben steht es auf dem Bild.

Seht! Er schaukel gar zu wild,
Bis der Stuhl nach hinten fällt:
Da ist nichts mehr was ihn hällt;

In the English translation:

Let me see if Philip can
Be a little gentleman;
Let me see, if he is able
To sit still for once at table;
Thus Papa bade Phil behave;
And Mamma look'd very grave.
But fidgety Phil,
He won't sit still.
He wriggles
And giggles,
And then, I declare,
Swings backwards and forwards
And tilts up his chair,
Just like any rocking horse;-
"Philip! I am getting cross!"

See the naughty restless child
Growing still more rude and wild
Till his chair falls over quite.

TABLE OF CONTENTS

		Page
Abstract		xii
Declaration		xiv
Acknowledgements		xv
CHAPTER 1	**GENERAL INTRODUCTION**	**1**
1.1	**Introduction**	1
1.2	**Diagnosis of ADHD**	3
	1.2.1 Diagnostic Criteria	3
	1.2.2 Subtypes	4
	1.2.3 Prevalence and Comorbidity	8
1.3	**Treatment of ADHD**	10
	1.3.1 Pharmacological Interventions	10
	1.3.2 Behavioural Interventions	13
1.4	**Aetiology of ADHD**	15
	1.4.1 Genetic Factors	15
	1.4.2 Psychosocial Factors	19
	1.4.3 Environmental factors	20
1.5	**Neuroimaging studies in ADHD**	21
CHAPTER 2	**COGNITIVE AND MOTOR IMPAIRMENTS**	**32**
2.1	**Concepts of attention and executive functions**	32
2.2	**Current models of ADHD**	35
	2.2.1 The behavioural inhibition model	35
	2.2.2 The state regulation model	39
	2.2.3 The delay aversion model	42
2.3	**Neuropsychology of ADHD**	44
	2.3.1 Deficits in inhibition	45
	2.3.2 Deficits in set-shifting	51
	2.3.2.1 Wisconsin card sorting test studies	51

	2.3.2.2 Trailmaking test studies	52
	2.3.2.3 Necker cube studies	53
	2.3.3 Deficits in planning	54
	2.3.4 Deficits in verbal fluency	55
	2.3.5 Deficits in working memory	56
	2.3.6 Deficits in sustained attention	59
	2.3.7 Deficits in motor functioning	60
	2.3.8 Hemispheric asymmetry	64
2.4	**Aims and approach of this thesis**	67
CHAPTER 3	**EXPERIMENTS 1-5: ASPECTS OF ATTENTION AND MOTOR FUNCTIONING IN NORMAL, UNMEDICATED ADHD, AND MEDICATED ADHD CHILDREN**	**69**
3.1	**Introduction to Experiments 1 – 5**	69
	3.1.2 Outline of Experiments 1 – 5	72
3.2	**Method for Experiments 1 – 5**	72
	3.2.1 Participants	72
	3.2.2 Apparatus and Procedure	73
3.3	**Data Analysis for Experiments 1 – 5**	77
3.4	**Experiment 1: Results for unmedicated ADHD children and their matched controls**	79
	3.4.1 Demographic data	79
	3.4.2 Reaction time data	79
	3.4.3 Movement time data for the reach task	80
	3.4.4 Reaction time data for the no-reach	80
	3.4.5 Asymmetries in performance/ spatial biases	82
	3.4.6 Error data	83
	3.4.6.1 Inattentive errors or misses	83
	3.4.6.2 Spatial biases/ performance asymmetries for inattentive error data	84

	3.4.6.3 Impulsive errors or premature responses	84
	3.4.6.4 Distractibility errors	85
	3.4.6.5 Spatial biases/ performance asymmetries for distractibility error data	86
	3.4.6.6 Proportional errors	87
	3.4.7 Correlations	88
	3.4.8 Discussion	89
3.5	**Experiment 2: Results for medicated ADHD children and their matched controls**	89
	3.5.1 Demographic data	89
	3.5.2 Reaction time data for the reach task	89
	3.5.3 Movement time data for the reach task	91
	3.5.4 Reaction time data for the no-reach task	91
	3.5.5 Asymmetries in performance/ spatial biases	92
	3.5.6 Error data	92
	3.5.6.1 Inattentive errors or misses	92
	3.5.6.2 Spatial biases/ performance asymmetries for inattentive error data	93
	3.5.6.3 Impulsive errors	93
	3.5.6.4 Distractibility errors	94
	3.5.6.5 Spatial biases/ performance asymmetries for distractibility error data	96
	3.5.6.6 Proportional errors	96
	3.5.7 Discussion	96
3.6	**Discussion for Experiments 1 and 2**	97
	3.6.1 Motor problems	97
	3.6.2 Errors	98
	3.6.3 Response inhibition/distractibility	99
	3.6.4 Performance asymmetries/spatial biases	100
	3.6.5 Set-shifting	101

	3.6.6 Correlations	102
3.7	**Experiment 3: Results for normal children aged 7-12 years of age; a developmental study**	103
	3.7.1 Demographic data	103
	3.7.2 Reaction time data for the reach task	103
	3.7.3 Movement time data for the reach task	105
	3.7.4 Reaction time data for the no-reach task	105
	3.7.5 Error data	108
	3.7.5.1 Inattentive errors or misses	108
	3.7.5.2 Impulsive errors or premature responses	111
	3.7.5.3 Distractibility errors	112
	3.7.5.4 Proportional errors	115
	3.7.6 Correlations	117
3.8	**Discussion for Experiment 3**	118
	3.8.1 Effect of age on reaction times and movement times	118
	3.8.2 Effect of age on errors made	119
	3.8.3 Response inhibition/ distractibility	120
	3.8.4 Set-shifting	121
	3.8.5 Correlations	122
3.9	**Experiment 4: Single-subject design: Effects of stimulant medication on reaction time, movement time, and errors in the change-set task: an on-off-off-on design**	123
	3.9.1 Participant	123
	3.9.2 Apparatus and Method	124
	3.9.3 Results	124
	3.9.4 Discussion	126
3.10	**Experiment 5: Case study of two children diagnosed with the inattentive type of ADHD**	126

	3.10.1 Participants	126
	3.10.2 Apparatus and Method	128
	3.10.3 Results	128
	3.10.4 Discussion	132
CHAPTER 4	**STUDIES 6 – 9: BEHAVIOURAL DEFICITS IN ADHD; PARENT-, TEACHER-, AND SELF-REPORT**	**134**
4.1	**Introduction to Studies 6-9**	134
4.2	**Study 6: Discrepancy of parent and teacher ratings for ADHD and normal children**	136
	4.2.1 Method	136
	4.2.1.1 Participants	136
	4.2.1.2 Materials and Procedure	136
	4.2.2 Results	136
	4.2.3 Discussion	137
4.3	**Study 7: Self-report in ADHD and normal children**	139
	4.3.1 Method	139
	4.3.1.1 Participants	139
	4.3.1.2 Materials and Procedure	139
	4.3.2 Results	139
	4.3.3 Discussion	141
4.4	**Study 8: Correlations between self-report and parent and teacher ADDES ratings**	142
	4.4.1 Method	142
	4.4.1.1 Participants	142
	4.4.1.2 Materials and Procedure	142
	4.4.2 Results	143
	4.4.3 Discussion	147
4.5	**Study 9: The relationship between self-report and experimental variables**	147

	4.5.1 Method	147
	4.5.1.1 Participants	147
	4.5.1.2 Materials and Procedure	148
	4.5.2 Results	148
	4.5.3 Discussion	149
4.6	**Conclusion**	149
CHAPTER 5	**EXPERIMENTS 10 AND 11: PERCEPTUAL ASYMMETRIES IN NORMAL CHILDREN AND CHILDREN WITH ADHD**	**151**
5.1	**Introduction to Experiments**	151
5.2	**Experiment 10**	155
	5.2.1 Method	156
	5.2.1.1 Participants	156
	5.2.1.2 Materials and Procedure	156
	5.2.2 Results	158
	5.2.3 Discussion	160
5.3	**Experiment 11**	162
	5.3.1 Method	163
	5.3.1.1 Participants	163
	5.3.1.2 Materials and Procedure	163
	5.3.2 Results	165
	5.3.3 Discussion	166
CHAPTER 6	**EXPERIMENTS 12 AND 13: BIMANUAL COORDINATION IN CHILDREN WITH ADHD AND THEIR CONTROLS**	**171**
6.1	**Introduction to Experiments**	171
6.2	**Experiment 12: Bimanual coordination in unmedicated ADHD children compared to controls**	173
	6.2.1 Method	173

	6.2.1.1 Participants	173
	6.2.1.2 Materials and Apparatus	174
	6.2.1.3 Procedure	174
	6.2.1.4 Data Analysis	177
	6.2.2 Results	178
	6.2.2.1 Results for the in-phase task	178
	6.2.2.2 Results for the out-of-phase task	183
	6.2.3 Discussion	187
6.3	**Experiment 13: Single subject design: Effects of stimulant medication on bimanual coordination: an off-on-on-off design**	**191**
	6.3.1 Participant	192
	6.3.2 Apparatus and Method	192
	6.3.3 Results	192
	6.3.3.1 Results for the in-phase task	192
	6.3.3.2 Results for the out-of-phase task	198
	6.3.4 Discussion	200
CHAPTER 7	**GENERAL DISCUSSION**	**202**
7.1	**Behavioural aspects of ADHD**	203
7.2	**Attention**	204
7.3	**Set-shifting**	207
7.4	**Spatial biases**	207
7.5	**Motor deficits**	209
7.6	**Summary**	211
APPENDICES		**217**
	APPENDIX A: DIAGNOSTIC CRITERIA FOR ADHD	218

APPENDIX B: HANDEDNESS QUESTIONNAIRE 223

APPENDIX C: COUNTERBALANCING OF EXPERIMENTAL CONDITIONS FOR ADHD AND NORMAL CHILDREN IN EXPERIMENTS 1 AND 2 224

APPENDIX D: INSTRUCTIONS TO PARTICIPANTS IN EXPERIMENTS 1-5 228

APPENDIX E: ONE-WAY ANOVA CONDUCTED ON AGE DATA FROM THE UNMEDICATED VERSUS MEDICATED ADHD GROUPS, FOR EXPERIMENTS 1 AND 2 242

APPENDIX F: ANALYSES FOR EXPERIMENT 1 243

APPENDIX G: ANALYSES FOR EXPERIMENT 2 292

APPENDIX H: ANALYSES FOR EXPERIMENT 3 330

APPENDIX I: ANALYSES FOR EXPERIMENT 4 364

APPENDIX J: ANALYSES FOR STUDIES 6-9 365

APPENDIX K: STUDENT SELF-EVALUATION SCALE 389

APPENDIX L: ANALYSES FOR EXPERIMENTS 10 AND 11 392

APPENDIX M: SAMPLES OF STIMULI USED IN EXPERIMENTS 10 AND 11 399

APPENDIX N: COUNTERBALANCING FOR THE BIMANUAL COORDINATION TASK IN EXPERIMENT 12 402

APPENDIX O: IN-PHASE AND OUT-OF-PHASE MOVEMENTS FOR EXPERIMENTS 12 AND 13 403

APPENDIX P: ANALYSES FOR EXPERIMENT 12 404

APPENDIX Q: COUNTERBALANCING FOR THE BIMANUAL COORDINATION TASK IN EXPERIMENT 13 430

APPENDIX R: ANALYSES FOR EXPERIMENT 13 431

REFERENCES 436

ABSTRACT

This thesis investigated aspects of attention and motor function in children with Attention Deficit/ Hyperactivity Disorder (ADHD), combined type. Experiments 1-5 investigated the performance of unmedicated ADHD, medicated ADHD, normal, and (two) predominantly-inattentive type of ADHD children on a task that required participants to respond to targets and ignore distractors. Unmedicated ADHD children when compared to controls showed slow and inaccurate responding. Slow responding reflected problems with movement preparation but not movement execution. Inaccurate responding reflected problems with (especially) response inhibition, selective attention, impulsive responding and difficulties maintaining vigilance. Slow and inaccurate responding (with the exception of impulsive responding) was, however, not evident in the medicated ADHD children. Set-shifting difficulties, in the form of higher distractibility errors (responses to distractors) were also found in the unmedicated but not the medicated ADHD children. Children with the inattentive type of ADHD appeared to have similar difficulties as the children with the combined type, possibly with additional difficulties in movement execution. Studies 6, 7, 8 and 9 investigated behavioural aspects of ADHD that were reported by parents, teachers and children in the form of rating scales. Results suggested a lack of concordance between parent, teacher and child ratings, and few significant correlations were evident between parent/ teacher/ child ratings and experimental task variables. Children with ADHD were able to self-report ADHD-related symptoms and other difficulties. Experiments 10 and 11 investigated perceptual biases in normal and ADHD children using various chimeric stimuli in free-viewing conditions. Leftward biases were found for normal children with no effects of age. Contrary to expectations, leftward biases were also found for ADHD children. In Experiment 12 ADHD children were found to be impaired in the accurate and stable execution of simple in-phase bimanual movements, but they could produce these as accurately as controls at the designated speeds. Although ADHD children did not differ significantly from controls in terms of (in)accuracy of the execution of complex out-of-phase bimanual movements, they did show a trend for less accurate performance. ADHD children were more variable in both velocity and production of the complex out-of-phase movements. A preliminary investigation into the effects of stimulant medication on bimanual coordination in one

child with ADHD was conducted in Experiment 13. The results suggested differential effects of medication on various aspects of bimanual coordination. In summary, the results of this thesis indicate problems of attention, inhibition, set-shifting, and motor functioning in children with ADHD. Further, a lot of these difficulties appear to normalize with stimulant medication.

DECLARATION

This thesis contains no material that has been accepted for the award of any other degree or diploma in any university or other institution. To the best of my knowledge, the thesis contains no material previously published or written by another person, except where due reference is made in the text.

Signed: [redacted] ..... Date: 25/11/02...

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CHAPTER 1
GENERAL INTRODUCTION

1.1 Introduction

Attention deficit/hyperactivity disorder (ADHD) is a childhood disorder characterised by inappropriate levels of inattention and/or hyperactivity and impulsivity. These behaviours themselves are not abnormal, but are pronounced in children with ADHD. Concerns are raised when the behaviours are causing significant ongoing difficulties in the life of the child and/or the family. The prevalence of ADHD is estimated at 3-5% in school-aged children (American Psychiatric Association, 1994). ADHD is persistent into adulthood in 30-50% of childhood diagnoses (Barkley, 1997b) and is a risk factor for a number of other disorders including personality disorders, psychiatric disorders, and delinquency (Barkley, 1997b).

Over recent years there has been increasing professional and public awareness of ADHD, and it is now one of the most commonly diagnosed conditions of childhood. There is a wide spectrum of opinion and debate about ADHD, ranging from the view that the disorder is underdiagnosed and undertreated, to the view that seriously questions whether it even exists as a discrete condition. Despite high prevalence rates, and increasing awareness of the condition, there is disagreement about diagnostic criteria among standard diagnostic manuals, and disagreement in the literature as to the nature of the difficulties in children with ADHD. Some of the controversy surrounding this disorder was generated by the many changes in the terminology of the disorder – changes that reflected historical trends in conceptualising either various aetiologies or the core features of the disorder. These changes are described briefly in the historical account of this disorder below.

One hundred years ago George Still described a number of cases of children with conduct problems, which he referred to as children with "defects of moral control" and noted that "a notable feature in many of these cases of moral defect without general impairment of intellect is a quite abnormal incapacity for sustained attention" (Still, 1902; p.1166). George Still also noted that boys were more often affected than girls, and proposed both organic and environmental aetiologies. Following the 1920s

encephalitis epidemic, many children who survived this condition showed behavioural disturbances, which gave rise to the concept of minimal brain damage or dysfunction (MBD) that was popular during the 1940s and 1950s (Taylor, 1998). The disorder became known as MBD despite the lack of evidence for brain damage. In the 1960s there was a decline in the use of the term MBD, and instead the term hyperkinetic syndrome of childhood became popular (Weiss, 1996). As the name implies, the emphasis was on hyperactivity during this time. In England hyperkinesis referred to symptoms of hyperactivity and inattention, and unlike in the United States, the presence of conduct problems, excluded children from this diagnosis (Weiss, 1996).

In the 1980s the emphasis was on the attention deficits underlying the disorder, rather than hyperactivity. Hence the disorder was referred to *attention deficit disorder (with or without hyperactivity)* in the American diagnostic manual, DSM-III (American Psychiatric Association, 1980). In 1987, restlessness or hyperactivity regained emphasis and the disorder's name was changed to *attention deficit hyperactivity disorder* in DSM-IIIR (American Psychiatric Association, 1987). The disorder now emphasised combined symptoms of inattention, impulsivity and hyperactivity. Whilst the name remained the same in the 1990s (American Psychiatric Association, 1994), emphasis has changed to *lack of inhibitory control* underlying the disorder. Barkley (1998) described this change as: "ADHD is not a disorder of attention per se, as had long been assumed. Rather it arises as a developmental failure in brain circuitry that underlies inhibition and self-control. This loss of self-control in turn impairs other important brain functions crucial for maintaining attention, including the ability to defer immediate rewards for later, greater gain." (p.45).

This review examines differences in diagnostic criteria, aetiology, treatment and neuroimaging studies conducted in ADHD. Further, research on the nature of the deficits in ADHD is reviewed in Chapter 2. Much of the research has been clinical, rather than experimental, and the nature of the impairments in ADHD remains unclear. The aim of this research is to offer a better understanding of the deficits underlying this disorder, by comparing and contrasting performance between children with ADHD and normal controls on tasks designed to quantify aspects of attention and motor performance.

1.2 Diagnosis of ADHD

1.2.1 Diagnostic criteria

ADHD is viewed as comprising inappropriate levels of inattention and impulsivity, often accompanied with hyperactivity (American Psychiatric Association, 1994). According the American diagnostic manual, DSM-IV (American Psychiatric Association, 1994), for a diagnosis to be made, a child's behaviour must be worse in persistence and severity than that of other children of the same age; symptoms must begin before 7 years of age and must be present in at least two settings (e.g., home and school)[1]. Inattention is characterized by failure to attend to details, or by distractibility. In school-work, for example, children may demonstrate inattention by making careless mistakes as a result of failing to pay close attention to details. These children tend to find it difficult to persist with tasks, act as though they are not listening, shift from one uncompleted activity to another, and fail to complete their assignments despite understanding task requirements. On a social level inattention may manifest in not listening to the flow of conversations and not following rules of games or activities. Impulsivity involves lack of patience or difficulty in delaying responses. Impulsivity may be displayed, for example, in children not waiting their turn to respond to teacher questions, initiating comments at inappropriate times, interrupting others, failing to wait for specific instructions before proceeding, and touching things that they know they should not. Hyperactivity manifests as excessive motor activity such as climbing and running, excessive talking, fidgetiness or restlessness. Adolescents and adults with ADHD tend to show less intense activity levels than toddlers and school children. That is, unlike younger children who express hyperactivity through excessive running and climbing, adolescents and adults express hyperactivity as feelings of restlessness and difficulty in participating in sedentary activities. These symptoms may become minimal or absent when the person is in a novel setting, engaged in especially interesting activities, or whilst he/ she experiences frequent rewards for appropriate behaviour.

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[1]See Appendix A for a copy of DSM-IV diagnostic criteria for ADHD.

Associated features of the disorder may include temper outbursts, dysphoria, stubbornness, bossiness, becoming frustrated easily, academic underachievement, low self-esteem, and problems in social relationships (American Psychiatric Association, 1994). The core symptoms of the disorder may impair learning, but it is not clear whether learning problems are attributable to deficits in motivation, attention, impulse control, problem solving, poor organizational skills or some combination of these factors. Relative to other children, children with ADHD have few friends and experience high rates of peer rejection (Olson, 1996). Ratings from peers indicate that children with ADHD are perceived as a causing trouble, getting others into trouble, and bothering others. According to peer-ratings they are also not well liked. Undesirable behaviour such as interrupting and intruding on others (one of the DSM-IV symptoms of impulsivity) such as interrupting conversations or games, may play a substantial role in peer rejection. Several potential explanations for the social problems of children with ADHD have been proposed, including deficits in social knowledge, attributional style and social reasoning (Olson, 1996).

1.2.2 Subtypes

DSM-IV identifies three subtypes of the disorder; *predominantly inattentive*, *predominantly hyperactive-impulsive* and a *combined type* (American Psychiatric Association, 1994). The predominantly inattentive type is diagnosed when six or more of the nine symptoms of inattention are present, but fewer than six of the nine symptoms of hyperactivity-impulsivity are present[2]. The predominantly hyperactive-impulsive type is diagnosed when the reverse is the case. The combined type is diagnosed when six or more of the symptoms of inattention and six or more symptoms of hyperactivity-impulsivity are present. More children and adolescents with the disorder are diagnosed with the combined type (American Psychiatric Association, 1994). McBurnett et al. (1999) classified 692 referrals to a paediatric ADHD clinic into one of each of the three DSM-IV subtypes using parent and teacher checklist ratings of ADHD symptoms. This classification resulted in 65% classified as the combined type, 28% classified as predominantly inattentive and 7% as predominantly

[2] See Appendix A for full DSM-IV diagnostic criteria

hyperactive-impulsive. Similar results were found in a study by Faraone, Biederman, Weber and Russel (1998), who classified 61% of children as having the combined type, 30% as having the predominantly inattentive type, and 9% as having the predominantly hyperactive-impulsive type of ADHD.

Prior to DSM-IV ADHD only had one main subtype (ADHD) as well as a provision for an undifferentiated attention-deficit disorder (in DSM-III-R). Eight out of fourteen symptoms comprising inattention, hyperactivity and impulsivity needed to be present for a diagnosis of ADHD. When signs of impulsivity and hyperactivity were not present, diagnosis was one of undifferentiated attention-deficit disorder. Thus the ADHD subtype in DSM-III-R (American Psychiatric Association, 1987) roughly encompasses the diagnoses of the predominantly hyperactive and the combined types in DSM-IV, and does not differentiate between the two. Prior to DSM-III-R, the disorder had two subtypes, attention deficit disorder with hyperactivity and attention deficit disorder without hyperactivity (in DSM-III). There were also provisions for a residual subtype for individuals once diagnosed as having attention deficit disorder with hyperactivity in which hyperactivity was nc longer present, but within whom other signs of the disorder persisted (American Psychiatric Association, 1980). Unlike DSM-IV's predominantly hyperactive type, in order to qualify for a diagnosis of attention deficit disorder with hyperactivity, at least three of five symptoms of inattention must be present in conjunction with three of six symptoms of impulsivity and two of five symptoms of hyperactivity (American Psychiatric Association, 1980). This subtype could therefore roughly encompass DSM-IV's combined type, and predominantly hyperactive type. Criteria for attention deficit disorder without hyperactivity are the same as for attention deficit disorder with hyperactivity, except that symptoms of hyperactivity are absent. This resembles DSM-IV's predominantly inattentive type, except that impulsivity symptoms are required for a diagnosis. This change in diagnostic criteria has made interpretation of past research in the area of ADHD more difficult.

In comparison to DSM-IV, ICD-10 (Word Health Organization, 1993) used as a current diagnostic tool primarily in Europe, identifies four subtypes/variants under the diagnostic category of F90 hyperkinetic disorders (HD): F90.0 disturbance of activity

and attention, F90.1 hyperkinetic conduct disorder, F90.8 other hyperkinetic disorders and F90.9 hyperkinetic disorder, unspecified[3]. Symptoms of inattentiveness, hyperactivity and impulsivity are essentially the same in DSM-IV and ICD-10. However there are differences in diagnostic criteria, such as the number of impulsive and hyperactive symptoms that must be present for a diagnosis. The major difference between the two diagnostic tools, however, is that it is possible to have ADHD without being inattentive (predominantly hyperactive-impulsive type) and without being hyperactive-impulsive (predominantly inattentive type) according to DSM-IV. In comparison, ICD-10 requires symptoms of inattentiveness, hyperactivity and impulsivity for a diagnosis of hyperkinetic disorder. Thus an ICD-10 diagnosis of hyperkinetic disorder is most similar to a DSM-IV diagnosis of ADHD (combined type), and a DSM-IIIR diagnosis of ADHD.

There are a number of differences in the behavioural profiles of children with different subtypes of ADHD. The predominantly inattentive type ADHD children tend to exhibit behaviour "internalising" in nature (Boliek & Obrzut, 1997), which is defined as problems with overcontrol, or behaviour directed inwards to the thoughts and feelings of the self (Kazdin & Weisz, 1998). Prominent examples of internalising problems are withdrawal, anxiety, and depression. In comparison, children with the predominantly hyperactive-impulsive type (and/ or the combined type) tend to exhibit behaviour consistent with externalising behaviour (Boliek & Obrzut, 1997). Externalising behaviour is defined as problems with undercontrol, or behaviour directed outwards to other people and the environment (Kazdin & Weisz, 1998). Prominent examples of externalising problems are overactivity, oppositional and aggressive behaviour, and delinquency.

Predominantly inattentive ADHD children characteristically exhibit more lethargy, social withdrawal, poorer organizational skills and learning difficulties relative to the predominantly hyperactive-impulsive type (Boliek & Obrzut, 1997). Speed of processing is slow, and their problems are postulated to be in the area of focused or selective attention, which is the ability to focus attention on pertinent aspects and to

[3] See Appendix A for ICD-10 diagnostic criteria

ignore irrelevant aspects of information (Fisher, 1998; Barkley, DuPaul, & McMurray, 1990; but cf. Hynd et al., 1989). They are often described as more underactive, shy and daydreaming (Goodyear & Hynd, 1992) than their hyperactive counterparts. They have also have a higher incidence of developmental learning disorders (Goodyear & Hynd, 1992) language disorders (Cantwell & Baker, 1992) and depression and anxiety (Lahey & Carlson, 1991).

Predominantly hyperactive-impulsive and combined type children are postulated to have deficits in sustained attention (the ability to work for increasing periods at a set task) and inhibition of inappropriate responses (Barkley, 1997b). They are viewed as being more aggressive and behaviourally disruptive, and have a higher incidence of comorbid conduct disorder and oppositional defiant disorder (Goodyear & Hynd, 1992). Conduct disorder is characterized by a persistent pattern of behaviour in which the basic rights of others are violated, or in which major age-appropriate societal norms or rules are ignored (American Psychiatric Association, 1994). Oppositional defiant disorder is characterized by a recurrent pattern of negativistic, defiant, disobedient, and hostile behaviour toward authority figures (American Psychiatric Association, 1994).

A study by Barkley, DuPaul and McMurray (1991) suggests that children with different subtypes of ADHD also respond differently to stimulant medication. The authors examined clinical response to three dose levels of methylphenidate in children with ADD with hyperactivity (which would presumably include children diagnosed with either DSM-IV's predominantly hyperactive-impulsive, and combined types) and ADD without hyperactivity (most similar to DSM-IV's predominantly inattentive type). Results showed that children without hyperactivity had either no clinical response to methylphenidate, or responded best to a low dose. In comparison, children with hyperactivity responded positively to moderate and high doses of methylphenidate. These findings led Barkley and his colleagues to conclude that ADD without hyperactivity is a different disorder than ADD with hyperactivity, rather than being a subtype of the same shared attention disturbance.

1.2.3 Prevalence and Comorbidity

The prevalence of ADHD is estimated at 3%-5% in school-aged children (American Psychiatric Association, 1994), with boys being over-represented by approximately 3:1 (Barkley, 1997b). ADHD is persistent into adolescence in 50-80% of childhood diagnoses, and to adulthood in 30-50% (Barkley, 1997b). ADHD is a major risk factor for later personality disorders, psychiatric disorders, delinquency, substance abuse, driving accidents and speeding violations, repeated accidents, as well as difficulties in adult social relationships, marriage and employment (Barkley, 1997b; Sagvolden & Sergeant, 1998). Most of these developmental risks may be exacerbated by the presence of comorbid aggression/conduct problems (Barkley, 1997b).

Between 50-80% of children with ADHD also meet diagnostic criteria for other disorders (Tannock, 1998). The most frequent comorbid disorders are oppositional defiant disorder and conduct disorder, followed by mood disorders, anxiety disorders and specific learning disorders (Tannock, 1998). Language and speech disorders are also common (Cantwell & Baker, 1992). Approximately 30-85% of those with Tourette's syndrome, a disorder characterized by multiple motor tics and one or more vocal tics, also have a diagnosis of ADHD although the reverse association is not the case (Comings, 1995). Some authors (Comings & Comings, 1984) have even suggested that ADHD may be an alternative expression of a Tourette's syndrome gene, although this is not the predominant view in the literature (Pauls et al., 1986; Eapen & Robertson, 1996). Generally the presence of a comorbid disorder indicates a more serious problem with a worse prognosis (Weiss, 1996).

The fact that so many children with ADHD have comorbid disorders could mean a number of things: that comorbid disorders are in fact different expressions of the same disorder; that comorbid disorders may represent distinct disorders; that comorbid disorders share a common vulnerability; that comorbid disorders may represent a subtype in a heterogenous syndrome of ADHD; or that ADHD may be an early manifestation of the comorbid disorder.

Both ADHD and conduct disorder have been reported to have common symptoms, associated characteristics, and family psychiatric histories. However, they may be

overlapping dimensions of externalizing behaviour, or comorbid conditions that frequently occur together but are not synonymous and have different degrees of risk for academic failure, substance abuse, psychiatric disturbance and family dysfunction (Barkley, 1991). Nevertheless, the core deficit in pure conduct disorder seems to lie outside the domain of such 'executive functions' as self-regulation, sequencing of behaviour, flexibility of thinking or responding, response inhibition and planning and organization of behaviour. Unless ADHD is comorbid with conduct disorder, there seems to be little evidence in the latter of the deficits in executive functions, which are otherwise thought to be characteristic of ADHD (Pennington & Ozonoff, 1996; cf. Moffitt, 1993).

Antisocial behaviour and delinquency during adolescence are more likely among children previously diagnosed with ADHD (Jacobvitz, Sroufe, Stewart, & Leffert, 1990). According to DSM-IIIR (American Psychiatric Association, 1987), oppositional defiant disorder or conduct disorder often develop later in childhood in those with ADHD. Also, among those who develop conduct disorder, a significant number are found to have antisocial personality disorder in adulthood. Antisocial personality disorder is characterised by a pervasive pattern of disregard for, and violation of, the rights of others, that begins at least by early adolescence in the form of conduct disorder and continues into adulthood (American Psychiatric Association, 1994).

Babinski, Hartsough and Lambert (1999) investigated the relative contributions of conduct problems, hyperactivity-impulsivity and inattention to later criminal involvement in a group of young adults previously identified as hyperactive when they were children. The results of this study suggest that symptoms of hyperactivity-impulsivity alone, as well as symptoms of early conduct problems alone, are predictive of both official criminal arrests and a high level of self-reported crime for males. The comorbidity of hyperactivity-impulsivity and conduct problems also predicted later criminal involvement. Symptoms of inattention, however, seemed to be largely unrelated to adult criminal activity. Furthermore, the results of this study also suggest that individuals with a history of conduct problems alone are more likely to commit more serious offences, such as crimes against people (e.g., assault and robbery). Those

with hyperactivity-impulsivity alone may be at higher risk for less serious crimes such as public disorder and property crimes, which may be related specifically to their impulsivity and inability to delay gratification. Comorbidity of hyperactivity-impulsivity and conduct problems consistently predicted arrests in all categories of crime. These individuals were, in fact, at a higher risk than those with conduct problems or hyperactivity-impulsivity alone.

Other common deficits in delinquents are language or verbal deficits (Moffitt, 1993). These include poorer performance on tests of reading, naming, vocabulary, receptive language, memorisation of a word list (Rey Auditory Verbal Learning Test), verbal fluency (generating words), and Wechsler Intelligence Scale for Children subtests of Information, Similarities, Arithmetic and Vocabulary (Moffitt, 1993). Thus it may not be ADHD *per se* that increases the risk of delinquency but, rather, comorbid verbal or language deficits.

1.3 Treatment of ADHD

1.3.1 Pharmacological Interventions:

ADHD is usually treated with psychostimulants such as methylphenidate and dextroamphetamine (Sagvolden & Sergeant, 1998). These stimulants are primarily dopaminergic, although they also affect noradrenergic and serotonergic systems (Leonard, 1997). In clinical practice approximately 70-75% of children with ADHD respond to stimulant medication (Weiss, 1996; Jacobvitz et al., 1990). Poor response to one stimulant does not necessarily predict a similarly poor response to another. Tricyclic antidepressants, the most common alternative to stimulants (Schachar, Tannock, & Cunningham, 1996), are often used in children who fail to respond to stimulants or in those who experience side effects, such as dysphoria, tics or insomnia, that necessitate discontinuation of stimulants (Schachar et al., 1996). However, tricyclics may be associated with statistically significant increases in pulse, diastolic blood pressure and frequency of cardiac conduction defects. Several children have died suddenly while being treated with tricyclic medication (Popper & Zimnitzky, 1995). Also, the overall efficacy of tricyclics is less than that of stimulant medication (Quinn & Rapoport, 1975).

Whilst methylphenidate is sometimes reported to be the drug of choice (Sagvolden & Sergeant, 1998; Schachar et al., 1996), research suggests that methylphenidate and dextroamphetamine are equally efficacious (Elia, Borcherding, Rapoport, & Keysor, 1991). A study by Elia et al. (1991) compared response to dextroamphetamine, methylphenidate, and placebo in ADHD boys, and found both stimulants to be equally efficacious in terms of teacher and parent ratings of behaviour. In the Australian public health system dextroamphetamine may be prescribed more commonly because it is cheaper than methylphenidate. Hazel, McDowell and Walton (1996) examined the management of children prescribed psychostimulant medication in the Hunter region of New South Wales, and found that dextroamphetamine was the most commonly prescribed psychostimulant, having been given to 70% of the children at some time, followed by methylphenidate (60%). Tricyclic antidepressants were also prescribed for 18% of children at some time, as were clonidine (an anti-hypertensive agent sometimes used in children with ADHD who have comorbid aggression, and in children where sleep disturbance is a difficulty that cannot be resolved with adjustment to the timing of the stimulant; 19%), thioridazine (a neuroleptic; 2%), and moclobemide (a reversible inhibitor of monoamine oxidase (antidepressant); 2%).

Stimulants are short-acting, with methylphenidate reported to affect behaviour for a duration of 1-4 hours, and dextroamphetamine reported to affect behaviour for a duration of 1-8 hours (Elia, Ambrosini, & Rapoport, 1999). Treatment with stimulants results in an improvement in the core behavioural symptoms of ADHD (Brown, Wynne, & Slimmer, 1984). Activity level typically decreases, and there is significant improvement in sustained attention and impulse control (Brown et al., 1984). Improved behaviour and attention with medication in turn facilitate family, school and peer relations (Schachar et al., 1996). Pelham (1993) reported that stimulant medication improved behaviour in the classroom, daily academic productivity, compliance with teacher commands, and teacher-rated disruptive behaviour. In a study of children with ADHD and conduct disorder who were treated either with methylphenidate or placebo for five weeks, not only did ratings of ADHD-related behaviour improve in the methylphenidate group, but ratings of antisocial behaviour also improved (Klein et al., 1997).

Stimulants improve performance on tasks sensitive to sustained attention, such as the Continuous Performance Test (CPT; Brown et al., 1984), and on tasks sensitive to impulsivity such as the Matching Familiar Figures Test (MFFT; Brown et al., 1984). The CPT requires the participant to detect an infrequent stimulus embedded in a series of irrelevant stimuli. The scores derived from this test are the number of correct responses, number of target stimuli missed (omission errors) and number of responses following non-targets (commission errors), measured over blocks of trials. The number of correct responses and omission errors are presumed to assess sustained attention, and commission errors to assess a combination of sustained attention and impulse control (Barkley, 1990). A test that requires sustained performance over time, such as the CPT, is sensitive to sustained attention and vigilance. In the MFFT, a picture of a recognisable object is presented and the identical matching picture from among an array of very similar variants must be chosen (Barkley, 1990).

Side effects of stimulants include lack of appetite (reported in approximately 80% of children (Elia et al., 1999) and a delay in the onset of sleep, which occurs in approximately 30% of children on moderate doses of stimulants (Leonard, 1997). Abdominal pain, irritability, headaches, dry mouth, dizziness, and depression tend to be less frequent side-effects (Elia et al., 1999). Stimulants may in some cases increase underlying symptoms of anxiety and seizures, and hence may induce an adverse reaction in those with comorbid Tourette's syndrome or mood and anxiety disorders. Rebound effects may also arise with stimulant disuse. Rebound effects reflect the deterioration in behaviour, in excess of that expected from baseline, which occurs as the beneficial effects of stimulant medication wear off (Jacobvitz et al., 1990). These effects are usually observed between 5 and 10 hours following administration of medication.

The literature refutes the notion of an atypical stimulant response by children with ADHD (see Jacobvitz et al., 1990 for a review). Rapoport et al. (1978), for example, conducted a double blind study administering amphetamines to children with ADHD, normal children and normal adults. All groups were found to respond to dextroamphetamine with reduced activity level and enhanced vigilance and memory

performance in laboratory tasks. Although effects of stimulants on ADHD children appear to be paradoxical, they are not genuinely so. The children appear "slowed down", but reductions in activity may be an indirect consequence of enhanced attention and concentration, consistent with the effects which stimulants have on responders of other populations, such as army personnel, normal children and normal adults (Jacobvitz et al., 1990; Aman, Vamos, & Werry, 1984).

1.3.2 Behavioural Interventions

Non-psychopharmacological treatments for ADHD include behaviour therapy, behaviour management techniques, social skills training and cognitive-behavioural training (Barkley, 1991). The position paper on ADHD developed by the Australian Psychological Society (1997) outlines a number of interventions for ADHD including medication, programs aimed at assisting caregivers in managing their child's behaviour, programs aimed at assisting teachers to manage disruptive behaviour in the classroom, and individual counselling for children with ADHD (addressing issues related to medication and self-regulation and social skills).

A strategy for teachers is to reinforce positive behaviour and provide negative reinforcement for disruptive behaviour. Cognitive behaviour therapy intervention aims to enhance self-control by teaching hyperactive children self-instructional strategies to increase self-regulation and reduce impulsiveness. Generally, behavioural interventions are believed to be effective, but are thought not to constitute a complete treatment for ADHD (Schachar et al., 1996). The major limitations of these therapies appear to be their poor generalisation across situations. Classroom-based interventions do not generalise to the home; parent training programmes are unlikely to improve classroom behaviour without parents linking school behaviour to home-based incentives, and without teachers employing effective classroom management strategies. Similarly, social skills training may not generalize from the clinical settings in which training is conducted to educational and social contexts (Schachar et al., 1996).

A long-term treatment study conducted by the National Institute of Mental Health, served to clarify the effectiveness of behavioural and pharmacological treatments in

children aged 7-9 years with ADHD, combined type (The MTA Cooperative Group, 1999a, 1999b). The 579 children were randomly assigned to either medication management (including monthly visits), behavioural treatment (targeting parent, school and child), medication and behaviour treatment combined, or community care (standard treatment by community providers). They found that combined treatment and medication treatment were significantly more effective than behavioural treatment and community care in reducing ADHD symptoms as rated by teachers and parents. Combined treatment did not differ significantly from medication treatment in terms of reduction in ADHD symptoms, or other measures of functioning (oppositional/ aggressive symptoms, internalising symptoms (e.g., anxiety and depression), teacher-rated social skills, parent-child relations, and reading achievement). Combined treatment, however, was superior to behaviour treatment and/ or community treatment in terms of internalising problems, oppositional/ aggressive symptoms and reading achievement, whereas medication treatment was not. Interestingly, medication treatment was superior to community treatment even though two-thirds of the community treatments included a medication component. These differences may have been due to dosage, number of meetings with parents, and/ or the amount of feedback obtained from teachers.

The long-term treatment study (The MTA Cooperative Group, 1999b) further examined the influence of moderators (sex, comorbid anxiety disorders (excluding simple phobia), comorbid oppositional defiant disorder/ conduct disorder) and mediators (treatment acceptance/ attendance) on treatment response. While there were no moderator effects for comorbid oppositional defiant disorder/ conduct disorder on treatment response, this was not the case for comorbid anxiety disorders. For children with comorbid anxiety disorders, behaviour treatment (in a similar fashion to medication and combined treatments) was superior to community care in terms of ADHD symptoms and internalising symptoms. In families receiving some form of welfare, medication treatment resulted in a decrease of reported closeness in parent-child interactions, and combined treatment resulted in greater benefits for teacher reported social skills. The acceptance of treatment and regular attendance (mediator) was found to be particularly important for medication treatments.

This study highlighted the importance of stimulant medication, and the often suboptimal response to behaviour therapy. This being said, behaviour therapy may be useful as an adjunct to medication therapy, for specific outcomes such as improvement in parent-child and peer relationships.

1.4 Aetiology of ADHD

1.4.1 Genetic Factors

The genetic aetiology of ADHD has been indicated by evidence from three types of studies: *family studies, twin studies* and *adoption studies*. Briefly, *family studies* investigate the families of individuals with ADHD and determine whether their biological relatives are affected more often than the general population or a control group. Family studies typically show a higher incidence of ADHD among biological relatives of those with ADHD than controls, providing evidence for a familial involvement in ADHD (e.g., Faraone et al., 2000; Biederman, Faraone et al., 1995). However, family studies have been criticised (e.g., Joseph, 2000) in terms of not being able to distinguish between potential environmental or genetic aetiologies, because disorders may run in families for non-genetic reasons (e.g., shared environmental adversity, social learning etc.).

Due to identical genetic material between monozygotic twins and shared genetic material between dizygotic twins or siblings, *twin studies* using these populations provide concordance rates of heritable traits. Typically, twin studies have found higher correlations for ADHD-related behaviours among monozygotic twins (Levy, Hay, McStephen, Wood, & Waldman, 1997; Sherman, Iacono, & McGue, 1997; Neuman et al., 1999). A literature review by Tannock (1998) revealed that, on average, the larger twin studies yield concordance rates of .66 for monozygotic twins and .28 for dizygotic twins, with heritability estimated at .80 (ranging from .50 to .98). This finding is interpreted as indicating that approximately 80% of the differences in attention, hyperactivity and impulsivity between individuals with ADHD and without ADHD can be explained by genetic factors. Results from a large Australian twin study (Levy et al., 1997) suggest that ADHD is best viewed as the extreme of a behaviour, which

varies genetically throughout the entire population rather than a disorder with discrete determinants.

Twin studies have, however, been criticised on the grounds that the effects in twins reflect unique shared pre- and perinatal events or postnatal environment (Sherman et al., 1997). That is, monozygotic twins have a more similar environment than other siblings, which may provide the basis for increased heritability estimates. Joseph (2000) reviewed some empirical evidence in support of this contention (such as identical twins spending more time together, having the same close friends, dressing alike, etc., compared to fraternal twins).

Adoption studies are designed to discriminate genetic heritage from environmental factors. Studies by Cantwell (1975), and Morrison and Stewart (1973) indicated that adoptive relatives of a group of ADHD children are less likely to have ADHD or associated disorders, than biological relatives of a separate group of ADHD children. However, diagnoses of relatives were made retrospectively by parents' descriptions, rather than by rated behavioural observations, relatives' self-report etc., and may thus reflect reporter bias. Another study (Alberts-Corush, Firestone, & Goodman, 1986) indicated greater measured attention deficits (but not impulsivity) as assessed by tests such as the Porteus Maze Test (this was purported to measure impulsivity), a forced choice letter recognition task, and a reaction time task (both thought to measure attention) in the biological parents of a group of hyperactive children compared to biological parents of a group of normal children, adoptive parents of a group of hyperactive children, and adoptive parents of a group of normal children. No studies have yet been undertaken to compare biological and adoptive relatives of the same adopted child, which would be ideal for studying the genetic basis of ADHD because this allows greater separation of genetic from environmental factors.

Although some researchers propose that ADHD may be attributed to the effects of a single major gene, the most common view in the literature is of polygenic transmission (Barkley, 1998; Tannock, 1998). It is commonly held that genes coding for the neurotransmitter dopamine are involved in the aetiology of ADHD (Zametkin & Rapoport, 1987; Levy, 1991). However, the involvement of genes involved in coding

for serotonin (Quist & Kennedy, 2001; Leonard, 1997) and noradrenalin (Biederman & Spencer, 2000; Leonard, 1997) has also been suggested. The study of the role of neurotransmitters in ADHD is complicated by the interrelationship between neurotransmitter systems; a change in one results in a change in another. In summary, no single neurotransmitter deficit has been validated, and the relative importance of one neurotransmitter compared to another in ADHD is currently unclear.

Dopaminergic genes are implicated for several reasons. First, ADHD symptoms may be reduced by medications that act primarily on the dopaminergic and noradrenergic systems (Zametkin & Rapoport, 1987); and second, results from brain imaging studies implicate structures with rich dopamine innervation, such as the fronto-striatal circuitry (Tannock, 1998). Several different dopaminergic genes have been implicated in ADHD, but have suffered from inconsistent findings across studies. Dopamine transporter gene DAT1 and dopamine D2 receptor gene DRD2 (see Swanson, 1997 and Faraone & Biederman, 1998 for reviews), dopamine D4 receptor gene DRD4 (see Faraone, Doyle, Mick, & Biederman, 2001 for a meta-analysis of the studies to date), as well as dopamine D5 receptor gene (Birchard, 1999) have all been associated with ADHD. At this stage, more work is necessary to disentangle the relationship between these genes.

The theory of a dopamine defect is complicated by the finding that neuroleptics (e.g., thioridazine, chlorpromazine and haloperidol), which are primarily known for their dopamine blocking action, have also been found to be effective in the treatment of ADHD (Fisher, 1998; Zametkin & Rapoport, 1987). It is difficult to reconcile observations that both stimulants, which potentiate dopaminergic activity, *and* neuroleptics, which block dopamine receptors, could lead to similar therapeutic effects.

However, the therapeutic effects of neuroleptics have not been documented consistently in the literature. Levy and Hobbes (1996) for example, found that methylphenidate significantly improved reaction times in the second block of the Continuous Performance Test, which is a task that requires the detection of infrequent targets among non-targets, in children with ADHD. However, when methylpheridate was preceded by a moderate dose of haloperidol this improvement in reaction time was

not found. Thus haloperidol appeared to block the normalizing effects of methylphenidate.

Involvement of the noradrenergic system has been implicated by the efficacy of stimulants and tricyclic antidepressants in ADHD, and from animal studies that have observed that hyperactivity caused by the depletion of cerebral noradrenalin (Curran & Taylor, 2000). Tricyclics such as desipramine are postulated to primarily, but not exclusively, inhibit noradrenalin reuptake (Biederman & Spencer, 2000). Further support for noradrenergic involvement comes from the implication of clonidine, an alpha2-adrenergic receptor agonist that inhibits the release of noradrenalin, in the treatment of ADHD (Solanto, 1998). The noradrenergic system has been associated with the modulation of higher cortical functions such as attention, alertness, and vigilance (Biederman & Spencer, 1999).

Stimulants and tricyclics (especially imipramine) also act on serotonergic systems, and serotonin has been implicated in treating hyperactivity in animals, such as in mice with inactivated genes for dopamine transporter (Marx, 1999). These hyperactive mice showed a clinical response to stimulants, but the concentration of extracellular dopamine remained unchanged, and both fluoxetine and a direct serotonin receptor agonist (agonists are substances that bind to a receptor to activate it) mimicked the action of stimulants (Gainetdinov et al., 1999). This finding suggests that the calming effects of stimulants may be due to the effects of serotonin.

The genetic aetiology of ADHD raises questions about its relatively high prevalence rate, considering its apparently maladaptive nature. ADHD may not just be a condition that disrupts academic, social and career success, but may have some survival value in our evolutionary history (Jensen et al., 1997; Shelley-Tremblay & Rosen, 1996). Hyperactivity, or increased motor behaviour for example, has been suggested (Jensen et al., 1997) to have had a useful role in hunter-gatherer environments, in terms of exploration of the environment, that is, in terms of effective spotting of new opportunities and anticipating dangers. Rapidly shifting attention has been proposed to have been advantageous for monitoring dangers, and impulsivity may have been adaptive in situations where time is of the essence (e.g., in order to quickly pounce on

potential prey; Jensen et al., 1997). Aggression that occurs comorbidly with ADHD may also have been useful for hunters in a hunter-gatherer society (Shelley-Tremblay & Rosen, 1996). High energy and willingness to take risks have also been seen as adaptive qualities associated with ADHD (Shelley-Tremblay & Rosen, 1996), and may even be beneficial for certain modern-day occupations such as soldier, entrepreneur, salesperson, and sky-diving instructor (Bradshaw, 2001).

1.4.2 Psychosocial Factors

The aetiology of ADHD is generally considered to be biological rather than determined by psychosocial factors in the child's environment. However, as is true of most disorders, biological vulnerabilities will interact with psychosocial factors (Weiss, 1996). Rutter, Cox, Tupling, Berger and Yule (1975) studied the prevalence of mental disorders in children, and revealed six risk factors that correlated with childhood mental disorders. These risk factors were marital discord, low social class, large family size, paternal criminality, maternal mental illness, and foster placement. As the number of adverse conditions accumulated, the risk of impaired outcome in the children increased proportionally. Biederman, Milberger et al. (1995) investigated these risk factors (with the exception of adoption) in 140 ADHD and 120 control children, and found that ADHD children, compared to controls, came from families with higher conflict, were of lower socio-economic status, and had more mothers with psychiatric diagnoses. Family size and rates of paternal antisocial personality disorder did not differentiate ADHD from control children.

Szatmari, Offord and Boyle (1989) investigated the association between ADHD and various developmental and psychosocial factors in a cross-sectional study. Their results suggest that a number of household, family, parent- and child-centred variables are more common in ADHD than non-ADHD children. The authors undertook a logistic regression analysis (controlling for the presence of other disorders), which revealed mainly child-centred variables, such as chronic health problems in the child, young age, urban living, developmental problems/ delays (consisting of trouble with speech, clumsiness, delay in learning to walk and low birth-weight), and being on welfare (especially in girls rather than boys). These child-centred variables were not

uniquely associated with ADHD, but they were associated with ADHD over and above their relationship with other disorders.

Weiss (1996) reviewed the literature on psychosocial variables and reported that associations of family stress/ dysfunction, lower economic status, and negative mother-child relationships all contribute to the severity of ADHD. Family stability and quality of parenting interacted with child factors to predict long-term outcomes in ADHD. However, correlations do not show causation, which leaves the question of whether ADHD causes those psychosocial factors, or whether these psychosocial factors are an effect of ADHD. Follow-up studies are needed to determine whether these psychosocial factors are the cause or the effect of ADHD, perhaps by determining whether these variables occur prior to the onset of the disorder and continue to be positively related to it, or occur subsequently to the onset of the disorder. Further, it appears that most of the psychosocial variables are not specific to ADHD, but instead are universal risk factors for various psychiatric illnesses.

1.4.3 Environmental factors

Environmental factors may interact with genetic predisposition, or perhaps even present an independent aetiological pathway in some cases of ADHD. Environmental factors typically implicated in ADHD include premature birth, maternal alcohol and tobacco use, and exposure to lead in childhood (Barkley, 1998). In the past, there have been claims that sugar and food additives contribute to ADHD, but there is no empirical support for this position, and diet is generally not accepted as a contributory factor in current literature (e.g., Levy, Barr, & Sunohara, 1998; Barkley, 1998; Weiss, 1996).

Complications during pregnancy, delivery and infancy are often implicated because they may cause damage to the developing brain at critical times (Milberger, Biederman, Faraone, Guite, & Tsuang, 1997). Studies suggest that factors from early rather than later in a child's medical history are best predictors of subsequent ADHD (e.g., Hartsough & Lambert, 1985). A study of children with very low birth weight at 12 years (Botting, Powls, Cooke, & Marlow, 1997) indicated that the main psychiatric risk associated with low birth weight was ADHD, with 23 % of children with very low

birth-weight meeting clinical criteria, compared to 6% of matched controls. Another study of problems in children born to mothers who had abused alcohol throughout pregnancy indicated that 10 out of the 24 children had ADHD, and three had autistic spectrum disorders (Aronson, Hagberg, & Gillberg, 1997). Maternal smoking during pregnancy may also be a risk factor for ADHD (Milberger, Biederman, Faraone, Chen, & Jones, 1996).

A study by Sprich-Buckminster, Biederman, Milberger, Faraone, and Krifcher (1993) found that pregnancy, delivery and infancy complications were associated with ADHD (diagnosed using DSM-III criteria). Risk of complication was greatest for children with ADHD and comorbid disorders, and ADHD children without first-degree relatives with ADHD. However, children with ADHD but without comorbidities and children with ADHD who also had a first-degree relative with the disorder, had lower risks than controls. Another study investigating the association of pregnancy, delivery, and infancy complications with ADHD (Milberger et al., 1997) found that maternal factors (specifically bleeding, smoking, illicit drug use, emotional problems, and family problems during pregnancy) were associated with outcome of ADHD (diagnosed using DSM-IIIR criteria), whilst delivery complications were not. In this study there were no significant differences between ADHD children with and without comorbid conditions. In contrast to the former study by Sprich-Buckminster et al. (1993), a greater association was found in this study between complications and non-familial ADHD (i.e., ADHD children with no first-degree relatives with the disorder). Differences in findings between these studies may reflect differences in DSM-III versus DSM-IIIR diagnostic criteria, and limitations such as relying on parent report rather than medical records to determine complications in pregnancy, delivery and infancy.

1.5 Neuroimaging studies in ADHD

Localized hemispheric structural anomalies that have been reported in ADHD are consistent with theoretical models that postulate abnormal frontal-striatal function. Studies utilizing magnetic resonance imaging are summarised in Table 1. Overall, the studies report smaller right prefrontal cortex in individuals with ADHD (Castellanos et al., 1996); reduced size of the corpus callosum in individuals with ADHD (Giedd et

al., 1994; Baumgardner et al., 1996; cf. Castellanos et al., 1996); smaller cerebellum (Castellanos et al., 1996; Berquin et al., 1998); and smaller than normal structures of the basal ganglia (specifically the caudate nucleus) corresponding to the loss or reversal of the caudate-asymmetry found in normal controls (Castellanos et al., 1996). However, it is noteworthy that even the direction of the normal pattern of caudate asymmetry (left larger than right, or right larger than left) is controversial (Hynd et al., 1993; Filipek et al., 1997).

The basal ganglia and cerebellum have traditionally been considered as contributing to motor planning and execution, respectively. Motor execution problems may result in deficits in motor coordination (e.g., lack of motor smoothness), which are seen as an important feature of cerebellar dysfunction (Bradshaw & Mattingley, 1995). Both structures have also been implicated in cognitive functions such as rule-based learning and planning of future behaviour (Middleton & Strick, 1994). In reports of patients with lesions in the basal ganglia (specifically caudate lesions), some patients showed apathetic behaviour with decreased spontaneous verbal and motor activity, others were disinhibited, inappropriate and impulsive, and others showed affective symptoms (depression, anxiety) with psychotic features (Mendez, Adams, & Lewandowski, 1989). These patients were also found to be impaired on various neuropsychological tests that required planning and sequencing ability. Children with ADHD have also been found to be impaired on a variety of neuropsychological tests (see Chapter 2) requiring planning ability (Pennington & Ozonoff, 1996).

The corpus callosum facilitates communication and integration of information between the two hemispheres (Bradshaw & Mattingley, 1995; Witelson, 1989). Abnormalities in a specific area of the corpus callosum are interpreted as reflecting abnormalities in the corresponding region of the brain from where these fibres originate (Giedd et al., 1994). Two studies have implicated involvement of the rostral body of the corpus callosum in ADHD (Giedd et al., 1994; Baumgardner et al., 1996). The rostral body contains projections to the premotor and supplementary motor regions (Witelson, 1989). Premotor and supplementary motor regions are believed to be important in temporal organization, timing, initiation and execution of voluntary movements, and sequencing (Bradshaw & Mattingley, 1995). Callosal damage may result in difficulty

inhibiting unintended behaviour, and callosal damage in conjunction with premotor or supplementary motor area damage may lead to synkinesis, in which during movement of one limb, simultaneous symmetrical movement in the other limb cannot be inhibited (Bradshaw & Mattingley, 1995). Neurological examinations for "soft" signs related to motor coordination and motor overflow movements (which are for example, associated movements in the hands on moving the feet), have found that hyperactive children demonstrate more such signs and movements than control children (e.g., McMahon & Greenberg, 1977).

The prefrontal cortex is postulated to be involved in 'supervisory control' or 'executive functioning', subserving the capacity to manage behaviours sequentially in space and time, organize goals, attend to several components simultaneously, think flexibly, resist distraction and interference, grasp context, follow multi-step instructions, and inhibit responses (Bradshaw & Mattingley, 1995; Mesulam, 1986). A variety of behavioural changes have been reported in patients with prefrontal lesions, including: profane and irresponsible behaviour; apathy and loss of initiative, spontaneity and curiosity; restlessness and impulsivity; lack of judgment, foresight, insight and loss of ability to delay gratification; impairment of abstract reasoning, problem solving and mental flexibility (Mesulam, 1986; Stuss & Benson, 1984). Children with ADHD have also been found to demonstrate difficulties (see Chapter 2) similar to those of patients with prefrontal lesions (Pennington & Ozonoff, 1996).

Whilst anomalies in structure may not necessarily correlate with functional deficits, the structural anomalies observed in the prefrontal cortex, basal ganglia, cerebellum and corpus callosum of persons with ADHD may reflect deficits in executive cognitive processes, which are often reported in ADHD (e.g., Pennington & Ozonoff, 1996). Further evidence for the involvement of frontal regions in ADHD comes from functional imaging results. Functional methodologies used to study brain metabolism and regional change in brain activity include various techniques such as positron emission tomography (PET), single photon emission computerized tomography (SPECT), and functional magnetic resonance imaging (fMRI; Toga & Mazziota, 1996). Table 1 summarises the findings of several functional neuroimaging studies in ADHD.

Lou, Henrikson, Bruhn, Borner and Nielsen (1989) measured regional cerebral blood flow in children with ADHD, and found striatal regions of the basal ganglia to be hypoperfused and hypofunctional. Hypoperfusion was most marked in the right striatum in children with ADHD, and in both left and right striatal regions in children with ADHD and various other neurological symptoms. Low striatal activity was found to be partially reversible with methylphenidate. Hypofunctioning of the basal ganglia predicts difficulties in movement preparation and higher-order cognitive planning deficits (Bradshaw & Mattingley, 1995), all of which have been implicated in ADHD (Barkley, 1997b; Van der Meere, 1996).

Zametkin et al. (1990; 1993) used PET scanning to study adolescents with ADHD and parents of ADHD children who themselves had a childhood history of ADHD. In adults, they observed a widespread and bilateral reduction in glucose metabolism that was most pronounced in the premotor cortex and superior frontal cortex. These areas have been reported to be involved in control over movements and sequencing (Bradshaw & Mattingley, 1995) and executive functioning (Mesulam, 1986). Findings in the adolescent group were somewhat inconsistent with those of the adults. In adolescents, Zametkin and colleagues found decreased glucose metabolism in the left frontal lobe, left thalamic, and right hippocampal areas, but no significant overall reduction in glucose metabolism.

A study by Vaidya et al. (1998) on the effects of methylphenidate on cerebral glucose metabolism indicated that whilst methylphenidate reduced inhibition errors on a go/ no-go task (a task on which participants are required to inhibit their usual go response upon presentation of an infrequent no-go stimulus) for both ADHD children and controls, it also increased striatal activation in ADHD and decreased striatal activation in controls. Without medication, striatal activation was greater during this task in controls than in ADHD children, and conversely, with medication, striatal activation was greater in ADHD children than controls. Thus the reduction in inhibition errors made by ADHD children appears to be associated with greater striatal activation that results from the administration of methylphenidate.

In summary, structural and functional neuroimaging techniques suggest dysfunction of frontal brain regions in ADHD. It is possible that the deficits observed in children with ADHD may be caused by the anomalies in brain structure and function observed in the neuroimaging studies, or on the other hand, that the deficits in children with ADHD *per se* cause these anomalies. The question of whether a particular disorder causes structural or functional differences in the brain, or whether these differences cause a particular disorder, cannot be easily resolved.

Table 1: Structural MRI and functional neuroimaging studies of individuals with ADHD

Study and Technique	Sample	Details and findings
Hynd et al. (1993) MRI	11 ADHD children (3 girls) 11 control children (5 girls) Mean age = 11 years IQ: Controls > ADHD ADHD + comorbid diagnoses	Basal Ganglia: - reverse of normal left > right asymmetry (of the head) of the caudate nucleus (due to smaller left caudate nucleus)
Castellanos et al. (1994) MRI	50 ADHD boys 48 control boys aged between 5-19 years 39/50 previously treated with stimulant medication ADHD + comorbid diagnoses	Basal Ganglia: - loss of normal right > left caudate (head + body) asymmetry - smaller right caudate - lack of normal decrease of caudate volume with age Smaller total brain volume
Giedd et al. (1994) MRI	18 ADHD boys 18 control boys aged between 6 and 15 years	Corpus Callosum: - smaller rostrum and rostral body Smaller rostral body correlated with higher behavioural ratings of impulsivity/ hyperactivity
Castellanos et al. (1996) MRI	55 control boys 57 ADHD boys aged between 5 and 17 years	Smaller total cerebral volume Smaller cerebellum Smaller right anterior frontal region No significant differences in corpus callosum

Study and Technique	Sample	Details and findings
Castellanos et al., continued	used children from previous study Castellanos et al 1994 the majority of children with ADHD (53/55) had previous exposure to psychostimulants ADHD participants had comorbid diagnoses	Basal Ganglia: - lack of normal right > left caudate (head and body) asymmetry (due to reduced right caudate volume) - no difference in putamen volume or symmetry - smaller right globus pallidus Decreased (normal) caudate asymmetry was associated with increased perinatal risk in the ADHD group only
Baumgardner et al. (1996) MRI	13 ADHD boys 16 children with Tourette syndrome 21 children with Tourette syndrome + ADHD 27 normal children 11 of the 77 children were female children were aged 6-16 years	Corpus Callosum: - ADHD was associated with smaller rostral body area - Tourette syndrome was associated with 4 larger corpus callosum subregions (splenium, isthmus/ posterior body, mid-body, rostral body), total area and perimeter of the corpus callosum - for several measures, values for the Tourette + ADHD group fell midway between the control and the Tourette group, whereas the ADHD values fell below those of controls. Thus Tourette syndrome and ADHD were described as resulting from distinct neuro-developmental processes.
Mataró, Garcia-Sánchez, Junqué, Estévez-González, & Pujol (1997) MRI	8 boys, 3 girls with ADHD Controls- 16 boys, 3 girls 14-16 years of age DSM-IIIR criteria. None receiving psychotropic medication.	Basal Ganglia: - larger right caudate nucleus (head) area in ADHDs No significant results in terms of asymmetry scores

Study and Technique	Sample	Details and findings
Filipek et al. (1997) MRI	15 ADHD boys (average age 12.4 years) 15 controls boys (average age 14.4 years) age range = 8-19 years all ADHD boys were taking medication prior to the study; 10 were considered stimulant responders, 5 were considered stimulant nonresponders	Smaller volume of the total en bloc and white matter of anterior-superior (frontal) hemispheric region (particularly in the right hemisphere) Smaller bilateral anterior-inferior (peri-basal ganglia) hemispheric region en bloc Smaller white matter volumes of the bilateral retrocallosal (posterior parietal-occipital) hemispheric regions Basal Ganglia: - smaller total left caudate (head and tail combined) - smaller left caudate head - reversed left > right caudate head asymmetry Medication effects: Stimulant responders – smallest and symmetric caudate volumes, smallest left anterior-superior cortex volumes Stimulant nonresponders – reversed caudate asymmetry, smallest retrocallosal (parietal-occipital) white matter volumes.
Casey, Castellanos et al. (1997) MRI	26 ADHD boys 26 control boys. aged 5-12 Subset of the boys used in study by Castellanos et al. 1996	Performance differences on three response inhibition measure tasks purported to measure response inhibition at different stages of processing (1 sensory selection, 2 response selection, 3 response execution) were correlated with MRI anatomical measures of frontostriatal circuitry. Sensory selection task correlated with right prefrontal and right caudate measures Response selection and execution tasks correlated with caudate symmetry and left

Study and Technique	Sample	Details and findings
Casey, Castellanos et al. continued		globus pallidus measures. Prefrontal measures correlated with inhibitory conditions in task (whereas caudate and globus pallidus were correlated with both normal/ control and inhibition trials)
Berquin et al. (1998) MRI	46 ADHD right-handed boys 47 control right-handed boys aged between 5 and 18 years participants also used in Castellanos et al. 1996	Significantly smaller total cerebral volume Cerebellum: - smaller total cerebellar volume was not significant after controlling for total cerebral volume - smaller cerebellar vermis (this reduction involved mainly the posterior inferior lobe, but not the posterior superior lobe).
Semrud-Clikeman et al. (2000) MRI	10 right-handed ADHD boys (aged 8-17) 11 controls (aged 9-18) participants from Filipek et al. 1997 (the stimulant responders participated in this study)	Performance differences on measures of inhibition (Stroop test) and cognitive flexibility (Wisconsin Card Sorting Test) were correlated with MRI measures. Poorer performance on test of inhibition as significantly related to reversed (reversal of the normal left > right asymmetry) asymmetry of the caudate Smaller left caudate head, and smaller bilateral white matter, both correlated with higher scores on the Externalizing Scale of a behavioural rating scale (The Child Behaviour Checklist) Participants with rightward caudate asymmetry tended to lose set more frequently on the cognitive flexibility task than those with the expected leftward asymmetry

Study and Technique	Sample	Details and findings
Lou et al. (1989) SPECT	6 ADHD 13 ADHD + other neurologic symptoms 9 controls (a lot of siblings of ADHD children) 6-15 years old	Striatal regions hypoperfused – right striatum in ADHD children, both striatal regions in ADHD + neurologic symptoms. Low striatal activity was improved with methylphenidate
Zametkin et al. (1990) PET with auditory attention task (Continuous Performance Task)	25 adults (7 females) with a childhood history of hyperactivity and were parents of children with ADHD 50 controls (22 females) no exposure to stimulant medication	No group difference with Continuous Performance Task Lower global cerebral glucose metabolism Lowest metabolism in premotor cortex and superior prefrontal cortex
Zametkin et al. (1993) PET With auditory continuous performance task	ADHD: 7 boys, 3 girls; mean age = 14.3 years Controls: 7 boys, 3 girls; mean age = 14.5 years 70% of controls had siblings with ADHD. 70% of ADHDs had previous exposure to stimulant medication.	No difference in global cerebral glucose metabolism Reduced glucose metabolism in left frontal lobe, left thalamus, right hippocampus No group difference with Continuous Performance Task Lower metabolism in left-anterior frontal lobe correlated with more severe symptoms

Study and Technique	Sample	Details and findings
Vaidya et al. (1998) fMRI	Performed 2 go/ no-go tasks of inhibition. On versus off stimulant medication 10 ADHD boys, 6 control boys. DSM-IV criteria (8 combined types, 2 inattentive types). Age range: 8-13 years.	ADHDs improved inhibition errors with methylphenidate on both tasks, controls improved error rate with methylphenidate on one task. For the one task in which ADHD and controls improved with medication: - medication increased striatal activation in ADHDs and decreased it in the controls - striatal activation greater in controls than ADHDs (off medication) - striatal activation greater in ADHD than controls (on medication) Frontal activation increased with medication in both groups
Schweitzer et al. (2000) PET during working memory task (paced auditory serial addition task)	6 ADHD adult males 6 control males two of the ADHDs had previous exposure to stimulant medication	Task related changes in cerebral blood flow in normals were more prominent in frontal and temporal brain regions (anterior cingulate, medial frontal regions, left middle frontal regions) Task related changes in ADHD males were more widespread and primarily located in the occipital regions (left middle temporal lobe, right lenticulate, left parahippocampal gyrus, bilateral cerebellum) Men with ADHD also reported use of visual imagery to perform the working memory task, which may reflect compensatory strategies.

CHAPTER 2
COGNITIVE AND MOTOR IMPAIRMENTS

The involvement of fronto-striatal regions in ADHD predicts motor and (higher-order) cognitive impairments, including problems with attention. Before discussing specific impairments in ADHD it is necessary to outline briefly concepts central to the topic of attention.

2.1 Concepts of attention and executive functioning

Attention can be defined as a set of dynamic processes that enables individuals to direct themselves to appropriate aspects of external environmental events and internal operations (Everett, Thomas, Cote, Levesque, & Michaud, 1991; Cohen, 1993). LaBerge (1995) identified three major benefits of being able to pay attention: accuracy, speed and maintenance of mental processing.

Posner and Boies (1971) posited three major categories of attention: alertness, selective attention, and attentional capacity. *Alertness* refers to the notion of maintaining or *sustaining attention* over an extended period, and incorporates the notion of *vigilance*, in which there is a demand for anticipatory readiness for infrequent targets. In this situation, where target stimuli are rare, it is most difficult to sustain attention. Difficulties in sustaining attention manifest as decrements in performance over longer periods on a task. Individuals who exhibit deficits in sustaining attention may show short attention spans, such that their behaviour is impersistent and their activities are brief (Taylor, 1995). *Selective or focused attention*, refers to the ability to select information from one source or of one kind rather than another (Posner & Boies, 1971), and thus incorporates focusing on pertinent aspects and ignoring irrelevant aspects of stimuli/ information. One way of selecting information is to *orient* to it. Orienting attention involves *disengaging* from the current focus, *shifting* attention and *(re)engaging* attention at the new focus (Posner & Petersen, 1990). Attention may also need to be *divided* between two or more sources (Kinsbourne, 1994). Individuals who are impaired at selecting between different sources of information are likely to be described as "distractible", because their attention is easily captured by many irrelevant aspects of the world (Taylor, 1995).

Attentional capacity refers to the idea of limited processing capacity (Posner & Boies, 1971).

Another concept in the literature is *automatic* versus *deliberate or effortful* processing (Shiffrin & Schneider, 1977). In the former case, attention is applied to tasks without the individual being conscious of what he/ she is attending to; there is no sense of attentional effort, whereas in the latter case, distinct attentional effort or concentration is required. When learning to drive for example, it takes considerable effort and deliberate concentration. However, over time, driving gradually demands less attentional effort and eventually can be performed automatically, so that attention can be diverted to other things. Shallice (1982) proposed that when novel events occur, deliberate control of action operates, better known as the *supervisory attentional system.* Shallice posited that impairments in the supervisory attentional system would manifest in difficulties with non-routine tasks (independent of performance on routine tasks). Shallice suggested that patients with frontal lobe damage have a supervisory attentional system impairment, thus accounting for their difficulty in coping with novelty or in planned initiative.

The anomalies in brain regions observed in the neuroimaging studies in Chapter 1 may also be associated with the neuroanatomical networks of attention specified by Posner and Raichle (1994). The three proposed networks are:

1) An *executive control* network for divided attention, coordinating multiple specialised neural processes and for ordering multiple responses so as to direct behaviour towards a goal (e.g., by detecting the presence of a target, starting and stopping mental operations, ordering multiple responses). This network involves the anterior corpus callosum, anterior cingulate, and basal ganglia.
2) A *vigilance network* for sustaining attention or alertness. This network involves the right frontal lobe and the noradrenergic system originating in the brainstem.
3) An *orienting network* for selective attention (by disengaging attention from current focus, shifting attention to the new focus and engaging attention to the new focus). This network involves the superior colliculus, thalamus and posterior parietal lobe.

Swanson et al. (1998) proposed that DSM-IV criteria that describe poor sustained attention are related to a deficit in the vigilance network; those that describe poor selective attention are related to a deficit in the orienting network; and those that describe poor conflict resolution or divided attention are related to an executive control deficit. Describing psychopathology in attentional terms, assuming that this reflects the underlying psychological processes, may not always be so straight-forward. For example, behaviours giving rise to the description of distractibility would include engaging only briefly in any given activity and frequently changing activities. Observation alone could not distinguish whether these behaviours were due to difficulties in sustaining attention, or perhaps due to attention being captured by irrelevant stimuli (Taylor, 1995).

There is considerable overlap between processes considered to be attentional, such as Shallice's (1982) *supervisory attentional system,* and processes considered as *executive functions.* Pennington and Ozonoff (1996) describe the domain of executive function as:

> "..distinct from cognitive domains such as sensation, perception, and many aspects of language and memory. It overlaps with domains such as attention, reasoning, and problem solving, but not perfectly. Typical lists of executive functions include set-shifting and set maintenance, interference control, inhibition, integration across space and time, planning, and working memory. A central idea in the concept of executive function is context-specific action selection, especially in the face of strongly competing, but context-inappropriate, responses." (p. 54)

Barkley (2000) described functions as executive if they involved the *when* or *whether* aspects of behaviour, compared to the *what* and *how* of non-executive functions. In neuropsychology, the term executive functioning appears to refer to tasks on which patients with frontal lesions perform poorly (Pennington & Ozonoff, 1996). As it is difficult to differentiate between "higher-level" attention and executive functions, it may be best to consider the difference as one primarily of semantics, at least for the purposes of this review.

2.2 Current models of ADHD

Neuropsychological/ cognitive deficits observed in children with ADHD have led to a variety of models describing the nature of the core deficit in ADHD. Although all the models mention problems with disinhibition, they vary in what they claim is the *underlying cause* of this disinhibition problem. Descriptions of the underlying deficit in ADHD included problems with delay aversion, difficulties with regulating state activation and effort, and problems with behavioural inhibition *per se*. These models have all focused on the combined type of ADHD, and are outlined briefly below.

2.2.1 The behavioural inhibition model

Barkley (1997b) proposed a model of ADHD based on the neuropsychological functioning of the brain's prefrontal lobes, and a review of research findings on ADHD. Barkley suggested that ADHD (combined and hyperactive-impulsive type) is not a deficit of *attention*, but rather a deficit in *behavioural inhibition*. Barkley's term "behavioural inhibition" refers to three interrelated processes:

1) Inhibition of the initial prepotent response (response for which immediate reinforcement is available, or has been previously associated with that response).
2) Stopping of an ongoing response, which thereby allows a delay in the decision to respond.
3) The protection of this period of delay and the self-directed responses that occur within it from disruption by competing events and responses (otherwise known as interference control).

Barkley's (1997a) model ascribes the impairments in ADHD to abnormalities in the structure and function of the prefrontal cortex and its networks with other brain regions, especially the striatum. Behavioural inhibition is postulated to directly influence motor control. Further, behavioural inhibition is proposed to impact on four executive functions: working memory, self-regulation, internalisation of speech and reconstitution (the analysis and synthesis of internally represented information), necessary for internal control of motor actions. Thus inhibition and the executive functions contribute greater control, timing, persistence, flexibility, novelty, and complexity to goal directed motor actions.

Barkley (1997b) excluded the predominantly inattentive type of ADHD children from his model, claiming that the type of inattention manifested by individuals with this subtype of ADHD, reflects deficits in speed of information processing and in selective attention, and is qualitatively different from the type of inattention manifested by individuals with the combined type of ADHD, which reflects problems in sustained attention and distractibility. Poor sustained attention represents an impairment in goal or task directed persistence arising from poor inhibition and the effect this has on self-regulation. Distractibility is postulated as arising from poor interference control that allows other external and internal events to disrupt the executive functions that provide for self-control and task persistence.

Barkley (1997b) outlined a number of clinical observations and studies to support his argument of deficient inhibition, working memory, self-regulation of affect-motivation-arousal, internalisation of speech, reconstitution and motor control/ fluency/ syntax. He suggested that impulsivity was a measure of behavioural inhibition. For example, the clinical observation that ADHD children talk more than other children (which is one of the hyperactive-impulsive diagnostic criteria in DSM-IV) was taken as evidence of poor behavioural inhibition. Further evidence for poor behavioural inhibition came from studies that involved withholding responses, cessation of ongoing responses and resisting distraction or disruption by competing events. These studies are briefly outlined below.

The ability to withhold a response is measured by the go/ no-go paradigm in which participants are required to make a simple motor response to the go stimulus while inhibiting the response to the no-go stimulus. Commission errors, that is, failure to inhibit the response to the no-go stimulus, are interpreted as difficulties in inhibition, whilst omission errors, or failure to respond to the go signal are interpreted in terms of inattentiveness. Typically, children with ADHD have been found to make more commission errors on this task (e.g., Trommer, Hoeppner, Lorber, & Armstrong, 1988; Shue & Douglas, 1992). The ability to cease an ongoing response is often studied via the stop-signal task. In the primary task, a response is made to a go signal, and occasionally a stop signal is presented after the initial go signal, requiring the

participant to inhibit their response to the primary task. Stop signals are presented at different intervals after the go signal, and the greater the interval between the initial go signal and the subsequent stop signal, the more difficult it is to inhibit the response. ADHD children appear to have consistent difficulties with efficient response inhibition on this task (Schachar & Logan, 1990; Oosterlaan, Logan, & Sergeant, 1998), but their performance improves with administration of methylphenidate (Tannock, Schachar, Carr, Chajczyk, & Logan, 1989).

Barkley (1997b) referred to studies using the continuous performance test (CPT) and the Stroop test as further evidence for deficient inhibition. The CPT is a task requiring the participant to detect an infrequent stimulus embedded in a series of irrelevant stimuli. Children with ADHD have typically been found to make more commission errors, that is, responses to non-targets, than controls (see Corkum & Siegel, 1993 for a review), which is interpreted as a problem in ignoring irrelevant (non-target) stimuli. The Stroop word colour interference test is a measure of the ability to inhibit the interference of automatic responses. The Stroop test requires participants to name the ink colour of congruent or incongruent colour names. An incongruent trial, for instance, would require the participant to respond 'red' to the word BLUE printed in red ink. When the name and ink colour are incongruent, there is conflict between a relatively automatic word-reading response, and a more controlled or demanding colour naming response, resulting in more errors and hesitations (and thus an increase in reaction time) than when the word and ink colour are congruent (Stroop, 1935). Typically, children with ADHD are slower than controls to name ink colours of incongruent colour words (Leung & Connolly, 1996; Pennington, Grossier, & Welsh, 1993), which suggests difficulties with inhibition of interference.

Barkley (1997b) suggested that poor performance of ADHD children on mental arithmetic and digit span backwards tasks (repetition of digits in the reverse order) was evidence for a working memory deficit in ADHD. He did not present any direct evidence supporting his self-regulation of affect/ motivation/ arousal hypothesis in ADHD, but did cite studies showing a relationship between emotional responses and ratings of interference control/ disruptive behaviour in children, disorders of emotion occurring after frontal lobe injury, and clinical reports of negative emotional reactions

in children with ADHD. Barkley also reported that impaired persistence in ADHD children was evidence for difficulties in self-regulation of motivation, and that neuroimaging studies showing frontal lobe underactivity were evidence for deficits in arousal. Whilst Barkley reported studies that have investigated rule-governed behaviour in children with ADHD, he could not report any studies examining the internalisation of speech. Barkley also argued that deficits in speech when it must be goal directed, such as those observed in verbal fluency tasks (these are basically word generation tests), support his proposal of difficulties in reconstitution. For evidence of difficulties in motor control-fluency-syntax, Barkley cited studies showing overflow movements, deficits in fine motor coordination, and reports of poor handwriting, drawing and speech problems in ADHD.

In summary, whilst Barkley's (1997b) model is very attractive because it encompasses most of the impairments that have been reported in the ADHD literature, there is still a lack of direct evidence to support all facets of his model (for example, internalisation of speech). There is also no compelling evidence to suggest that problems in sustained attention arise as a secondary impairment, from the effects of poor behavioural inhibition. Similarly, there is no evidence supporting the assumption that impairment in behavioural inhibition leads to secondary impairments in the four executive functions, or that these lead to decreased motor control. Whilst one way of testing this may be to determine whether improvements in inhibition are correlated with improvements in the four executive functions, it would still be difficult to show any directional causal relationship between deficits in behavioural inhibition, working memory, motor control etc. Also, whilst children with the predominantly inattentive type of ADHD are less frequently studied than the combined type, there is emerging evidence that these children show similar deficits to their combined type counterparts, on several tests, including those measuring the ability to withhold responses (Trommer et al., 1988; Prout, 2000), working memory (Siegel & Ryan, 1989) and motor coordination (Piek, Pitcher, & Hay, 1999). These findings are inconsistent with Barkley's proposition that inattentive type children have different underlying impairments than those with the combined type of ADHD.

2.2.2 *The state regulation model*

Van der Meere (1996) and Sergeant (2000) investigated ADHD from an information-processing perspective, and have suggested that children with ADHD do not show deficits in encoding or central information processing stages, but rather, exhibit deficits in the *response selection and motor output stages of processing* (cognitive processes just preceding the overt motor action, i.e., response decision and response organization processes).

In a visual search study by Van der Meere, Van Baal and Sergeant (1989) children were instructed to respond either in the direction of the target-set location (compatibie response), or in the opposite direction from the target location (incompatible response). The authors also manipulated memory load (number of items in the target set). They postulated that an increase in reaction time as a function of increasing memory load reflects divided attention processes, and an increase in reaction time as a function of incompatible responses reflects the rate of motor decision or preparation processes. The finding of delayed incompatible responses of hyperactive children compared to controls was interpreted in terms of a motor decision problem, whilst the finding of slower responses with higher memory load in the learning disabled children, compared to hyperactive and control children, was interpreted in terms of a deficit in divided attention.

This motor output deficit was seen as a consequence of a primary *state regulation problem*, where ADHD children are unable to sustain the energy required to maintain efficient processing (Van der Meere, 1996; Sergeant, 2000). Three energetic mechanisms have been proposed: *arousal,* which enhances processing of sensory activity and is postulated to be located in the fronto-limbic forebrain; *activation,* which is concerned with control of motor readiness and is postulated to be located in the basal ganglia and corpus striatum; and *effort,* which is influenced by motivational factors such as knowledge of results, pay-off and self-regulation versus external regulation (Van der Meere, 1996; Sergeant, 2000). The effort system is suggested to be controlled by an executive function system (associated with planning, monitoring, and detection of errors), which monitors the arousal and activation states, and compensates

for suboptimal states through effort (effort refers to the energy necessary for the regulation of an individual's actual state). The hippocampus is believed to be involved in such compensatory control. Specifically, the deficits in ADHD are proposed to be in activation, or readiness to respond, and in effort, or the energy required to modulate arousal and activation in completing a task (Van der Meere, 1996). Because motor preparatory processes require activation, tasks that put a high demand on activation, such as low event-rate tasks, result in poorer performance by ADHD children who cannot maintain this activation. Accordingly, the observed problems in motor response processes in ADHD, which manifest typically as slow, inaccurate responding on tasks with slow event-rates, are believed to reflect an underlying dysfunction in effort and activation components of energetic mechanisms.

Support for the state-regulation model comes from several experiments that have examined the role of state factors such as presentation rate of stimuli and length of time spent on-task. When reaction time attention tasks were short and administered in the presence of an experimenter, it has been found that ADHD children, despite showing general task inefficiency compared to controls, could divide their attention among simultaneously presented stimuli (Van der Meere & Sergeant, 1987) and could ignore irrelevant stimuli in favour of processing relevant stimuli (Van der Meere & Sergeant, 1988b). Similarly, ADHD children could sustain attention over time, that is, their performance did not deteriorate with time spent on task, when tasks were self-paced (Van der Meere, Wekking, & Sergeant, 1992). They did however exhibit a decrement in task performance with task duration when stimuli on the CPT were presented at a slow presentation rate (Van der Meere, Shalev, Boerger, & Gross-Tsur, 1995). These sustained attention deficits were found to be exacerbated with the absence of the experimenter, and normalized (in both experimenter absent and present conditions) when the ADHD children received methylphenidate (Van der Meere, Shalev et al., 1995).

ADHD children are postulated to have particular difficulty in regulating their state in order to cope with variations in presentation rate (Van der Meere, Stemerding, & Gunning, 1995). A fast presentation rate is thought to lead to overactivation, so in order to perform accurately in this condition, participants must regulate their state, and

reduce activation. The reverse is thought to be true for a slow presentation rate, where participants are required to increase activation. Van der Meere, Stemerding et al. (1995) studied ADHD children's ability to inhibit responses in a go/ no-go task under fast (Inter-Stimulus-Interval (ISI)= 1s), medium (ISI= 4 s), and slow (ISI = 8 s) event rate conditions. The authors found that compared to controls, the ADHD group had difficulties in refraining from responding to the no-go stimulus under fast and slow conditions, but not in the medium event rate condition. Thus poor response inhibition was interpreted as a result of ADHD children's difficulties in adjusting their activation state towards the task demands, rather than as a result of problems with response inhibition per se. Similar findings that may be explained in terms of a state regulation model have been indicated using the matching familiar figures test, where participants were required to select a previously seen target picture from a set of similar foil pictures (Sonuga-Barke, 2002a). ADHD children were found to perform poorly on trials of 5 and 15 seconds of duration, but performed no differently to controls on 10-second trials.

Manipulation of energetic factors such as presence of experimenter and stimulant medication should also interact with trial length, in accordance with the state regulation model. For example, performance under short and long trials would be expected to normalize following the administration of reward or stimulant medication, whilst trials of intermediate length in which performance is already normal, would be expected to show no change. Van der Meere, Gunning and Stemerdink (1999) investigated the performance of ADHD children taking placebo, methylphenidate and clonidine following a baseline assessment, on a go/ no-go task that presented its go/ no-go stimuli at 1, 4 and 8 second inter-stimulus intervals (ISI). The authors found that there was a significant effect of session, with better overall performance in the experimental than baseline session. However, session did not interact significantly with group, suggesting that the children did not differ in terms of task performance while on placebo or on active medication. There was also no significant group x session x presentation rate interaction to support the predicted improvements at fast and slow, but not medium, presentation rates, when on stimulant medication.

2.2.3 The delay aversion model of ADHD

Sonuga-Barke and colleagues (Sonuga-Barke, Taylor, Sembi, & Smith, 1992; Sonuga-Barke, Taylor, & Hepinstall, 1992; Sonuga-Barke, Williams, Hall, & Saxton, 1996) view the core deficit in ADHD as aversion to periods of delay. According to this model ADHD behaviours are expressions of an underlying motivational style. The impulsive, disorganized and undirected behaviour of children with ADHD is posited to be a functional expression of aversion to periods of delay. The delay-aversion model is based on findings from a number of experiments conducted by Sonuga-Barke and colleagues.

In a choice delay task, Sonuga-Barke, Taylor, Sembi et al. (1992) investigated the choice of small immediate rewards over larger delayed rewards in different conditions. In the first condition, where choosing smaller immediate rewards led to shorter session-length and more total reward over the session, both hyperactive and control children preferred the immediate rewards. In the second condition, where both immediate and delayed rewards were associated with the same overall session-length but delayed rewards were associated with more overall reward, both hyperactive and control children showed preference for the large delayed reward. In the third condition where both immediate and delayed rewards resulted in the same session-length, but the immediate rewards were associated with more overall reward, both hyperactive and control groups chose the small immediate rewards. However in the fourth condition, where the large delayed rewards were associated with longer session-length and greater overall reward than the small immediate rewards, the hyperactive children showed less preference for the delayed rewards than controls. This suggests that hyperactive children were more concerned with reducing overall delay as reflected in session-length, than with maximizing reward amount or immediacy.

Subsequently, Sonuga-Barke and colleagues also investigated how delay aversion may account for findings of poorer performance by ADHD children on measures of memory (Sonuga-Barke, Taylor, & Hepinstall, 1992) and impulsivity (Sonuga-Barke, Houlberg, & Hall, 1994; Sonuga-Barke et al., 1996). In the memory study, stimuli were presented for different durations. In the self-imposed condition children chose

the length of presentation of the stimulus themselves, whereas in the externally-imposed condition stimuli were presented for 30 seconds. Hyperactive children selected shorter inspection times and performed significantly worse than controls under self-imposed conditions, but did not differ significantly from controls in their performance in the externally-imposed conditions. Thus, hyperactive children may have adopted shorter inspection times due to an aversion to long periods of delay.

The matching familiar figures test (MFFT) in which participants are required to select a previously seen target picture from a set of similar foil pictures was used as a measure of impulsivity (Sonuga-Barke et al., 1994). Trial length was fixed in one condition and determined by response speed in another condition. Hyperactive children responded more quickly and made more errors than controls (responded "impulsively"), and completed each trial more quickly than controls. When trial length was fixed however, they took the same amount of time as controls to search for the target, but still made more errors, suggesting that they did not make effective use of the extra time. The authors speculated that hyperactive children attempted to modify their experience of time passing by attending to other aspects of the environment that were peripheral to the task, at the cost of good performance. Thus when actual levels of delay cannot be altered, the apparently disorganized behavioural style of hyperactive children may serve to reduce the perceived length of time that has passed during delay.

Further investigation, by comparing a condition where both correct and incorrect responses were immediately followed by the next trial, with a condition where only correct responses were followed immediately by the start of the next trial (and if children made a mistake a fixed trial length was imposed), revealed that hyperactive children withheld responses for as long as controls when this strategy offered them the best chance of avoiding extra delay (Sonuga-Barke et al., 1996). Whilst hyperactive children made less errors when they withheld their responses for a longer period of time, suggesting that they made some use of extra time, their performance on the MFFT was still poorer than that of controls. Under these circumstances, poor use of time in children with ADHD cannot be due to premature task disengagement, and the quality, not just the quantity, of processing while engaged with the task is implicated.

Executive functions such as working memory (for stimuli to be held in mind during search), planning and monitoring (for systematic search of stimuli), attentional flexibility and spatial memory (Sonuga-Barke, 2002a) may play a role in efficient performance on the MFFT. Sonuga-Barke (2002b) stated that, in the delay aversion model, "cognitive deficits associated with the provision, protection and use of time, such as working memory and planning, arise as secondary effects of delay aversion associated with patterns of reduced task engagement." (p. 30).

Sonuga-Barke (2002b) also proposed that the "poor inhibitory control" observed on stop-signal tasks may reflect the temporal structure of the stop signal paradigm. In one study (Solanto et al., 2001) children with ADHD performed the standard stop signal task and the choice delay task, which was essentially the same as that first used by Sonuga-Barke, Taylor, Sembi et al. (1992). The effect of ADHD on performance of both tasks was as expected from prior studies, and did not alter when comorbid problems of conduct or anxiety were taken into account. However, performance on the tasks was not correlated, suggesting the independence of poor inhibitory control and delay aversion in ADHD. Also, whilst the tasks showed moderate ability to discriminate between ADHD and normal children when used separately, they showed greater discriminant validity when used together, correctly identifying over 85% of cases. The choice delay task correlated with teacher (but not parent) ratings of impulsivity, hyperactivity and conduct problems, and with observations of gross motor activity and physical aggression, whereas the stop-signal task only correlated with observations. The authors interpreted these results as suggesting that delay aversion is associated with a broad range of ADHD characteristics, whereas inhibitory failure taps a more discrete dimension of executive control. These findings are so difficult to reconcile, that subsequently Sonuga-Barke (2002b) introduced a model of ADHD combining the view of ADHD as a disorder of the regulation of thought and action resulting from inhibitory dysfunction, with the view of ADHD as a motivational style.

2.3 Neuropsychology of ADHD

The studies mentioned in Section 2.2 already give some insight into the neuropsychology of ADHD. The following section aims to give a more comprehensive account of the literature by reviewing the evidence for deficits in

inhibition, set-shifting, planning, verbal fluency, working memory, sustained attention and motor functioning in ADHD. Generally, neuropsychological studies in the ADHD literature tend to be fraught with inconsistent results, which perhaps reflect differences in diagnostic criteria, differences in the type of comorbid disorders, poor measurement properties of the test(s), and/ or the heterogeneity of ADHD.

2.3.1 Deficits in inhibition

As alluded to in Section 2.2, problems in inhibition in ADHD have been measured using cognitive and behavioural tasks that require the participant to withhold or delay a response, cease an ongoing response, or ignore distracting and irrelevant stimuli (also referred to as focused or selective attention). As described in the section above, neuropsychological tasks used to collect evidence for deficits in inhibition include the continuous performance test (CPT), the matching familiar figures test (MFFT), the Stroop test, the go/ no-go test, and the stop-signal task. The focus of this section was to review the evidence for deficits in response inhibition in ADHD, as measured by these tasks.

Children with ADHD have been found to exhibit more interference from distracting stimuli on the Stroop task than controls (Houghton et al., 1999; Seidman, Biederman, Faraone, Weber, & Ouellette, 1997; Barkley, Grodzinsky, & DuPaul, 1992; Gorenstein, Mammato, & Sandy, 1989; Leung & Connolly, 1996; Grodzinsky & Diamond, 1992; Everett et al., 1991; cf. Davis, 2001; Harrison, 1998), including those with predominantly inattentive type of ADHD (Barkley et al., 1992; Chhabildas, Pennington, & Willcutt, 2001; cf. Houghton et al., 1999). However this finding is not specific to ADHD, and has also been observed in individuals with other disorders such as learning disorders (Lazarus, Ludwig, & Aberson, 1984; Barkley et al., 1992), schizophrenia (Abramczyk, Jordan, & Hegel, 1983; Boucart, Mobarek, Cuervo, & Danion, 1999), depression (Moritz et al., 2002) and conduct disorder (Giancola, Mezzich, & Tarter, 1998; Lueger & Gill, 1990; Hurt & Naglierie, 1992; Wolff, Waber, Bauermeister, Cohen, & Ferber, 1982; cf. White et al., 1994; Leung & Connolly, 1996).

Problems with ignoring irrelevant stimuli have also been documented in terms of ADHD children making more commission errors than controls on the CPT (Grodzinsky & Diamond, 1992; Chhabildas et al., 2001; Levy & Hobbes, 2000; cf. Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001). More CPT commission errors have also been observed in individuals with conduct disorder (Dougherty, Bjork, Marsh, & Moeller, 2000; cf. Dimitry, 1998) and Parkinson's disease (Hart, Wade, Calabrese, & Colenda, 1998). In some studies using the MFFT, children with ADHD have been found to respond faster and make more errors than controls (Cohen, Weiss, & Minde, 1972; Robins, 1992; Pennington et al., 1993). Other studies have indicated that individuals with ADHD make only more errors (Hopkins, Perlman, Hechtman, & Weiss, 1979), whilst yet other studies have indicated that ADHD children do not differ from controls both in measures of response time and errors (Fischer, Barkley, Edelbrock, & Smallish, 1990; Houghton et al., 1999; Stoner & Glynn, 1987) on the MFFT. Higher errors on the MFFT may also discriminate learning disabled children from controls (Quay & Weld, 1980; Aman, 1979).

Difficulties for ADHD children in inhibiting a prepotent response have been shown using the go/ no-go paradigm. This task requires participants to make a simple motor response to one cue (the "go" stimulus) while inhibiting the response in the presence of another cue (the "no-go" stimulus). Failure to inhibit the response to the no-go stimulus (a commission error) is interpreted as difficulty in inhibiting a response, and failure to respond to the go stimulus (an omission error) is interpreted in terms of inattentiveness. A number of studies (e.g., Trommer et al., 1988; Shue & Douglas, 1992; cf. Kerns, McInerney, & Wilde, 2001) have demonstrated that ADHD children with and without hyperactivity (according to DSM-III criteria) make more commission errors than normals on the go/ no-go paradigm. Trommer, Hoeppner and Zecker (1991) have also found that the amount of commission errors made by ADHD children with and without hyperactivity (according to DSM-III criteria) decreased with administration of methylphenidate. Problems with inhibition in response to the no-go stimulus are not specific to ADHD, and have also been reported in schizophrenia (Weisbrod, Kiefer, Marzinik, & Spitzer, 2000; Kiehl, Smith, Hare, & Liddle, 2000) and autism (Ozonoff, Strayer, McMahon, & Filloux, 1994).

ADHD children have demonstrated difficulty in ceasing an ongoing response on Logan and Cowan's (1984) stop-signal task. This task requires fast and accurate execution of an arbitrary motor response (such as a button press) in response to a "go" signal in the primary task. Occasionally a stop signal is presented after the initial go signal, which requires the participant to inhibit the response to the primary task. Stop signals are presented at different intervals after the "go" signal. The greater the interval between the initial go signal and the subsequent stop signal, the more difficult it is to inhibit the response. That is, the closer in time the participant is to having executed the button-press response, the more difficult it becomes to stop this response. By varying the stop signal interval, an estimate of the speed of the inhibitory process can be derived (stop signal reaction time, SSRT). A longer stop-signal reaction-time represents a slower inhibitory process, and makes it less likely that a response will be inhibited. To determine the reason for poor inhibitory control, variability of go reaction times and SSRTs between the groups are investigated. If there are differences between groups in mean go reaction time, variability of go reaction times, or SSRT, inhibition functions are replotted in terms of a z-score (Z relative finishing time, ZRFT). If, after this transformation, the slope of one group remains shallower, this function is interpreted as reflecting deficient inhibitory control; that is, the stop-signal is either triggering the stop process less often, or is triggering a response that is slower and more variable. If however, after this transformation, inhibition functions between groups are equivalent, this indicates that any differences in SSRT, mean go reaction times, or in primary-task variability (i.e., high variability in the latency of responding) completely account for differences between inhibition functions. That is, differences between the inhibition functions are related neither to differences in the probability of triggering the inhibitory process, nor to differences in the variability in latency of the inhibitory process.

Schachar and Logan (1990) compared 13 children with ADHD (using DSM-III criteria for attention deficit disorder with hyperactivity), 9 with conduct disorder, 14 with ADHD plus conduct disorder, 13 with emotional disorders, 11 with learning disorders, and 10 control children. Their results indicated that children with ADHD inhibited fewer responses than control children, but not fewer than the other clinical groups. The ADHD group had a flatter inhibition function (even after ZRFT correction) than the

control group and the ADHD + conduct disorder group, leading the authors to conclude that the inhibition mechanism of the ADHD group was triggered less frequently, was substantially more variable, or slower.

Oosterlaan and Sergeant (1996) studied inhibitory control using the stop-signal task in ADHD (DSM-IIIR diagnostic criteria), aggressive, anxious and control children. ADHD children exhibited slower reaction time on the primary task, and along with aggressive children showed more variable reaction times than controls. Both ADHD and aggressive groups showed slower stop-signal reaction time and flatter inhibition functions than controls. However, this difference between groups disappeared with ZRFT correction, leading the authors to conclude that poor inhibitory control in ADHD and aggressive groups is related to these children's more variable response execution rather than slow inhibitory process. The authors postulated that this variability might reflect fluctuations in the ability to inhibit distraction or a failure in energetical allocation. Further, performance on the stop-signal task has been shown to improve with administration of methylphenidate (Tannock et al., 1989; Tannock, Schachar, & Logan, 1995; Tamm, 2001).

Some studies have utilized a modification of the stop task, known as the change task. Similar to the stop task, the "change" signal instructs participants to inhibit their response to the primary task. However, in the change task, the "change" signal also requires participants immediately to execute another response, the change response. The change task therefore is purported to measure the ability to inhibit the ongoing action (as in the stop-signal task), plus the ability to shift rapidly to an alternate action (response re-engagement). Using this change task, Schachar, Tannock, Marriott and Logan (1995) demonstrated that, in comparison with controls, ADHD children (DSM-IIIR criteria) had longer SSRT and flatter inhibition functions. However, this difference was eliminated by ZRFT transformation. ADHD children also demonstrated deficient response re-engagement, having longer and more variable change-task reaction times.

Similarly, Oosterlaan and Sergeant (1998) found poor response inhibition using the change task in both ADHD and disruptive children (who had aggressive, delinquent or

oppositional defiant problems) when compared with normal controls. The difference in inhibition functions however, also dissipated with ZRFT transformation. The speed of response re-engagement however, was not significantly different, but was more variable in both ADHD and disruptive children compared to normal controls.

Oosterlaan, Logan and Sergeant (1998) conducted a meta-analysis on eight independent studies conducted between 1990 and 1997 using the stop-signal or change task. These studies largely used DSM-IIIR criteria. The meta-analysis concentrated on five group comparisons, namely ADHD versus controls, conduct disorder versus controls, ADHD versus conduct disorder, ADHD plus conduct disorder versus ADHD, and anxiety disorder versus controls. The authors found that relative to controls, ADHD children demonstrated longer SSRT and flatter inhibition functions. However, this difference was no longer significant after ZRFT transformation. Response inhibition deficits were not unique to ADHD children, as these did not distinguish children with ADHD from children with conduct disorder and from children with both ADHD and conduct disorder. Children with anxiety disorders did not differ from controls in response inhibition.

Oosterlaan et al.'s (1998) meta-analysis suggests that children with ADHD, conduct disorder and ADHD + conduct disorder show difficulties in response inhibition, but that these problems are not related to the probability of triggering the inhibition process. Rather, these difficulties seem to reflect a higher variability of the latency of responding. This may reflect a deficit in sensorimotor control; a stable speed in motor output requires an ideal balance between excitatory and inhibitory functions. Alternatively, variability may reflect deficits at a higher executive level, like attentional or motivational/ energetical allocation problems.

The results of a study by Konrad, Gauggel, Manz and Schöll (2000) support the motivational/ energetic explanation of inhibitory deficit in children with ADHD. These researchers compared the performance of children with ADHD, children with traumatic brain injury, and control children, on the stop-signal task with and without reward contingencies. Whilst all children improved their performance under the reinforcement condition, only the performance of children with ADHD was brought up

to the performance level of normal controls under reward contingencies. Rewards were less effective at improving response inhibition in children with traumatic brain injury. The authors interpreted these results in terms of evidence for a motivational/ energetic deficit underlying poor response inhibition in ADHD, and a more general executive function impairment attributable to structural brain damage in children with traumatic brain injury. The findings of this study, however, are not consistent with one conducted by Oosterlaan and Sergeant (1998), who investigated the effects of reward (credits were earned for successful response inhibition) and response cost (loss of credits for failing to inhibit) on response inhibition via the stop-signal task, in ADHD, disruptive, anxious and normal children. They found that even in the presence of reward, ADHD children showed poor response inhibition compared to normals. ADHD children also did not differ significantly in their response inhibition in either reward or response cost conditions. However, this study does differ from that of Konrad and colleagues in that it does not allow determination of the effects of reward and response cost, as it did not include a no-contingencies condition.

Difficulties on the stop-signal task have also been evident in groups with behaviour problems such as conduct disorder (Oosterlaan et al., 1998), and those with schizophrenia (Badcock, Michie, Johnson, & Combrinck, 2002). However, the poor response inhibition in schizophrenia patients was related to difficulty in reliably triggering the inhibitory response, because unlike inhibition functions of children with ADHD, inhibition functions of schizophrenia patients remained flatter than those of controls after ZRFT correction. However, difficulties on the stop-signal task have *not* been found in children with anxiety disorders (Oosterlaan et al., 1998), autism (Ozonoff & Strayer, 1997), Tourette's syndrome (Johannes et al., 2001), and Obsessive Compulsive Disorder (Johannes et al., 2001). It has recently been found that children with the inattentive type of ADHD also show performance deficits on the stop-signal task. That is, children with the predominantly inattentive type of ADHD could not be differentiated from children with the combined type ADHD in terms of response inhibition deficits as measured by the stop-signal task (Prout, 2000).

2.3.2 Deficits in set-shifting

A predisposition to respond in one way when several alternatives are available can be referred to as a response set (Flowers & Robertson, 1985). *Changing-set* or *set-shifting*, is the ability to change this predisposition when changes in task demands or self-directed initiatives require the use of one of the alternatives (Richards, Cote, & Stern, 1993). The ability to change-set has been investigated in ADHD using the Wisconsin card sorting test (WCST) and the trailmaking test, part B (TMT-B). The Necker cube test has also been used to a lesser degree.

2.3.2.1 Wisconsin card sorting test studies

The WCST uses stimulus and response cards that display figures varying in form, colour, and number. The participant is instructed to sort a deck of response cards to match the stimulus cards, and is told whether he/ she is correct or incorrect after each response. Although the participant is never told how to sort the cards, the object is to sort ten cards to colour, ten to form and ten to number (Chelune, Ferguson, Koon, & Dickey, 1986).

Typically, compared to controls, children with ADHD make more perseverative errors on the WCST, that is, they respond in a manner that would have been correct during the previous sorting category (Boucugnani & Jones, 1989; Shue & Douglas, 1992; Seidman et al., 1997). Further, Everett, Thomas, Cote, Levesque and Michaud (1991) reported that after a year of psychostimulant medication treatment, hyperactive children no longer showed a difference from normal children with respect to their capacity to inhibit their perseverative tendency on the WCST. However, performance on the WCST is not consistently impaired in individuals with ADHD (e.g., Pennington et al., 1993). Barkley, Grodzinsky and DuPaul (1992) reviewed 13 studies in ADHD children (ADD with hyperactivity) using the WCST. Eight of these found significant deficits in ADHD children relative to control children. In their own study they found no significant differences between the performance of ADHD children (both ADD with and without hyperactivity), normal children and learning-disabled children. Similarly, in a review of 10 studies utilizing the WCST, Pennington and Ozonoff (1996) reported WCST impairments in only four of these studies in children with ADHD.

Poor WCST performance has also differentiated other patient groups from controls, such as patients with schizophrenia (Radant, Claypoole, Wingerson, Cowley, & Roy-Byrne, 1997; Johnson-Selfridge & Zalewski, 2001; Franke et al., 1994; Moritz et al., 2002), obsessive compulsive disorder (Head, Bolton, & Hymas, 1989), major depression (Merriam, Thase, Haas, Keshavan, & Sweeney, 1999; Franke et al., 1994; Moritz et al., 2002; cf. Crowe, 1996), conduct disorder (Chang, 1999), and autism (Prior & Hoffmann, 1990; Rumsey, 1985). Further, a study that has directly compared autistic, Tourette's syndrome and ADHD children found that autistic children performed more poorly on the WCST than both the ADHD and Tourette's children, who in turn did not differ from one another, nor from normal controls (Ozonoff & Jensen, 1999).

The WCST has been criticised on a number of grounds. Pennington and Ozonoff (1996) reviewed the poor measurement properties of the WCST, which include specificity problems in discriminating patients with focal frontal damage from patients with focal non-frontal damage, and in discriminating intact from impaired patients; a sensitivity problem, where patients with documented frontal lesions and "frontal problems in everyday life" perform normally on the WCST; and poor reliability in school-age populations. Schachar, Tannock, Marriott and Logan (1995) suggest that performance on the WCST may be a function of a range of factors in addition to the ability to switch to an alternative response, including task comprehension, speed of response, and the ability to stop an ongoing response.

2.3.2.2 Trailmaking test studies

The TMT is frequently used in clinical and neuropsychological evaluations. It requires scanning a visual array and organizing sequential output (Grodzinsky & Diamond, 1992). On part A, which controls for baseline speed, numbers must be connected in sequence. On part B, the participant must alternate between connecting numbers and letters in sequence, thus repeatedly shifting set. Completion time and errors are recorded.

Time to complete the TMT-B has been found to be longer in ADHD (using DSM-IIIR diagnostic criteria) children compared to controls (Boucugnani & Jones, 1989; Shue & Douglas, 1992), but not all studies consistently show this effect (e.g., Grodzinsky & Diamond, 1992). Pennington and Ozonoff (1996) reviewed six studies that investigated ADHD children's performance on TMT-B. Four of these indicated that longer completion times significantly differentiated children with ADHD from controls. Similarly, Barkley, Grodzinsky and DuPaul (1992) reviewed six studies that employed the TMT-B in children with ADHD (ADD with hyperactivity, according to DSM-III criteria). Three of these studies found that the time score on TMT-B differentiated ADHD children from controls. It is noteworthy that two of the three studies that failed to find differences used a different version of the standard test, known as the colour forms version. Further, Dugbartey, Townes and Mahurin (2000), who compared university students' performance on standard and colour forms of the trailmaking test, found that while there was no significant difference between performance on part A, there was a significant difference in performance on part B of the standard and the colour form. Thus the colour form of the trailmaking test may be measuring different underlying cognitive skills than the standard form.

Poor performance on the TMT-B is not restricted to individuals with ADHD, and has also been found in patients with schizophrenia (Radant et al., 1997; Johnson-Selfridge & Zalewski, 2001; Franke et al., 1994; Moritz et al., 2002), depression (Franke et al., 1994; Austin et al., 1999; Moritz et al., 2002), and obsessive compulsive disorder (Moritz et al., 2002).

2.3.2.3 Necker cube studies

In Necker cube studies the participant stares at a two-dimensional representation of a cube for 90 seconds and reports each time the front and back faces appear to reverse (Gorenstein et al., 1989). It is a test of an extreme case of reversible figures. Necker cube studies have been found to differentiate psychopaths (Gorenstein, 1982; cf. Hare, 1984) and schizophrenic patients (Levander, Bartfai, & Schalling, 1983) from normal controls. Further, patients with frontal lesions (in either hemisphere), and alcoholics report more reversals than controls (Gorenstein et al., 1989). In a study of various neuropsychological tests in 21 inattentive-hyperactive children and 26 control children

(Gorenstein et al., 1989) a trend (p = .07) was found for inattentive-hyperactive children to report more reversals of the Necker cube than the control group. However, as there is no way of verifying objectively that a perceptual reversal has occurred, these findings may simply reflect a tendency to report changes, perhaps due to greater boredom or agitation displayed by patient groups.

2.3.3 Deficits in planning

The Tower of Hanoi and Tower of London tasks require individuals to plan various ways of removing and replacing disks on a set of pegs or spindles before executing the rearrangement. The Tower of Hanoi, for example, consists of two identical boards (one for the participant and one for the experimenter), each holding three vertical pegs arranged in a straight line and three or four plastic rings of different sizes that fit on the pegs. The rules of the task include that a larger ring may not be placed on top of a smaller ring; only one ring can be moved at one time; and a ring has to be moved to one of the participant's pegs. The experimenter's board displays the desired configuration, and the initial set-up of the rings on the participant's board differs for each problem. The participant is required to replicate the experimenter's configuration in the fewest number of moves (Aman, Roberts, & Pennington, 1998).

Aman, Roberts and Pennington (1998) found that control boys exhibited better overall performance than boys with ADHD (diagnosed using DSM-IIIR criteria), with and without medication, on the Tower of Hanoi test. Although poorer performance on tower tests by children with ADHD compared to normal controls has been replicated in other studies (e.g., Pennington et al., 1993; Klorman et al., 1999; cf. Ozonoff & Jensen, 1999), these tasks may involve aspects of working memory and problem solving not just planning. Poorer performance than controls on tower tests have also been demonstrated by patients with schizophrenia (Langdon, Coltheart, Ward, & Catts, 2001; Marczewski, Van der Linden, & Lazoi, 2001), and depression (Elliott et al., 1997). A study comparing autistic, ADHD, Tourette's syndrome and control children directly found that autistic children were impaired on their performance on the Tower of Hanoi task compared to controls, Tourette's syndrome, and ADHD children who, in turn, did not differ significantly from one another (Ozonoff & Jensen, 1999).

The Porteus maze is another task used as a measurement of visuospatial planning ability. This task requires advanced planning, anticipation of blocked routes, and completion of a plan (Grodzinsky & Diamond, 1992). A score is derived based on the number of trials to successful completion. Once the subject has made a planning error on a Porteus maze, the copy is removed and a second trial is given on a new copy of the same maze. This task may also involve aspects of working memory, fine motor skills and problem solving, rather than just planning ability. The Porteus maze test has been found to be sensitive to the severity of traumatic brain injury and volume of prefrontal lesions in paediatric patients who had sustained a traumatic brain injury at least three years previously (Levin, Song, Ewing-Cobbs, & Roberson, 2001). Controls have been found to perform significantly better than ADHD children on the Porteus maze (Grodzinsky & Diamond, 1992; Kuehne, Kehle, & Mc Mahon, 1987; Homatidis & Konstantareas, 1981; cf. Frost, Moffitt, & Mc Gee, 1989), and the performance of children with ADHD has been found to improve with methylphenidate (Conners & Taylor, 1980). Poorer maze performance has also been reported in juvenile delinquents (Riddle & Roberts, 1977; cf. O'Keefe, 1975; Wolff et al., 1982) and patients with Alzheimer's disease (Mack & Patterson, 1995).

2.3.4 Deficits in verbal fluency

Studies of verbal fluency generally involve word generation tests. The subject is given one minute to generate words beginning with, for example, the letters F, A, and S; or to name words within a semantic category (e.g., animals, food; Grodzinsky & Diamond, 1992). Deficits in verbal fluency have been found in adult patients with frontal damage, with performance on the letter task being more impaired than on the semantic category task (Lezak, 1983). The letter task is more difficult for those who cannot devise a strategy to guide their search for words. Categories provide some of the structure for doing so. Cognitive skills involved in fluency include vocabulary, processing speed, semantic memory, working memory, and inhibition (Lezak, 1983).

Grodzinsky and Diamond (1992) administered the letter and semantic category task to children with ADHD (DSM-IIIR criteria) and control children. They found that controls performed significantly better than ADHD children on the letters task (FAS), whereas the groups performed similarly on the semantic category task (food, animals).

This pattern of poorer performance on the letters task (Klorman et al., 1999; Koziol & Stout, 1992; cf. Reader, Harris, Schuerholz, & Denckla, 1994; Barkley et al., 2001; Mahone, Koth, Cutting, Singer, & Denckla, 2001; Shallice et al., 2002) but not on the categories task (Barkley et al., 1992; Loge, Staton, & Beatty, 1990; Mahone et al., 2001) has not consistently been replicated in the literature. Deficits on verbal fluency tests have also been found in other patient groups, including those with autism (letter task: Turner, 1999; cf. Minshew, Goldstein, Muenz, & Payton, 1992; categories task: Turner, 1999; Minshew et al., 1992; cf. Boucher, 1988), depression (letters task: Franke et al., 1994; Crowe, 1996; categories task: Lafont et al., 1998), schizophrenia (letters task: Franke et al., 1994; Elvevag, Weinstock, Akil, Kleinman, & Goldberg, 2001; Danion, Meulemans, Kauffmann-Muller, & Vermaat, 2001; Crowe, 1996; categories task: Lafont et al., 1998), and obsessive compulsive disorder (letter task: Head et al., 1989).

2.3.5 Deficits in working memory

Working memory has been defined as "a system for the temporary holding and manipulation of information during the performance of a range of cognitive tasks such as comprehension, learning and reasoning" (p. 34; Baddeley, 1986). One model of working memory (Baddeley, 1986) assumes an attentional control system known as the central executive, which operates in conjunction with two slave systems: the phonological loop, which is concerned with auditory information and speech; and the visuospatial sketchpad, which is concerned with visual and spatial information.

A study by Barnett et al. (2001) found that, compared to controls, children with ADHD performed significantly worse on a spatial working memory task that involved children searching through boxes on a computer screen to find one with a token hidden inside (with the proviso that they could only look in each box once). This search task is purported to measure working memory for spatial stimuli. In addition, the authors found that a group of ADHD children that were medicated during testing performed just as well as controls on this task, suggesting that stimulant medication normalizes spatial working memory deficits. However, another study using the same spatial working memory task, failed to find significant spatial working memory deficits in unmedicated ADHD children compared to controls (Kerns et al., 2001).

Siegel and Ryan (1989) studied working memory in relation to verbal and numerical information in children with reading disability, arithmetic disability and ADD without hyperactivity, as well as normal control children. The verbal modality was explored via a Sentence task, in which the children were presented sentences aurally with the final word missing. The child's task was to supply the missing word and to repeat all the missing words from the set, in the order that the sentences had been presented. Numerical information was tested in a Counting task, which involved counting yellow dots from a field of blue and yellow dots arranged in an irregular pattern on a card. The counts for each set of cards were required to be recalled. The ADD children without hyperactivity did not perform significantly differently from controls, except at the youngest ages on the Working Memory - Sentences task. Reading disabled children, in comparison, showed problems on both tasks, and arithmetic disabled children tended to have problems on the counting task. The authors concluded that reading disability involves a generalised deficit in working memory, while arithmetic disability involves a specific deficit of working memory in relation to processing of numerical information. Children with ADD showed a lag in working memory in relation to language, performing like controls only when aged 9-10 years old.

Tannock, Ickowicz and Schachar (1995) studied the effects of methylphenidate on working memory in 22 children with ADHD (DSM-IIIR criteria) and 18 children with ADHD and comorbid anxiety. The authors used a serial addition task, in which children were required to add each new number presented to the immediately preceding number and give the answer aloud. For example, given the sequence 2 4 3 1, the child must add the new number 4 to the previous number 2 that was held in working memory and give the answer 6, and then add the next new number, 3, to the 4 to give the answer 7 etc. Although the study did not utilise control children and thus does not report on whether ADHD children were impaired relative to normal on this serial addition task, another study using this task reported impaired performance by adolescents with ADHD when compared to normal controls (McLeod & Prior, 1996). Tannock and colleagues found that methylphenidate enhanced performance in the ADHD group but not in the ADHD with comorbid anxiety group. Both groups contained children exhibiting oppositional defiant disorder, conduct disorder and

learning disabilities. However, analyses conducted to determine whether comorbid learning disabilities influenced stimulant response indicated that they did not. The authors concluded that comorbid anxiety, rather than learning disabilities, impeded the effects of methylphenidate on working memory in children with ADHD.

Another working memory study that compared ADHD children (ADHD), ADHD children with comorbid language impairment (ADHD + LI), children with other psychiatric diagnoses (OPD), and children with other psychiatric diagnoses with comorbid language impairment (OPD + LI) on verbal and visuospatial working memory tasks, found that children with language impairments (ADHD + LI and OPD + LI) exhibited poorer verbal and non-verbal working memory compared to ADHD and OPD children (Cohen et al., 2000). These results suggest that working memory is more closely associated with language impairment than with ADHD.

A study by Oie, Sundet and Rund (1999) contrasted the performance of ADHD, schizophrenic and normal adolescents on a battery of memory tests. They found that whilst schizophrenic adolescents showed verbal and visual memory deficits compared to normal controls, ADHD adolescents only showed verbal memory deficits on a task that required participants to remember a list of words. Neither group was impaired on the measure of working memory (digit span backwards, where participants have to remember some digits and repeat these in the reverse order). Individuals with ADHD, however, were impaired on a task purported to measure selective attention and distractibility (a digit span task were children had to repeat digits which were presented with and without distractors) when compared to controls and participants with schizophrenia. Similarly, a study by Barkley, Edwards, Laneri, Fletcher and Metevia (2001) failed to find impaired performance in a group of ADHD adolescents with comorbid oppositional defiant disorder, compared to controls on verbal and non-verbal working memory tasks. Verbal memory was measured by digit span backwards, and non-verbal memory was measured using the Simon game, where participants had to remember and repeat a sequence of tone/ key combinations.

In summary, there are conflicting findings regarding working memory impairments in children with ADHD. These differences may reflect differences between tasks

employed to measure working memory, and/ or perhaps the heterogeneity of ADHD samples. Individuals with learning disorders (Siegel & Ryan, 1989; Chiappe, Hasher, & Siegel, 2000; Plaza, Cohen, & Chevrie-Muller, 2002), autism (Benetto & Pennington, 1996; cf. Ozonoff & Strayer, 2001), and schizophrenia (Minor & Park, 1999; Gooding & Tallen. 2002; Tek et al., 2002) also exhibit impairment on tasks thought to measure working memory.

2.3.6 Deficits in sustained attention

Sustained attention has been defined as "the ability to self-sustain mindful, conscious processing of stimuli whose repetitive, non-arousing qualities would otherwise lead to habituation and distraction to other stimuli" (p.747; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). The continuous performance test (CPT) is one such test, requiring the participant to detect an infrequent stimulus embedded in a series irrelevant stimuli, postulated to be sensitive to sustained attention/ vigilance. The CPT has been found to differentiate children with ADHD from controls on a number of measures such as omission errors, sensitivity (the decrement in signal/ noise discrimination), and longer reaction times (Barkley et al., 2001; Seidman et al., 1997; Grodzinsky & Diamond, 1992; cf. Holocomb, Ackerman, & Dykman, 1985; Schachar, Logan, Wachsmuth, & Chajezyk, 1988), including those with the predominantly inattentive type of ADHD (Chhabildas et al., 2001). (See Corkum & Siegel, 1993 and Losier, Mc Grath, & Klein, 1996 for reviews). Furthermore, stimulant medication has been shown to reduce the rates of omission and commission errors, and improve sensitivity in children with ADHD (Losier et al., 1996). Consistent with these CPT performance findings is the comparison of the performance of 24 boys with ADHD and normal controls on subtests of the Test of Everyday Attention for Children (TEA-Ch). These results indicated that ADHD boys were impaired on the subtests of sustained (but not selective) attention (Manly et al., 2001).

Impaired CPT performance has also been observed in other disorders such as schizophrenia (Elvevag, Weinberger, Suter, & Goldberg, 2000; Walker, 1981; Strandburg et al., 1994), bipolar disorder (Liu et al., 2002), and in patients with frontal lobe lesions (Rueckert & Grafman, 1996). Whilst reduced CPT performance is often cited as evidence of a sustained attention deficit, as several researchers point out

(Denckla, 1996; Van der Meere & Sergeant, 1988a), what is often not documented is any greater ADHD-related *decline over time* in accuracy of responses than is seen in healthy controls. It may be argued that this decline over time is essential when interpreting poor CPT performance in terms of a deficit in sustained attention. Indeed, studies have indicated that ADHD children do not differ from controls when considering their rate of decline in CPT performance over time (Van der Meere & Sergeant, 1988a, O'Daugherty, Nuechterlein, & Drew, 1984; Schachar et al., 1988; cf. Sykes, Douglas, & Morgenstern, 1973), despite their generally lower levels of performance overall.

2.3.7 Deficits in motor functioning

ADHD children have often been described as clumsy and uncoordinated (Barkley, 1997b) and a number of problems related to motor coordination and execution of complex and coordinated sequences of motor movements have been described in the literature. DSM-IV (American Psychiatric Association, 1994) identifies a separate disorder for children lacking developmental, age-appropriate motor skills: developmental coordination disorder. This disorder is characterised by marked impairment in the development of motor coordination, manifested by pronounced delays in achieving motor milestones (e.g., walking, crawling, sitting), dropping things, "clumsiness", poor performance in sports, and poor handwriting. The DSM-IV section on differential diagnosis states that motor difficulties (bumping into things, knocking things over, falling) in children with ADHD are usually due to the symptoms of distractibility and impulsiveness rather than to motor impairment (American Psychiatric Association, 1994; p. 54). However, if criteria for both disorders are met, both diagnoses may be given. Piek, Pitcher and Hay (1999) found that in their study a high percentage of children with ADHD (9 out of their 16 children with ADHD combined type, and 11 out of their 16 children with ADHD predominantly inattentive type) displayed movement difficulties consistent with developmental coordination disorder.

Neurological examinations for "soft" signs related to motor coordination, and motor overflow movements which are for example, associated movements in the hands on moving the feet, have found that hyperactive children demonstrate more of these signs

and movements than control children (e.g., McMahon & Greenberg, 1977). Denckla and Rudel (1978) found that discriminant variables of speed, rhythm and overflow produced a significant degree of dissimilarity between hyperactive and control children. Of the entire sample 88.8% of boys were correctly classified in the appropriate groups on the basis of the discriminant scores (79% were correctly classified as hyperactive and 98% correctly classified as normal). Studies have also demonstrated that children with attentional difficulties display more soft signs and motor incoordination, than children with pure learning disorders such as dyslexia (Denckla, Rudel, Chapman, & Krieger, 1985), and than neurotic children (Werry et al., 1972). These overflow movements have been interpreted as indicating motor immaturity in ADHD children (Denckla, 1985). Problems in motor persistence, that is, the ability to sustain movement (Voeller & Heilman, 1988b), and in performance on kinaesthetic acuity tasks, that is, tasks based on relative body position such as the perception of one's own hand/ arm position (Whitmont & Clark, 1996; cf. Piek et al., 1999), have also been indicated in boys with ADHD.

Motor difficulties in children with ADHD have prevalence estimates varying from 8% to 52% (Piek et al., 1999). An Australian study (Doyle, Wallen, & Whitmont, 1995) found that despite one-third of the parents judging their children to be uncoordinated on ratings of both gross and fine motor skills, less than 10% of their clinic-referred sample, which consisted of children with a DSM-IIIR diagnosis of ADHD, exhibited motor skill deficits on a standardised measure. Fine motor skills were, however, found to be relatively deficient compared with gross motor skills in children with ADHD. Doyle et al. (1995) suggested that fine motor skills require greater application to task and therefore may be more problematic for children who have difficulties in the areas of sustained attention and effortful activity. The authors suggested that motor skill impairments may thus be a perceptual artefact of attention and concentration deficits, rather than a result of motor dysfunction. In addition, the authors found that of those children that usually took medication, children medicated during assessment performed significantly better on gross motor skills than those not medicated during assessment. However, medication status at the time of assessment was not studied systematically.

A correlational analysis by Whitmont and Clark (1996) revealed that fine motor skills (as measured by the Bruininks-Oseretsky Test of Motor Proficiency – Fine Motor Composite) were strongly associated with severity of ADHD pathology (as measured by the Conners Rating Scale – parent version – Hyperactivity Index) in the direction of greater pathology/ poorer fine motor skills. Studies that used tests of fine motor coordination such as drawing lines along fine curvilinear routes (Korkman & Pesonen, 1994), copying, and completing designs (Marcotte & Stern, 1997) have found more difficulties in motor coordination in ADHD children than controls. Marcotte and Stern (1997) found that children both with the predominantly inattentive and the combined type of ADHD showed lower scores compared to normative data when copying and completing designs. However, children with the combined type performed significantly worse than children with the inattentive type ADHD. It is possible that the poor handwriting commonly observed in ADHD children (Barkley, 1997b) may also be due to difficulties with graphomotor control. It is unclear whether this occurs in conjunction with, or independent of, the organizational and linguistic demands of writing. In addition, some authors (e.g., Denckla, 1996) have proposed that poor handwriting may be due to impairment in procedural memory. Alternatively writing problems may also be attributed to "distractibility and inattentiveness" or the "attention and concentration" problems in ADHD children (see p. 54; American Psychiatric Association, 1994 and Doyle et al., 1995).

Piek, Pitcher and Hay (1999) found that children with the predominantly inattentive type of ADHD had significantly poorer fine motor skills, as measured by three manual dexterity tasks on the Movement Assessment Battery for Children, while children with the combined type of ADHD were found to experience greater difficulty with gross motor skills, as measured by static and dynamic balance (three tasks on the Movement Assessment Battery for Children). This finding differs from that of Marcotte and Stern (1997), who found greater impairment in the combined type (compared to the predominantly inattentive type) on fine motor coordination tests consisting of copying and completing designs. Similarly, Doyle et al. (1995) found that fine motor skills were relatively deficient compared with gross motor skills in children with ADHD according to DSM-IIIR diagnostic criteria (which is similar to the combined type of ADHD). Unlike Whitmont and Clarke (1996), the severity of children's inattentive

symptomatology (not hyperactivity), was found to be a significant predictor of motor coordination difficulties (the total Movement Assessment Battery score; Piek et al., 1999).

It is difficult to reconcile the different results of these studies. One obvious difference concerns the measures of motor skills employed in the studies. In addition, Piek et al. (1999) reported that half of their children with the combined type of ADHD were medicated during testing, whereas none of the predominantly inattentive type children were. They did not report any examination of the differences between children on and off medication. It is possible, therefore, that medication improved fine motor skills in the children with the combined type of ADHD, and thus lowered group scores on fine motor skills. It is plausible that children with the combined type of ADHD do have greater fine motor skill deficits than predominantly inattentive type ADHD children (consistent with Marcotte & Stern, 1997), and greater fine than gross motor deficits (consistent with Doyle et al., 1995), but that medication significantly improves fine motor skills, thus significantly lowering group scores on this measure. This possibility is, however, not supported by some preliminary findings on the effects of medication on motor skills by Doyle et al. (1995). Although these authors did not study medication effects systematically, they compared the performance of children on and off medication. Children medicated during assessment performed significantly better than non-medicated children on measures of gross motor, but not fine motor skills.

Simple motor speed, as measured by finger-tapping rate, does not seem to be affected in children with ADHD (Seidman et al., 1995; Rubia, Taylor, & Taylor, 1999). Deficits have been found in motor speed in the execution of coordinated sequences of movements, such as time taken to complete 20 repetitions of a number of different arm and leg movements (Carte, Nigg, & Hinshaw, 1996). Deficits in execution of coordinated sequences of movements in ADHD children have also been reported in the literature. ADHD children (DSM-IIIR criteria) have for example been found to perform more poorly than controls on a test requiring imitation of a sequence of hand-movements (e.g., Mariani & Barkley, 1997; Grodzinsky & Diamond, 1992). This suggests a problem with temporal ordering of motor sequences in children with ADHD. However, Leung and Connolly (1998) found no deficits on a simple

sequential key-tapping task in children that met criteria for hyperactivity; this suggests that deficits may only be indicated in more complex motor tasks. None of the studies, however, have investigated whether problems in performing motor sequences could be better understood in terms of a problem in remembering sequential information, rather than a problem with motor control per se in ADHD children.

Motor problems are not specific to ADHD, and have been documented in various other disorders. For example, impairments on motor tests are shown by children with autistic spectrum disorders (e.g., on tests of ball skill, balance and manual dexterity, Manjiviona & Prior, 1995; on a test of manual dexterity, the grooved pegboard test, Minshew, Goldstein, & Siegel, 1997), and learning disorders (e.g., on tests of manual dexterity, ball skills and balance, Sugden & Wann, 1987; test batteries of fine and gross motor skills, Bruininks & Bruininks, 1977; Maloy & Sattler, 1979). A higher frequency of neuromuscular and psychomotor abnormalities have also been found in patients with schizophrenia and their first-degree relatives compared to healthy controls (Flyckt et al., 2000). A study of childhood motor predictors of adult psychiatric outcome found that deviance on motor coordination measures (e.g. finger-nose, finger pursuit, heel-knee, rapid alternation, rapid finger movement, buttoning, writing) at 7 years was associated with both adult schizophrenia and unaffected sibling status (Rosso et al., 2000). Similarly, another study found that a childhood deficit in gross motor skills is a predictor of schizophrenia in adulthood (Erlenmeyer-Kimling et al., 2000). In a study comparing the performance of schizophrenic, ADHD and normal adolescents on a neuropsychological battery, only schizophrenic patients differed significantly from controls on a test of manual dexterity, the grooved pegboard test (Oie & Rund, 1999).

2.3.8 Hemispheric asymmetry

There is some debate about whether ADHD reflects differential involvement of the two hemispheres. Malone, Kershner and Siegel (1988), for example, studied the effects of methylphenidate on different levels (feature, semantic, name) of word processing by left and right visual fields in children with attention deficit disorder without hyperactivity and attention deficit disorder with hyperactivity (DSM-III criteria). Same-different decisions were made to tachistoscopically presented word

pairs under methylphenidate or placebo. Methylphenidate was found to induce a right visual field advantage *(superior left hemisphere performance)* for the naming decision, which was interpreted as a normalization effect. The authors reported that normal participants also demonstrate superior performance to stimuli presented to the right visual field compared to the left visual field on a variety of word naming tasks; they thus assumed that grapheme-phoneme matching is a component of word processing that is carried out by the left hemisphere. The authors concluded that methylphenidate inhibited *excess right hemisphere activation* and allowed greater asymmetrical use of the left hemisphere for processing the phonological level of the task. However, as reviewed in the previous chapter, there are a number of recent neuroimaging studies that suggest right hemisphere *hypoarousal* rather than hyperarousal in children with ADHD.

Studies of target cancellation and line bisection tend to suggest a right hemisphere disturbance in ADHD. Studies of horizontal line bisection consist of participants marking the mid-point of a line. Adult patients with unilateral neglect after right hemisphere damage tend to bisect lines towards the right of their true centre, most probably because of a reduced ability to direct attention leftward (e.g., Mattingley, Bradshaw, & Bradshaw, 1995). Sheppard, Bradshaw, Mattingley and Lee (1999) have shown that ADHD children also tend to bisect horizontal lines to the right of centre, and that this rightward bias is overcome when children are given methylphenidate. These results are, however, inconsistent with those of Ben-Artsy, Glicksman, Soroker, Margalit and Myslobodsky (1996) who found no laterality trends or group differences in a line bisection task administered to six medicated ADHD (DSM-IIR criteria) children, 14 unmedicated children and 13 control children.

Voeller and Heilman (1988a) administered a letter cancellation task to seven right-handed ADHD boys (DSM-III criteria of ADHD with and without hyperactivity). The participants had to cross out specified target letters on a page containing a few targets, plus many non-target (distractor) letters. Their pattern of performance resembled that seen in adults with 'unilateral neglect' following acquired damage to the right hemisphere; they omitted more targets overall than did controls, and detected significantly fewer targets on the left side of the page than on the right. Similarly, a

letter cancellation task that was administered to adults with ADHD, including those with the inattentive type (41% of participants), found that ADHD patients omitted more targets on the left side of the page than on the right, compared to controls (Sandson, Bachna, & Morin, 2000).

In a study examining the effect of stimulant medication on visuospatial biases Malone, Kershner and Swanson (1994) found that children with ADHD made more left-sided than right-sided omission errors on a letter cancellation test only while taking placebo, and not while taking methylphenidate. This right-visual field bias appeared to be primarily accounted for by those ADHD children with comorbid learning disabilities, rather than those without learning disabilities. However, medication improved detection of left-sided targets but not right-sided targets in the entire group of children, not just the ADHD children with comorbid learning disabilities. Ben-Artsy, Glicksohn, Soroker, Margalit and Myslobodsky (1996) also examined the effect of stimulant medication on visuospatial biases, but their results differed from those of Malone and colleagues (1994). The authors administered two versions of a target cancellation test, a structured and a random version, to children with ADHD. The structured version consisted of geometric shapes arranged in rows and columns on the page, and the random version of geometric shapes randomly distributed on the page. In the random version, ADHD children, both medicated and non-medicated, made more omission errors than controls on both left and right sides of the page. In the structured version ADHD children made significantly more omissions on the left side but not on the right. To complicate matters, further analyses indicated that unmedicated ADHD children made more omissions on the right side of the page and medicated ADHD children more omissions on the left side of the page, whereas control children showed no left-right imbalance.

The target cancellation results of Ben-Artsy et al. (1996) may differ from the other target cancellation results due to differences in the stimuli used (geometric shapes rather than letters). The authors suggested that in *letter* cancellation tasks a compromised right hemisphere may be unable to restrain a shift of attentional bias to the right side of space, created by the verbal nature of the task activating the left hemisphere. In addition, there are differences in selection of subjects between the

studies. Voeller and Heilman's (1988a) children with ADHD also had subtle soft neurological signs, suggestive of right hemisphere dysfunction. Sheppard et al.'s (1999) participants were drawn from a clinical population who had received extensive cognitive, language and educational assessment, and Sandson and colleagues (2000) used a clinical group of adults with DSM-IV diagnoses of ADHD. In comparison, Ben-Artsy's (1996) participants came from regular and special education schools, and ADHD criteria were only confirmed in one setting (home or school), rather than from two settings as stipulated by DSM-IV criteria (this is not a criterion in DSM-III or DSM-IIIR). The difficulties of these children also included failure to comply with rules and academic underachievement. It is thus unclear whether the sample contained children with comorbid learning disorders and/ or oppositional defiant disorder, whose difficulties may be different to those of children with a diagnosis of ADHD per se.

2.4 Aims and approach of this thesis

The aim of this thesis was to examine aspects of attention and motor performance in children with ADHD, in order to document and improve the understanding of specific behavioural deficits in this disorder. Aspects of movement and attention in ADHD children were quantified and compared with individually matched normal control children using specially designed techniques, rather than the widely available, traditional clinical neuropsychological tests typically reported in the ADHD literature. The decision to use novel techniques rather than clinical neuropsychological tests was based on the fact that a lot of clinical tests are criticised in the literature for their poor measurement properties, especially in children (see for example, Pennington & Ozonoff, 1996; Anderson, 1998). Clinical tests for example, often employ gross measures, such as time taken to complete the test, where poor performance may reflect a variety of difficulties. The tasks used in this thesis were designed to reduce this problem by differentiating between various aspects of performance such as motor planning and execution etc. In addition, the tasks used were basic, so that children would have no difficulties understanding task requirements.

It was intended that children with the combined type of ADHD would be directly contrasted to those with the inattentive type of ADHD, as well as with healthy control children. The objective of this comparison was to obtain a better understanding of the

similarities and differences between these two groups, and to determine whether children with the inattentive subtype have different underlying deficits, as claimed by authors such as Barkley (1997b). It soon became clear, however, that children with the inattentive type of ADHD were not as readily available for study as the combined type, and consequently the studies focused on the combined type of ADHD children.

In Chapter 3 various aspects of attention and motor functioning were investigated in normal children, unmedicated ADHD children, medicated ADHD children and two children with the predominantly inattentive type of ADHD. The paradigm employed had the potential to quantify a variety of problems in a single novel task. It measured the ability to inhibit distracting stimuli and the ability to inhibit a response, impulsive responding, inattentiveness or vigilance, motor performance, set-shifting and spatial biases. Chapter 4 investigated behavioural aspects of ADHD that were reported by parents, teachers and ADHD children in the form of rating scales. Of particular interest was concordance between multiple informants and the ability of children to report their problems on a self-report visual analogue scale. Spatial biases or perceptual asymmetries were further investigated in normal right-handed children and children with ADHD, through the use of various chimeric stimuli in free-viewing conditions in Chapter 5. Finally, motor performance in children with ADHD was explored further in Chapter 6, using a bimanual coordination task that required participants to produce simple symmetrical bimanual movements and complex asymmetrical bimanual movements at both slow and fast speeds.

CHAPTER 3

EXPERIMENTS 1-5: ASPECTS OF ATTENTION AND MOTOR FUNCTIONING IN NORMAL, UNMEDICATED ADHD, AND MEDICATED ADHD CHILDREN

3.1 Introduction to Experiments 1 – 5

There are various emerging themes in the ADHD literature (as reviewed in the previous chapter) including difficulties in higher-level attentional processes/ executive functions such as response inhibition, difficulties in changing set, spatial biases to the right visual field, and motor deficits. The aim of this research was to investigate the performance of ADHD children using an integrated paradigm that has the potential to quantify these problems in a single task. The paradigm was used successfully in a recent study of adults with unilateral neglect (Mattingley, Husain, Rorden, Kennard, & Driver, 1998). The basic task involves participants reaching as rapidly as possible toward a target, which can appear to the left or right of fixation, while ignoring simultaneous distractors. The task, which is described more extensively in Section 3.2.2, measures:

- Distractibility, or the ability to inhibit distracting stimuli: by examining performance on trials where there are competing targets and distractors.
- The ability to inhibit a response: by examining ability to inhibit responding on trials where only a distractor is presented.
- Impulsivity: by examining the frequency of premature responding (that is, responses made prior to stimulus presentation).
- Vigilance or inattentiveness: by examining omission errors, or "misses".
- Spatial bias or performance asymmetries: by examining performance for targets in the left versus right visual field.
- Motor performance: by manipulating task requirements so that performance requires either reaching towards the target or responding to the target without reaching.

- Set-shifting: by adding blocks which have been adapted slightly from the basic paradigm, so that participants have to change their response strategy from trial to trial. Performance on these change-set blocks are compared with performance on the maintain-set blocks of the basic task.

As this task has only been used previously in adults with neglect, it was deemed important to determine how normal children would perform on this task; it was therefore administered to normal children aged 7-12 years. Consistent with previous developmental studies, which have indicated that younger children generally show slower reaction times than older children on simple and complex cognitive tasks (Keating & Bobbitt, 1978; Kail, 1988; Hale, 1990; Schachar & Logan, 1990), it was predicted that younger children would also show slower reaction times on this task. As Van der Meere, Gunning and Stemerdink (1996) found that 7-8 year old children were less able to change a response set than 11-12 year old children, it was also predicted that younger children would find set-shifting more difficult. It was also predicted that younger children would find it more difficult to inhibit their responses to distractors, that is, make more distractibility errors, than older children. Go/ no-go studies have revealed that inhibition improves with age (Casey, Trainor et al., 1997; Becker, Isaac, & Hynd, 1987). Becker et al. (1987) found that 6 year-old children performed more poorly than 8 year-old children, who in turn, performed more poorly than 10 year-old children on a go/no-go test. The performance of 12 year-old children, however, did not differ significantly from the 10 year-olds. In comparison, a stop-signal study (Schachar & Logan, 1990) has indicated that the ability to inhibit in children developed little after grade 2.

It was predicted that the overall performance of ADHD children taking stimulant medication would either not differ from those of normal controls, or be at least better than that of the *unmedicated* ADHD children. Compared to controls of the same age, unmedicated ADHD children, if suffering from poor response inhibition, were predicted to be slower to initiate responses to targets in the presence of a simultaneous distractor, compared to targets presented in isolation. They were also expected to commit a higher frequency of incorrect responses to distractors in trials where there are simultaneous targets and distractors, and to fail to withhold responses when distractors

are presented in isolation. Similarly, it was also predicted that difficulties with attention/ vigilance and greater impulsivity in children with ADHD would be reflected in a greater number of missed targets and more premature responses, compared with controls of the same age.

If ADHD involves a spatial bias to the right visual field, or deficit on the left, arising perhaps from dysfunction of the right hemisphere (see for example, Voeller & Heilman, 1988a), then reaction times to a left target should be slower than those to a right target when the starting position is central. This delay could be due to impaired *attention* for left targets or to impaired *motor initiation/ preparation* of movements toward left targets (or a combination of both). Manipulation of hand-start position in the task allows, via left, central and right start positions, evaluation of directional motor impairment. The left start position allows evaluation of directional motor impairment, because, in this condition, a *rightward* movement is required to reach towards a target on the *left* of fixation. Any problem in initiating leftward movements should be reduced or eliminated with a left start, because only rightward movements to the target are required in this condition.

Motor problems were investigated in terms of *reaction* and *movement execution time* in the reach task (which requires reaching towards the target), and reaction time in the no-reach task (which requires responding to targets without reaching). If difficulties for ADHD children are at the movement preparation stage rather than in motor execution, one would hypothesize deficits in *reaction time* rather than *movement time* in the reach task. As deficits in reaction time may reflect deficits in *attention* or in *motor preparation/ planning*, or a combination of both, investigation of reaction time results in the 'no-reach' task, where participants respond to targets by releasing the start key, rather than by reaching towards the target, serves to clarify this issue. If there is no true effect of motor planning, the results for reaction time in the reach task should be replicated in the no-reach task, which does not have a reaching component and therefore does not require planning of motor movements.

Finally, if children with ADHD are impaired in their ability to shift set, then ADHD children should exhibit impaired performance on the change-of-set component of the task relative to controls.

3.1.2 Outline of Experiments 1 – 5

Experiment 1	Investigated the performance of unmedicated ADHD children versus matched controls.
Experiment 2	Investigated the performance of medicated ADHD versus matched controls.
Experiment 3	Investigated the performance of 7-8, 9-10 and 11-12 year-old normal children.
Experiment 4	Investigated the performance of one child with ADHD on this paradigm whilst on and off stimulant medication (on, off, off, on design).
Experiment 5	Investigated the performance of two children diagnosed with the predominantly inattentive type of ADHD.

3.2 Method for Experiments 1 - 5

3.2.1 Participants

Thirty-five normal boys and thirty normal girls aged between 7 years and 14 years of age were recruited primarily through local primary schools. Six girls and twenty-one boys with a diagnosis of ADHD also participated in this task. The majority of ADHD children were recruited from a public paediatric outpatient unit (Southern Health), with the exception of three children recruited through a private paediatric outpatient unit (Cedar Court), two Children recruited through an ADHD support group (ADDVic), and one child who was known to the author. Children ranged in age from 7 years 2 months to 14 years 10 months with a mean age of 9 years and 11 months. All children had been diagnosed with ADHD by an experienced clinician, in accordance with DSM-IV criteria. Of the 27 clinical children, five children were not prescribed stimulant medication (either Ritalin or Dexamphetamine) at the time of the study. Of those 22 children prescribed stimulant medication, 12 children were tested off medication, where the last dose was administered at least 16 hours before testing, so that any residual effects of medication would have been minimal. Psychostimulants have an onset of action within 30 to 60 minutes, a peak clinical effect after 1-2 hours

after administration lasting 2-5 hours (Wilens, Biederman, & Spencer, 2002), and rebound effects (deterioration in behaviour in excess of that which is typical when medication wears off) typically occur 5-10 hours after stimulant administration (Jacobvitz et al., 1990). Ten children had received their normal dose of medication before testing (ranging from 30 minutes to 4 hours prior to testing).

The majority of the clinical group participating in the study were diagnosed with ADHD combined type, with only two children diagnosed with ADHD predominantly inattentive type. The majority (17) of children also had comorbid diagnoses, which is consistent with previous reports of the prevalence rate of comorbidities in children diagnosed with ADHD that range from 50-80% (e.g., Tannock, 1998). Table 2 indicates the type of comorbid diagnoses that were present in this sample. The most common comorbid diagnoses comprised behaviour and/ or learning disorders, with only two children receiving diagnoses that did not include either behaviour or learning disorders. Other comorbid diagnoses included language disorders, genetic disorders, Tourette's disorder, anxiety disorders, attachment disorder, and early infantile deprivation.

Seven of the 27 (26%) children with ADHD were left handed (see handedness questionnaire in Appendix B), which is higher than expected from the reported prevalence rate of less than 15% in the general population (Gilbert & Wysocki, 1992). Exclusion criteria included uncorrected visual problems (because of the visual demands of the tasks to be used), and Full Scale IQ scores less than 80 (which is the cut-off for IQ classed as low average). The results of an eight year-old right-handed girl were subsequently excluded because her Full Scale IQ score was less than 80. As ADHD and normal children were separated into different groups for data analysis, demographic data for each of the groups of children are reported in the results sections.

3.2.2 Apparatus and procedure

Each child's full scale IQ was measured using the Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1990), which, depending on the age of the child, took between 15- 40 minutes to administer. For two participants (both normal children), performance IQ was used instead of full scale IQ, because it was deemed to be a more

Table 2: Comorbid diagnoses in children with ADHD (n = 17)

Comorbid Diagnoses	Number of children
Learning disability only	2
Behaviour problem only *(Oppositional defiant disorder or disruptive behaviour disorder not otherwise specified)*	6
Learning disability + other comorbid diagnosis *(Other comorbidities included language disorder and a genetic disorder**)*	2
Behaviour problem + other comorbid diagnosis *(Other comorbidities included Tourette's disorder and language disorder)*	2
Other *(included anxiety disorder, language disorder, genetic disorder**)*	2
Learning disability + behaviour problem + other *(other includes language disorder, attachment, anxiety, early infantile deprivation)*	3*

** data from one of these children were subsequently excluded on the basis of IQ scores*

*** the genetic disorder in both cases was Simpson-Golabi-Behmel Syndrome, which is an X linked pre- and postnatal overgrowth syndrome (Savarirayan & Bankier, 1999). Mutations in the glypican-3 gene are implicated in this disorder (Savarirayan & Bankier, 1999). This gene is suggested to play an important role in growth control in mesodermal tissues and in tumour predisposition (Lapunzinza et al., 1998). Characteristic facial features of this syndrome include a broad nose, prominent jaw, upward slanting eyes, groove in the tongue, central groove in the lower lip. Most affected males are of average intelligence, although delayed speech and delayed motor milestones may be present (Lindsay et al., 1997). Physical abnormalities of the heart, kidney, central nervous system, skeletal system, and gastrointestinal tract may also be present (Lindsay et al., 1997). There is relatively little mention of the behavioural phenotype of this disorder, and it appears that, to date, a diagnosis of ADHD has only been reported in the two brothers that participated in the current research (see Savarirayan and Bankier (1999) for details on the presentation of these two children).*

accurate measure of IQ, considering that these children came from non-English speaking backgrounds. The school and the home version of the attention deficit disorder evaluation scale (ADDES; McCarney, 1995), which is a behaviour rating scale based on DSM-IV criteria, was filled out by teachers and parents of all children. Scoring of the ADDES results in scaled scores of inattention and hyperactive-impulsive behaviour, and an overall percentile ranking (based on American norms). An impulsivity raw score was also calculated by summing the scores for all the questions on the rating scale pertaining to impulsivity (question numbers 31, 32, 33, 34, 35, 36, 37, 41, 42, 43, 44, 47, 53 and 54 on the school version and question numbers 24, 25, 26, 27, 28, 30, 32 and 45 on the home version). In the group of ADHD children, one school and one home version was not returned. In the group of normal children, eight home and eleven school versions were not returned. Data were analysed for those questionnaires returned.

In addition to the screen session, each child participated in two separate 45 - 60 minute sessions, completing the experimental task that was carried out using the foam board depicted in Figure 1. The 33.5 cm x 60 cm board contained six 6.5 cm x 6.5 cm wooden boxes. Two boxes contained both a tri-colour light emitting diode (LED) and a small plastic push-button, three boxes contained only a small plastic push-button, and one box contained only an LED. Five boxes were placed in a row equidistant from one another (approximately 2 cm apart), and one directly in the middle of the board, approximately 2 cm above the mid box in the row (and 14 cm from the top of the board). A *Mitac 486* notebook computer generated the stimuli and recorded button-press responses.

Participants sat in front of the board with their arm extended so that their preferred hand rested over the start key. Visual fixation was maintained at a central position, and the fixation light illuminated for a duration of 500 – 1000 ms (the exact duration varied randomly between these two times). Visual targets in the basic task were green and appeared for a duration of 500 ms, with equal probability at one of two fixed locations to the left or right of fixation. Distractors in the basic task were red and could appear with equal probability at one of the two fixed locations to the left or right of fixation, either on their own, or in conjunction with a target. When the target and distractor

occurred in conjunction, the target always appeared on the opposite side of fixation to the distractor.

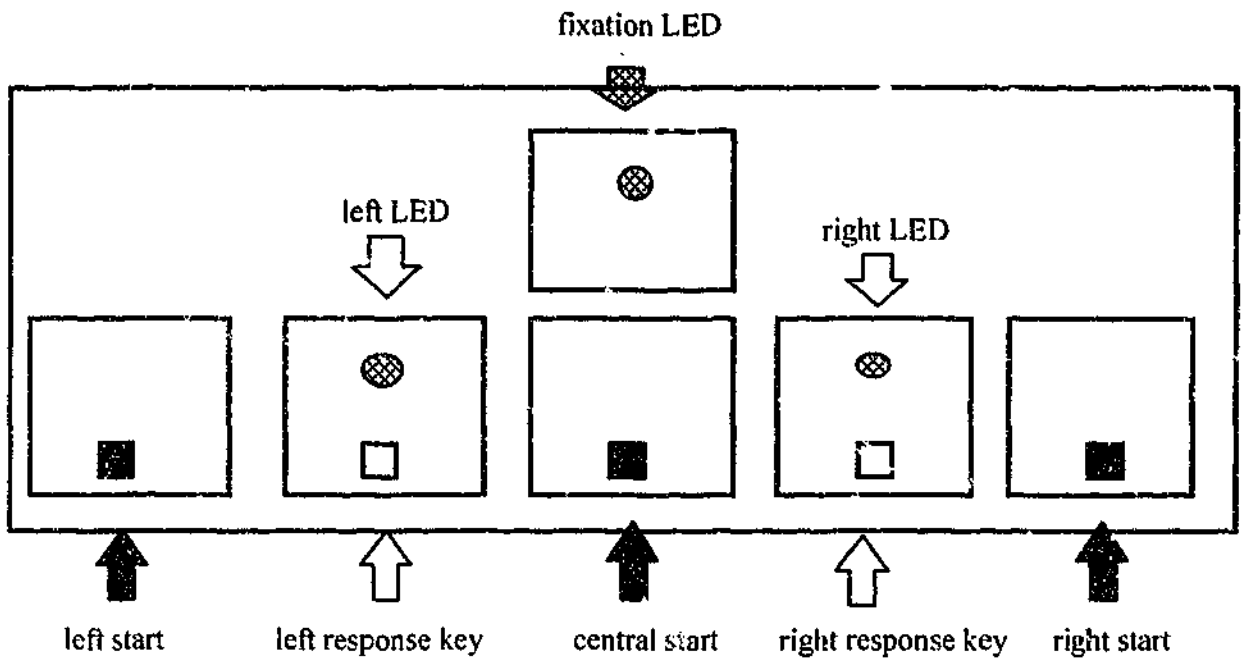


Figure 1: Schematic diagram of the experimental apparatus

Before each stimulus, the participant's hand rested on a start-key, which was located either centrally, or to the left or right of the two possible target locations. Hand-start position was counterbalanced among participants (see Appendix C). Participants could determine the start of each trial by depressing the start-button. A new trial started 2000 ms after the start button was depressed.

In the *reach task*, participants were instructed (see Appendix D) to release the start-key and reach towards the response-key beneath the LED that turned green (the target), ignoring any red 'distractor'. If there was no response within 1500 ms of target presentation, it was recorded as an error. In the case of a red 'distractor' on its own, participants were instructed to withhold their response, keeping the start-key depressed. Movement preparation and initiation was measured in terms of time taken to release the start-key (reaction time) and the time taken to execute the movement

(movement time). Errors were also recorded. For each trial either a green LED (target-only trials), red LED (distractor-only trials), or both LEDs (target+distractor trials) were illuminated. Distractors were illuminated on the opposite side to the target. Participants completed one block per hand-start position, which consisted of 10 left target-only trials, 10 right target-only trials, 10 left target+distractor trials, 10 right target+distractor trials, 10 left distractor-only trials, and 10 right distractor-only trials. Participants engaged in practice trials until they demonstrated that they had understood the instructions. Trials in which errors occurred were recorded and replaced with an identical trial placed at the end of the block, allowing a more accurate measure of reaction time.

The *no reach task* was identical to the *reach task*, with the exception that participants were instructed (see Appendix D) just to release the start-key (and not reach toward the response key) in response to a green target, ignoring any red 'distractor'. Thus, only time taken to release the start-key (reaction time) was measured, along with errors. Order of presentation of *reach* and *no reach* tasks was counterbalanced across participants (see Appendix C). Again, participants engaged in practice trials until they demonstrated that they had understood the instructions.

The *set-shifting task* was a repetition of the above, with one variation. In the set-shifting task the fixation light acted as a cue for the designated target in the forthcoming trial. The fixation LED was green on 50% of the trials and red on 50% of the trials, and these were randomly intermingled within a block. Thus, participants were instructed (see Appendix D for instructions to participants) to respond to green target LEDs and ignore any red distractors when the fixation LED illuminated green, and the reverse, when the fixation LED illuminated red. Comparison of data from these change-of-set blocks with data from blocks of the basic task allows investigation of the ability to change set.

3.3 Data Analysis for Experiments 1 – 5

As the aim of the study was to determine how the performance of ADHD children compares with that of normal children of the same age, it was decided to choose normal children that matched ADHD children as closely as possible, in terms of age, sex, handedness and IQ from the pool of 65 normal children tested, and to use the

remaining normal children in a small "developmental" study to investigate task performance over the ages 7-12 years. Thus results of (unmedicated) ADHD children are reported under Experiment 1, results of (medicated) ADHD children are reported under Experiment 2, and the results for the normal children are reported under Experiment 3. Experiment 4 was a single-subject investigation, that examined the performance of an ADHD child whilst on and off medication.

Of the 27 children with ADHD, one child's data were excluded on the basis of IQ, and the data of two children were excluded because they did not finish all of the change-of-set blocks. Results of the two children diagnosed with predominantly inattentive ADHD were excluded from analyses, and are discussed separately in Experiment 5. This leaves a remainder of 16 right-handed and 6 left-handed children with ADHD. Because handedness may have implications for spatial biases/ performance asymmetries data, it was decided, in order to make the best use of sample size, to exclude left-handed children only for (separate) analysis of the laterality/ performance asymmetries data. Therefore data were collapsed across start and target position for analysis of data from both left and right-handers, and data from the centre start position were examined, only for the right-handed children, in the investigation of performance asymmetries for target and/ or distractor location.

While it would have been optimal to compare unmedicated and medicated ADHD children directly, this was not possible because there was a significant difference between the ages of the unmedicated and medicated groups (see ANOVA table in Appendix E). Hence, the relationship between age and the dependent variables was not equivalent across groups. Therefore, the unmedicated group was closely matched to a group of normal, healthy children on the basis of age, sex, handedness and IQ, as was the medicated group, and their data were analysed separately in Experiments 1 and 2.

Of the normal children, one child's data were excluded because he did not finish all blocks of the change-of-set task. Matched controls for the ADHD children (including the two with inattentive type diagnoses) were removed, leaving a sample of 35 right-handed and 5 left-handed children for the "developmental study". As for the clinical children, data were collapsed across start and target position when investigating the

effects of age on reaction and movement times, and error data. In the event that the clinical children in the previous analyses were to show atypical performance asymmetries when compared to normal children, normal children's performance asymmetries would be explored in more detail via analysis of centre start data in right-handers. (Analyses of left minus centre start and right minus centre start data would also be conducted if performance asymmetries were revealed for the centre start data.)

Reaction time, movement time, and error data of all participants were analysed separately using repeated measures Analyses of Variance (ANOVA) with the Statistical Package for the Social Sciences (SPSS) Version 10. Post-hoc tests were adjusted with Bonferroni corrections. Correlational analyses (using Pearson's correlation coefficient) were also conducted for the data of the children in the developmental study, and the unmedicated ADHD children.

3.4 Experiment 1: Results for unmedicated ADHD children and their matched controls

3.4.1 Demographic data:

Table 3 indicates the demographic details of the ten right-handed and five left-handed unmedicated ADHD children and their individually matched controls. One-way ANOVAs (see Appendix F) revealed that the unmedicated ADHD and control children did not differ significantly in terms of age ($F(1, 28) = .008$, $p = .93$), grade ($F(1, 28) = .045$, $p = .834$), nor Full Scale IQ ($F(1, 28) = 1.338$, $p = .257$). As expected, children with ADHD had significantly lower scores on all aspects of the ADDES than controls, indicating that according to both parent and teacher report, children with ADHD engage in inattentive and hyperactive-impulsive behaviours more frequently than controls.

3.4.2 Reaction time data for the reach task

The data were collapsed across start position and target location (which are considered separately in Section 3.4.5), and submitted to a three-way ANOVA with the between-subjects factor of group (unmedicated ADHD, control children), and within-subjects

factors of set (change-set, maintain- set), and distractor (absent, present). This analysis (see Appendix F) revealed a significant effect of group ($F(1, 28) = 11.5$, $p = .002$), with the unmedicated ADHD children displaying sl· wer reaction times (mean = 666 ms) compared to control children (mean = 542 ms). A significant effect of distractor ($F(1, 28) = 15.76$, $p < .001$) was also revealed, with children displaying slower reaction times when the distractor was present (mean = 615 ms) than when it was absent (mean = 594 ms). There was no significant effect of set changing ($F(1, 28) = .003$, $p = .96$), with children showing similar reaction times in the change-of-set (mean = 605 ms) and maintain-set (mean = 604 ms) condition. None of the interactions were statistically significant at $\alpha = .05$.

3.4.3 Movement time data for the reach task

A three-way ANOVA with factors of group (unmedicated ADHD, control children), set (change-set, maintain-set), and distractor (absent, present), was conducted on movement time data that were collapsed across start position and target location (see Appendix F). There was no significant difference in movement time between the groups ($F(1,28) = .195$, $p = .662$), with the unmedicated ADHD children showing similar movement times (mean = 314 ms) to control children (mean = 325 ms), and there were no significant interactions. There were however, significant effects for set ($F(1,28) = 7.94$, $p = .009$), and for distractor ($F(1, 28) = 8.201$, $p = .008$). Children moved on average 30 ms slower in the set changing compared to the set-maintenance condition, and an average 12 ms slower when a distractor was present, than when it was absent.

3.4.4 Reaction time data for the no-reach task

As with the reaction time data in the reach task, a three-way ANOVA for the reaction time data in the no-reach task (see Appendix F) revealed a significant effect of group ($F(1, 28) = 7.18$, $p = .012$), with unmedicated ADHD children reacting approximately 19 ms slower overall than control children. There was also a significant effect of distractor ($F(1,28) = 15.51$, $p < .001$), with children performing unexpectedly slower (by approximately 38 ms) when the distractor was absent then when it was present.

Table 3: Demographic details of unmedicated ADHD children and their matched controls

	Unmedicated ADHD children	Matched control children	1-way ANOVA p-values
Sex	male = 10 female = 5	male = 10 female = 5	-
Handedness	right = 10 left = 5	right = 10 left = 5	-
Mean age (standard deviation)	9.3 years (1.6)	9.3 years (1.5)	.93
Mean grade (standard deviation)	3.5 (1.9)	3.6 (1.5)	.83
Mean Full Scale IQ (standard deviation)	100.9 (11.7)	105.5 (9.7)	.26
ADDES – School version Mean overall percentile ranking (standard deviation)	27.5 (14.4)	85.1 (17.2)*	.00
ADDES – Home version Mean overall percentile ranking (standard deviation)	5.5 (7.9)	68.1 (25.8)	.00
ADDES. Home version Mean inattentive ratings (standard deviation)	2.5 (2.2)	11.1 (2.1)	.00
ADDES. Home version Mean hyperactive-impulsive ratings (standard deviation)	3.2 (2.4)	11.8 (1.8)	.00
ADDES. School version Mean inattentive ratings (standard deviation)	7.7 (1.7)	12.6 (1.6)*	.00
ADDES. School version Mean hyperactive-impulsive ratings (standard deviation)	7.8 (2.1)	12.5 (1.0)*	.00

** one rating scale was not returned*

Distractor condition also interacted significantly with set condition (F (1,28) = 14.08, p = .001), although there was no significant main effect of set (F (1,28) = .018, p = .893). Figure 2 depicts the effect that change-set and maintain-set conditions had on reaction time when a distractor was present and when it was absent. As can be seen from Figure 2, the interaction is driven by the greater cost (i.e., increased reaction time) in the absence of a distractor, in the change-set (mean cost = 62 ms) than the maintain-set condition (mean cost = 14 ms). Further, one-way (repeated measures) ANOVAs revealed that this cost was only significant in the change-set (F (1,29) = 19.73, p < .001), but not in the maintain-set condition (F (1,29) = 2.85, p = .102).

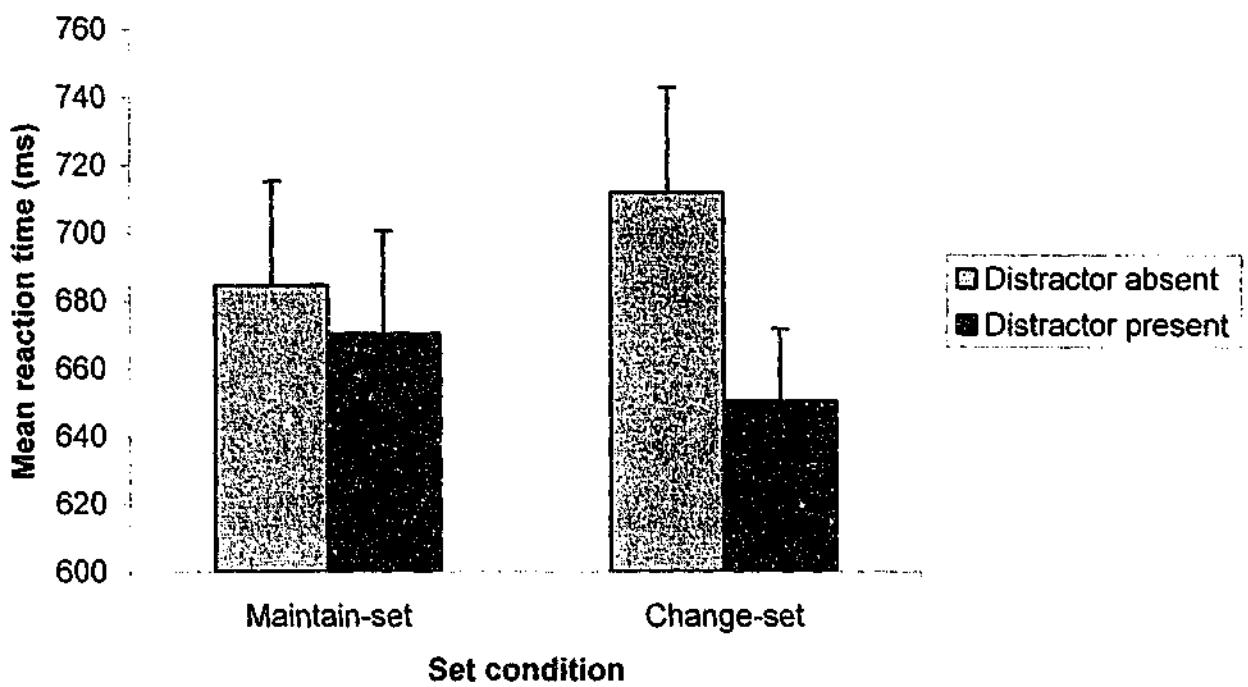


Figure 2: Mean reaction time (with standard error bars) for children in the no-reach task when distractor is present or absent, in maintain-set and change-set conditions.

3.4.5 Asymmetries in performance/ spatial biases

In order to investigate whether, compared to controls, ADHD children show anomalous asymmetrical performance for target location or distractor location (when the distractor is present it is located either left or right, opposite to the target), data for the central start position were examined for right-handed children. Separate three-way

ANOVAs with factors target (left, right) distractor (absent, present) and group (10 right-handed unmedicated ADHD, 10 right-handed control children) were conducted, for centre-start data in the change-set and the maintain-set conditions (see Appendix F for ANOVA tables). Anomalous asymmetrical performance in ADHD children is indicated with a significant group x target, or a significant group x target x distractor interaction. In the event that anomalous asymmetrical performance was found for central-start data, performance in left and right start positions would be examined via analysis of the difference scores for left-minus-centre-start, and right-minus-centre-start data.

The group x target x distractor ANOVAs conducted on centre-start data in the maintain-set condition, revealed no significant group x target, or group x target x distractor effects for reaction time (reach and no reach conditions) and movement time (reach condition). Similarly, for the same analyses conducted on the set-change data, there were no significant group x target, or group x target x distractor effects.

3.4.6 Error data

Again, to make best use of sample size, data for right-handers were only analysed separately when examining effects of target and distractor position in Sections 3.4.6.2 and 3.4.6.5. See Appendix F for the corresponding ANOVA tables.

3.4.6.1 Inattentive errors or misses

Inattentive errors are incorrect non-responses, or, in other words, missed targets. Inattentive error data were collapsed across start position and target location, and subjected to separate three-way ANOVAs for reach and no-reach data, with the factors set (maintain-set, change-set) x distractor (absent, present) x group (unmedicated ADHDs, controls). Results for the reach data revealed a significant effect of set ($F(1, 28) = 7.3$, $p = .012$), with children making more inattentive errors in the change-set (mean number of errors = .71) than the maintain-set (mean number of errors = .47) condition. There was no significant effect of distractor ($F(1, 28) = 1.6$, $p = .217$) with children making a similar number of inattentive errors in the presence of a distractor (mean number of errors = .56) and in its absence (mean number of errors = .612). There was a significant effect of group ($F(1, 28) = 11.9$, $p = .002$), with unmedicated

children making significantly more errors (mean number of errors = .98) than control children (mean number of errors = .19). There were no significant interactions.

Results for the no-reach data also revealed a significant effect of set ($F(1, 28) = 5.26$, $p = .030$), with children making more errors in the change-set (mean number of errors = .21) than maintain-set (mean number of errors = .15) condition. A significant effect of distractor ($F(1, 28) = 19.1$, $p < .001$) revealed more inattentive errors when the distractor was absent (mean number of errors = 1.0) than present (mean number of errors = .06). The main effect of group ($F(1,28) = 14.7$, $p = .001$) was significant, with unmedicated ADHD children making more errors (mean number of errors = 1.4) than controls (mean number of errors = 0.2). Group also interacted significantly with distractor ($F(1, 28) = 5.89$, $p = .022$), and the data suggest that the cost in the distractor absent condition was greater for unmedicated ADHD (mean cost = .7 errors), than control children (mean cost = .2 errors). Follow-up one-way ANOVAs indicated that this cost was significant for unmedicated ADHD children ($F(1, 14) = 14.74$, $p = .002$), and on the cusp of significance for controls ($F(1, 14) = 4.4$, $p = .056$). There was also a significant interaction between distractor and set ($F(1, 28) = 9.58$, $p = .004$). This interaction was driven by the cost in the absence of a distractor in the change-set condition (mean cost = .9 errors), which is not evident in the maintain-set condition (mean cost = .01 errors).

3.4.6.2 Spatial biases/ performance asymmetries for inattentive error data

Inattentive error data in the centre-start position, for the ten unmedicated right-handed children and their matched-controls, were examined separately for evidence of anomalous performance asymmetries for target location, and/ or distractor location. There were no significant group x target, or group x target x distractor interactions for reach or no-reach data in either maintain-set or change-set tasks, that would have otherwise indicated such anomalous performance in unmedicated ADHD children.

3.4.6.3 Impulsive errors or premature responses

An impulsive error is made when the participant responds prematurely, prior to stimulus presentation. Impulsive error data were submitted to a group (unmedicated

ADHDs, controls) x set (maintain-set, change-set) x reach (reach, no-reach) ANOVA with repeated measures on the last two factors.[4] There was no significant effect of set ($F(1,28) = .047$, $p = .831$) with children making a similar number of premature responses in the change-set (mean number of errors = 4.1) and maintain-set conditions (mean number of errors = 4.2). Similarly, there was no significant effect of reach ($F(1,28) = .214$, $p = .647$), with children performing similarly in the reach (mean number of errors = 4.3) and no-reach (mean number of errors = 4.0) conditions. There was, however, a significant effect of group ($F(1, 28) = 6.3$, $p = .018$), with unmedicated ADHD children committing more impulsivity errors (mean number of errors = 7.2), than control children (mean number of errors = 1.1).

3.4.6.4 Distractibility errors

Distractibility errors are responses to distractors. Distractibility error data were collapsed across start position (left, centre, right) and distractor location (left or right), which will serve as factors in a separate analysis in section 3.4.6.5 below. A group (unmedicated ADHD, controls) x set (maintain-set, change-set) x target (absent, present) ANOVA, with repeated measures on the last two factors, was conducted for reach data, and a group (unmedicated ADHD, controls) x set (maintain-set, change-set) ANOVA was undertaken for the no-reach data[5].

Results for the reach task reveal a significant main effect of group ($F(1, 28) = 17.87$, $p < .001$), with unmedicated ADHD children making significantly more distractibility errors (mean number of errors = 2.3) than controls (mean number of errors = 0.6). There was also a significant effect of set ($F(1, 28) = 9.44$, $p = .005$), with children making more distractibility errors in the change-set (mean number of errors = 1.8) than the maintain-set (mean number of errors = 1.1) condition. This main effect must be considered in light of the near-significant set x group interaction ($F(1, 28) = 3.98$, $p = .056$), which suggests that the increase in distractibility errors in the change-set condition is driven by the ADHD group (mean error increase = 1.2), rather than the

[4] Data were collapsed across start, target and distractor conditions, because these factors should have little impact on responses made prior to stimulus presentation

[5] Note that there is no target condition in the no-reach task, because whenever a target is present (distractor + target condition) and the participant responds, this is recorded as correct, and no distractibility errors are recorded.

control group (mean error increase = 0.2). The significant effect of target ($F(1, 28) = 44.69$, $p < .001$), which indicates that children make more errors when the target is absent (that is in the distractor-only condition; mean number of errors = 2.1), than when the target is present (mean number of errors = 0.8), must also be considered in light of the significant target x group interaction ($F(1, 28) = 9.07$, $p = .005$). One-way ANOVAs suggested that unmedicated ADHD children made more errors (mean number of errors for distractor-only condition = 3.2, mean number of errors for target+distractor condition = 1.4) than controls (mean number of errors for distractor-only condition = 0.9, mean number of errors for target+distractor condition = 0.3) for both distractor-only ($F(1, 28) = 20.03$, $p < .001$) and target+distractor ($F(1, 28) = 9.5$, $p = .005$) conditions. What appears to be driving the interaction is, therefore, the greater difference between ADHD children and controls for the distractor-only than the target+distractor condition.

No-reach results reveal a significant main effect of set ($F(1, 28) = 7.28$, $p = .012$), with significantly more errors in the change-set (mean number of errors = 3.9) than the maintain-set (mean number of errors = 2.7) condition. There was also a significant effect of group ($F(1,28) = 6.8$, $p = .014$), with unmedicated ADHD children making significantly more errors than the controls (mean number of errors = 4.5 for unmedicated ADHDs, and mean number of errors = 2.3 for controls). Interpretation of these main effects must take into consideration the significant set x group interaction ($F(1, 28) = 6.33$, $p = .018$), which indicates that the main effect of set is driven by the unmedicated ADHD group (mean error increase = 2.2, compared to mean error increase = 0.1 for controls). Follow-up with one-way ANOVAs revealed that this increase in errors in the change-set condition was only significant for the unmedicated ADHD group ($F(1, 14) = 13.05$, $p = .003$), and not for the control group ($F(1, 14) = .017$, $p = .897$).

3.4.6.5 Spatial biases/ performance asymmetries for distractibility error data

Distractibility error data in the centre-start position, for the ten unmedicated right-handed children and their matched-controls were examined separately for evidence of anomalous performance asymmetries for distractor location, and/ or target location.

There were no significant group x distractor, or group x distractor x target interactions for either reach or no-reach data, in either maintain-set or change-set conditions that would have otherwise indicated such anomalous performance in unmedicated ADHD children.

3.4.6.6 Proportional errors

Results so far have indicated that unmedicated ADHD children make significantly more errors than their matched controls. But the question remains, whether they show the same pattern of errors as controls. The analysis of the proportions of each error type yields information about which kind of errors contribute mostly to ADHD psychopathology.

The inattentive, impulsive and distractibility errors were converted to proportions of the total errors made by each participant. These data were then subjected to a group (unmedicated ADHD, controls) x set (maintain-set, change-set) x reach (reach, no-reach) x error type (inattentive, impulsive, distractibility) ANOVA. Results revealed that there was no significant effect of set, with children performing similarly in the maintain-set (mean proportional errors = .327) and the change-set condition (mean proportional errors = .322; $F(1,28) = .577$, $p = .454$). Similarly, there was no effect of group ($F(1,28) = .751$, $p = .394$) with unmedicated ADHD children (mean proportional errors =.327) performing similarly to control children (mean proportional errors = .322). There was a significant effect of reach ($F(1,28) = 10.28$, $p = .003$), which indicates that children made errors *other* than those classified as impulsive, inattentive and distractibility errors in the reach condition, errors that due to experimental design, they were unable to make in the no-reach condition.[6] There was a significant effect of error type ($F(2,56) = 105.83$, $p < .001$), but no significant interactions. The data show that the majority of errors made were distractibility errors (66%) and the proportion of inattentive errors (22%) was slightly higher than impulsive errors (9%). Post-hoc tests with Bonferroni corrections indicated that the proportion of distractibility errors was significantly higher than inattentive ($p < .001$)

[6] In the reach condition "other" errors constituted a correct release of the start-key to targets, coupled with an incorrect button-press. This type of error could not be made in the no-reach condition where there was no button-press component.

and than impulsive ($p < .001$) errors, and that the proportion of inattentive errors was significantly higher than the proportion of impulsive errors ($p = .001$).

3.4.7 Correlations

In addition to the main analyses, correlational analyses (using Pearson's r) were undertaken for the unmedicated ADHD group, between participant variables (age, FSIQ, ADDES - home version inattentive ratings, ADDES - home version hyperactive-impulsive ratings, ADDES – school version inattentive ratings, ADDES – school version hyperactive-impulsive ratings, ADDES home impulsivity score (which was just the sum of the raw scores for all questions on the rating scale pertaining to impulsivity), ADDES school impulsivity score (again the sum of raw scores for all questions pertaining to impulsivity), ADDES - home version percentile rank, and ADDES - school version percentile rank) and experimental variables (overall reach reaction-time, overall no-reach reaction time, overall reach movement-time, and overall inattentive, distractibility and impulsive errors). See Appendix F for the correlations summary table.

Negative correlations for age and reach reaction time ($r = -.59$, $p = .021$), and for age and no-reach reaction time ($r = -.64$, $p = .010$) indicated that young age is associated with longer reaction times. There was also a positive correlation between reach and no-reach reaction times ($r = .74$, $p = .012$), perhaps reflecting that the reach and no-reach tasks address similar processes. In contrast, a positive correlation for movement time ($r = .54$, $p = .039$) indicates that young age is associated with faster movement times. There were no significant correlations between any of the school and home ratings on the ADDES and reaction and movement times. Inattentive, distractibility and impulsivity errors did not correlate with any measures of the ADDES rating scale, suggesting that the cognitive measures of impulsivity, inattentiveness and distractibility are measuring something different to the behavioural measures of inattentiveness and impulsivity. There were however positive correlations between all three error types ($r = .59$, $p = .005$, for inattentive and distractibility errors; $r = .75$, $p = .001$, for inattentive and impulsive errors; $r = .69$, $p = .004$, for impulsive and

distractibility errors) suggesting an underlying commonality in all these error measures.

3.4.8 Discussion

Discussion of these results is deferred to Section 3.6.

3.5 Experiment 2: Results for medicated ADHD children and their matched controls

3.5.1 Demographic data:

Table 4 indicates the demographic details of the one left-handed and six right-handed medicated ADHD children and their matched controls. One-way ANOVAs (see Appendix G) revealed that the ADHD and control children differed neither in terms of age ($F(1, 12) = .028$, $p = .869$), grade ($F(1, 12) = .017$, $p = .899$), nor Full Scale IQ ($F(1, 12) = .516$, $p = .486$). As expected, children with ADHD had significantly lower scores on all aspects of the ADDES (except for teacher hyperactive-impulsive ratings which were, however, on the cusp of significance) than controls, indicating that according to both parent and teacher report, children with ADHD engaged in inattentive and hyperactive-impulsive behaviours more frequently than controls.

3.5.2 Reaction time data for the reach task

As for the unmedicated children, the data for the medicated ADHD children (and their matched controls) were collapsed across start position and target location (which are considered separately in Section 3.5.5), and submitted to a three-way ANOVA with the factors of group (medicated ADHD, control children), set (change-set, maintain-set), and distractor (absent, present), with repeated measures on the last two factors. Results (see Appendix G) revealed no significant effect of group ($F(1,12) = .87$, $p = .369$), with the medicated ADHD children (mean = 503 ms) performing similarly to control children (mean = 544 ms). There was no significant effect of distractor ($F(1,12) = 4.07$, $p = .067$), with similar reaction times when the distractor was present (mean = 530 ms) and when the distractor was absent (mean = 516 ms). There was also no significant effect of set ($F(1,12) = 2.74$, $p = .124$), with children performing similarly in the change-set (mean = 540 ms) and the maintain-set (mean = 506 ms)

Table 4: Demographic details of medicated ADHD children and their matched controls

	Medicated ADHD children	Matched control children	1-way ANOVA p-values
Sex	male = 7 female = 0	male = 7 female = 0	-
Handedness	right = 6 left = 1	right = 6 left = 1	-
Mean age (standard deviation in brackets)	11.2 years (2.2)	11.0 years (2.1)	.87
Mean grade (standard deviation in brackets)	5.0 (1.9)	5.1 (2.2)	.90
Mean Full Scale IQ (standard deviation in brackets)	99.7 (11.7)	104.4 (12.8)	.49
ADDES – School version Mean overall percentile ranking (standard deviation in brackets)	44.5 (35.5)*	81.3 (15.2)	.03
ADDES – Home version Mean overall percentile ranking (standard deviation in brackets)	2.4 (2.9)	67.7 (28.0)	.00
ADDES. Home version Mean inattentive ratings (standard deviation in brackets)	1.7 (0.8)	11.4 (2.4)	.00
ADDES. Home version Mean hyperactive-impulsive ratings (standard deviation in brackets)	2.4 (1.9)	11.1 (1.9)	.00
ADDES. School version Mean inattentive ratings (standard deviation in brackets)	7.5 (5.2)*	12.4 (1.3)	.03
ADDES. School version Mean hyperactive-impulsive ratings (standard deviation in brackets)	8.2 (5.6)*	12.7 (1.0)	.06

* one rating scale was not returned

conditions. There were no significant interactions, but there was a trend for an interaction of group with set (F (1 12) = 2.742, p=.056), which appeared to be driven by the slower reaction time in the change-set condition for the controls (mean = 78 ms slower), which was absent for the medicated ADHD children (mean = 6 ms faster).

3.5.3 Movement time data for the reach task

A three-way ANOVA with factors of group (medicated ADHD, control children), set (change-set, maintain-set), and distractor (absent, present), was conducted on movement time data that were collapsed across start position and target location (see Appendix G). The main effect for group approached significance (F (1,12) = 4.25, p = .062), with a tendency for medicated ADHD to be faster (mean = 290 ms) than control children (mean = 378 ms). Group interacted significantly with set (F (1, 12) = 7.58, p = .018), with controls showing a greater *cost* (mean cost = 69 ms) in the change-set compared to the maintain-set condition, while medicated ADHD children showed an *advantage* in the change-set condition (mean advantage = 25ms). Follow-up with separate one-way repeated-measures ANOVAs with the factor set revealed that this difference was near-significant for controls (F (1, 6) = 4.83, p = .07), but not for the medicated ADHD children (F (1, 6) = 3.45, p = .113). There was no significant effect of distractor (F (1, 12) = 1.02, p = .33), with children performing similarly when the distractor was absent (mean = 331 ms) and when the distractor was present (mean = 337 ms), nor any significant interactions.

3.5.4 Reaction time data for the no-reach task

The group (medicated ADHDs, controls)x set (maintain-set, change-set) x distractor (absent, present) ANOVA conducted on reaction time data in the no-reach task (see Appendix G) revealed no significant main effect of group (F(1, 12) = .499, p = .493), with medicated children performing similarly (mean = 615 ms) to control children (mean = 672 ms). Children also performed similarly in the change-set (mean = 650 ms) and the maintain-set (mean = 638 ms) conditions (F(1, 12) = .272, p = .611), and similarly when a distractor was present (mean = 633 ms) and when it was absent (mean = 655 ms; F(1, 12) = 3.19, p = .10). There were no significant interactions.

3.5.5 *Asymmetries in performance/ spatial biases*

As for the unmedicated ADHD children, analyses for the six right-handed medicated ADHD children and their matched controls (see Appendix G) revealed no significant group x target, or group x target x distractor effects for reaction time (reach and no-reach conditions) and movement time (reach condition) centre-start data in either maintain-set or change-set tasks.

3.5.6 *Error data*

3.5.6.1 Inattentive errors or misses

Inattentive errors, or misses, were collapsed across [illegible] and target condition, and subjected to two, set (maintain-set, change-set) x distractor (absent, present) x group (medicated ADHDs, controls) ANOVAs with repeated measures on the first two factors, for reach and no-reach data. Results for the reach data revealed no significant effect of set ($F(1, 12) = 1.73$, $p = .213$), with children making a similar number of inattentive errors in the change-set (mean number of errors = .24) and the maintain-set (mean number of errors = .13) condition. There was no significant effect of distractor ($F(1, 12) = .153$, $p = .703$), with children making a similar number of inattentive errors in the presence of a distractor (mean number of errors = .17) and in its absence (mean number of errors = .19). There was also no significant effect of group ($F(1, 12) = .89$, $p = .365$), with medicated ADHD children making a similar amount of inattentive errors (mean number of errors = .22) as control children (mean number of errors = .14). There were no significant interactions.

Results for the no-reach data revealed that there was no significant main effect of group ($F(1, 12) = 1.08$, $p = .32$), with medicated ADHD children making a similar amount of inattentive errors (mean number of errors = .315) to controls (mean number of errors = .19). There was a significant effect of distractor ($F(1,12) = 7.244$, $p = .02$), with children making more errors in the absence (mean number of errors = .345) than the presence (mean number of errors = .161) of a distractor. There was also a significant main effect of set ($F(1,12) = 8.64$, $p = .012$) with children making more errors in the change-set (mean number of errors = .375) than the maintain-set condition

(mean number of errors = .131). These must be considered in light of the significant set x distractor ($F(1, 12) = 8.41$, $p = .013$) and the near-significance set x group ($F(1,12) = 4.32$, $p = .06$) interaction. The data indicate that the increase in errors for the distractor absent condition (compared to distractor-present condition) is greater in the change-set (mean error increase = .35) than the maintain-set condition (mean error increase = .02). Follow up with one-way ANOVAs (for the factor distractor) indicated that the effect of distractor was only significant for the change-set condition ($F(1, 13) = 8.06$, $p = .014$), and not for the maintain-set condition ($F(1, 13) = .65$, $p = .435$). The data also indicated that there was a trend for medicated ADHD children to show more errors than control children in the change-set condition (mean increased errors = .29), whereas they showed slightly less errors in the maintain set condition (mean *decreased* errors = .05).

3.5.6.2 Spatial biases/ performance asymmetries for inattentive error data

Inattentive error data from the central start position, for the six medicated right-handed ADHD children and their matched-controls, were examined separately for evidence of anomalous performance asymmetries for target location, and/ or distractor location (see Appendix G). There were no significant group x target, or group x target x distractor interactions for reach or no-reach data in either maintain-set or change-set tasks, that would have otherwise indicated such anomalous performance in medicated ADHD children.

3.5.6.3 Impulsive errors

Impulsive errors, or premature responses, were submitted to a group (medicated ADHDs, controls) x set (maintain-set, change-set) x reach (reach, no-reach) ANOVA with repeated measures on the last two factors. Results revealed that there was a significant effect of group, with medicated ADHD children making significantly more impulsive errors (mean number of errors = 1.75) than controls (mean number of errors = 0.4; $F(1, 12) = 10.01$, $p = .008$). Whilst there were no significant main effects of set ($F(1,12) = 1.655$, $p = .223$) or reach conditions ($F(1,12) = 2.52$, $p = .139$), there was a significant set x reach interaction ($F(1, 12) = 6.56$, $p = .025$) which is depicted in

Figure 3. The data indicate that the set x reach interaction is driven by the reduction in impulsive errors when changing-set in the no-reach condition.

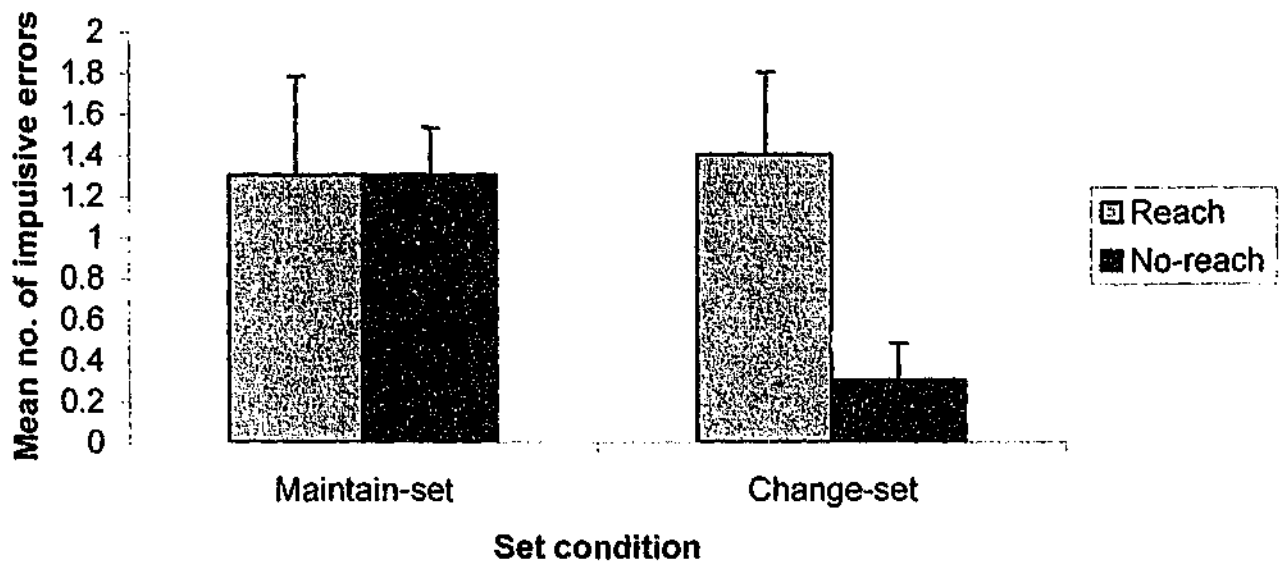


Figure 3: Mean number of impulsive errors (with standard error bars) made by children in reach and no reach conditions, for both maintain and change set conditions.

3.5.6.4 Distractibility errors

Distractibility errors, or incorrect responses to distractors, were collapsed across start position (left, centre, right) and distractor location (left or right), which will serve as factors in a separate analysis in section 3.5.6.5 below. A group (medicated ADHD, controls) x set (maintain-set, change-set) x target (absent, present) ANOVA, with repeated measures on the last two factors, was conducted for the reach data, and a group (medicated ADHDs, controls) x set (maintain-set, change-set) ANOVA for the no-reach data (see Appendix G).

Results for the reach data revealed no significant effect for group ($F(1, 12) = 1.64$, $p = .225$) with medicated participants performing similarly (mean number of errors = 1.04) to controls (mean number of errors = 0.58). There was also no significant effect of set ($F(1,12) = .106$, $p = .75$), with children performing similarly in the maintain-set (mean number of errors = .79) and the change-set (mean number of errors = .83) condition.

There was a significant main effect of target (F (1,12) = 11.07, p = .006) with children making significantly more errors in the absence of a target (that is, distractor-only condition; mean number of errors = 1.3) than in the presence of a target (target + distractor condition; mean number of errors = .32). Target also interacted with set (F (1, 12) = 8.842, p = .012), and the mean distractibility errors for the target absent and target present conditions in maintain-set and change-set conditions are given in Figure 4. Follow-up with one-way ANOVAs revealed that the increase in errors in the absence of a target was significant for the maintain-set condition (F (1,13) = 13.82, p = .003), but only approached significance for the change-set condition (F(1, 13) = 4.1, p = .064). Thus the cost associated with the absence of the target was much greater for the maintain- than change-set condition.

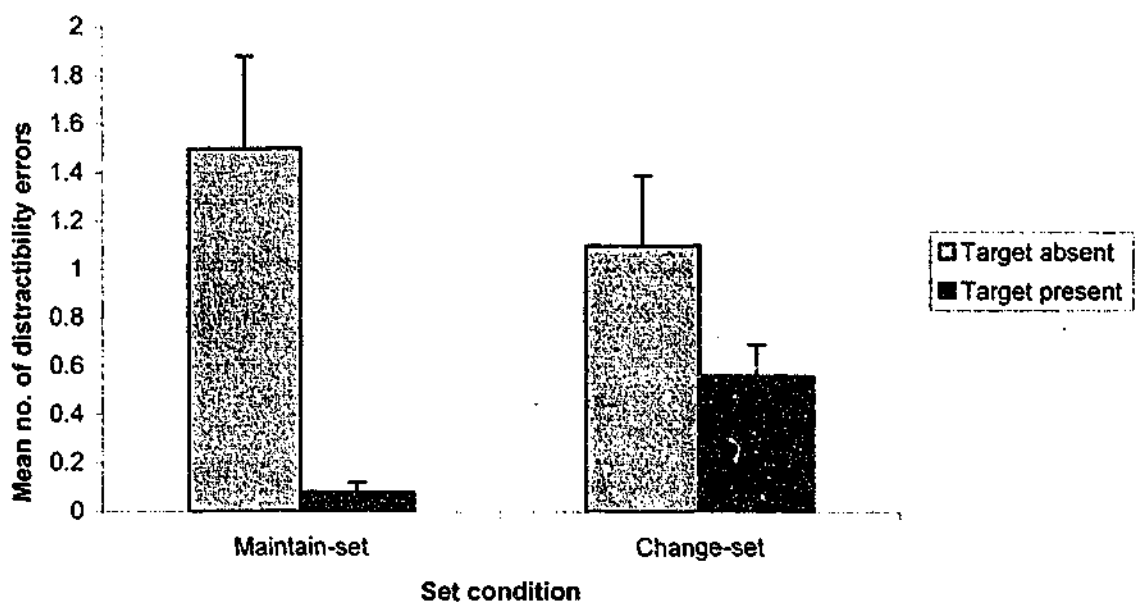


Figure 4: Mean number of distractibility errors (with standard error bars) for the reach task in the maintain and change set conditions, in the absence and presence of a target

Results for the no-reach data indicated no significant effect of set (F (1,12) = .119, p = .737), and only a trend for the main effect of group (F (1,12) = 4.03, p = .068), with medicated children making slightly more distractibility errors (mean number of errors

= 2.3) than controls (mean number of errors = .7). There was no significant interaction between group and set.

3.5.6.5 Spatial biases/ performance asymmetries for distractibility error data

Distractibility error data for the six medicated right-handed children and their matched-controls were examined separately for evidence of anomalous performance asymmetries for distractor location, and/ or target location (see Appendix G for ANOVA tables). There were no significant group x distractor, or group x distractor x target interactions for either reach or no-reach data in either maintain-set or change-set tasks, that would have otherwise indicated such anomalous performance in medicated ADHD children.

3.5.6.6 Proportional errors

The inattentive, impulsive and distractibility errors were converted to proportions of the total errors made by each participant, and subjected to a group (medicated ADHD, controls) x set (maintain-set, change-set) x reach (reach, no-reach) x error type (inattentive, impulsive, distractibility) ANOVA. Results revealed similar results to those of the unmedicated ADHD children and their controls; there was no significant effect of group ($F(1, 12) = 1.814$, $p = .203$), nor of set ($F(1, 12) = 0.194$, $p = .667$); an (uninteresting) effect of reach ($F(1, 12) = 7.414$, $p = .019$); a significant effect of error type ($F(2, 24) = 92.69$, $p < .001$); and no significant interactions. Again, the majority of errors made by children were distractibility errors (69%), followed by inattentive errors (18%), and then by impulsive errors (8%). Post-hoc tests with Bonferroni corrections indicated that the proportion of distractibility errors was significantly higher than the proportion of inattentive errors ($p < .001$) and than the proportion of impulsive errors ($p < .001$), and that the proportion of inattentive errors was significantly higher than the impulsive errors ($p = .017$).

3.5.7 Discussion

Discussion of these results is deferred to Section 3.6 below

3.6 Discussion for Experiments 1 and 2

3.6.1 Motor Problems

Motor problems were investigated in terms of reaction and movement-execution time in the reach task, and reaction time in the no-reach task. As hypothesised, unmedicated ADHD children showed significantly slower *reaction* times than controls, but did not show any deficits in movement *execution* time. This suggests that difficulties for ADHD children lie in the *movement preparation* rather than in *motor execution*. This finding is consistent with a study by Van der Meere and colleagues (1989) who found motor preparation problems in hyperactive but not learning disabled children.

However, deficits in reaction time in the reach task may reflect deficits in *attention* and/ or *motor preparation/ planning*. It was postulated that the no-reach condition would reduce the motor preparation component of the task, in its measure of reaction time, as no planning of motor movements (except for releasing the start-key) are required. Results showed that unmedicated ADHD children were also slower than controls in the no-reach task. However, the difference in reaction time scores between ADHD children and controls, whilst not compared directly, appears to be smaller in the no-reach task (19 ms) than the reach task (124 ms), suggesting that motor planning deficits may be present *in addition to* attentional deficits in ADHD. Alternatively, the difference in reaction times may simply reflect more complex motor programming in the reach task (where a directional movement was required) than the no-reach task (where the release-of the start key was required), rather than attentional impairment.

Medicated ADHD children, on the other hand, did not show the deficits in reaction time (nor any deficits in movement time) for the reach or the no-reach tasks. There was even a trend for them to be faster (in movement time) than controls. Although the effect of stimulant medication was not studied systematically, the findings suggest that performance involving motor planning (and attention) may be normalized with medication.

3.6.2 Errors

As hypothesised, unmedicated ADHD children made significantly more inattentive errors (misses), and impulsivity errors (premature responses), for the reach and the no-reach tasks, than controls. The finding of greater inattentive errors in ADHD children is consistent with other studies showing impaired vigilance using the Continuous Performance Test (Barkley et al., 2001; Seidman et al., 1997). Unmedicated ADHD children also made more distractibility (responses to distractors) errors in the reach task compared to controls, especially with the additional demand of set-shifting. Unmedicated ADHD children made significantly more distractibility errors than controls, for both the distractor-only and the distractor + target condition, but this difference between unmedicated ADHD children and controls appeared to be greater in the distractor-only condition. In the no-reach task, the significantly greater distractibility errors made by the unmedicated children relative to the controls again reflects their difficulty in inhibiting their response in the distractor-only condition. Thus, it appears that ADHD children have even greater difficulty with inhibiting unwanted responses, than with ignoring distractors, compared to controls. These response inhibition problems are consistent with those documented for ADHD children in go/ no-go and stop-signal studies (Shue & Douglas, 1992; Trommer et al., 1988; Oosterlaan & Sergeant, 1996; Schachar & Logan, 1990).

Although medicated ADHD children did not make significantly more inattentive errors than controls in the reach and the no-reach tasks, they did show a trend for making more inattentive errors than controls when there was the additional demand of set-shifting in the no-reach task. Medicated ADHD children made significantly *more* impulsive errors, or premature responses, than controls. There was no significant difference between the number of distractibility errors made by medicated ADHD children and their controls for either the reach or the no-reach task, although there was a trend ($p = .068$) for this in the latter. The apparent improvement in distractibility errors with medication is consistent with a study showing an improvement in response-inhibition to the no-go signal in the go/ no-go task (Trommer et al., 1991). Overall, these results suggest that while medication improves the amount of errors made by ADHD children, it does not do this across different error types as consistently as it

improves reaction-time and movement-time. Premature responses, or impulsivity errors, appear to be a difficulty that remains despite stimulant medication.

Whilst, as expected, unmedicated ADHD children made more of every type of error than controls, when the pattern of error types as a proportion of total errors made is examined, they did *not* show a different pattern to that of controls. The greatest proportion of errors made by unmedicated ADHD and control children was distractibility errors (66%), followed by inattentive errors (22%) and then by impulsive errors (9%). This was similar for the medicated ADHD children who also did not differ from controls in their pattern of errors made, and showed a greater proportion of distractibility errors (69%), followed by inattentive errors (18%) and then by impulsive errors (8%). The finding that there is no difference in the proportions of the different errors made suggests that children with ADHD do not show an unusual or pathological pattern of responding, but rather exacerbate the errors shown by normal children. Thus, they may be showing a *developmental delay*, responding like younger children. This will be explored further in consideration of the results for the normal children in Experiment 3. It would also be of interest to investigate the pattern of error types made by children with the predominantly inattentive type ADHD, in order to determine whether this group makes a larger proportion of inattentive errors than other groups. A case study outlining findings for two inattentive type ADHD children is reported in Experiment 5.

3.6.3 Response inhibition/ distractibility

Problems with ignoring distracting or irrelevant stimuli, and the ability to withhold a response, have been discussed in terms of the errors made in response to distractors in the above section. The following discussion focuses on the effects of the addition of a distractor on reaction and movement times, as well as on the number of inattentive errors made.

Results revealed that, contrary to predictions, inclusion of a distractor did not result in slower reaction and movement times for unmedicated ADHD children in the reach task; rather, *both* unmedicated ADHD children and their controls showed slower reaction and movement times. This effect was not significant for the medicated

ADHD children and their controls. Unexpectedly, both unmedicated ADHD and control children performed slower in terms of reaction time in the no-reach task in the absence of a distractor, when changing-set. Again, this was not significant for medicated ADHD children and their controls. Whilst the finding of slower reaction time in the no-reach task in the absence of a distractor appears to be paradoxical, comments made by some of the children give some insight into this result. Children reported that they found the target+distractor condition very easy because in this condition they saw two LEDs and would thus always respond; if however there was only one LED they had to decide whether or not to respond, based on the LED's colour. Thus it appears that the distractor served to facilitate or cue their response, rather than distract them from the task in the no-reach condition.

Inattentive errors made by medicated and unmedicated ADHD children and their controls were not significantly affected by the addition of a distractor in the reach task. In the no-reach task, however, similar to the reaction time data, a cost (more inattentive errors) was associated with the *absence* of a distractor for both medicated and unmedicated ADHD children and their controls in the change-set condition. *This cost was greater for unmedicated ADHD than the control children.* Thus it appears that the presence of a distractor also ensured that children missed less targets, probably for the same reason that they also responded faster (reaction time) in the presence of a distractor.

3.6.4 Performance asymmetries/ spatial biases

ADHD children, both medicated and unmedicated, did not show anomalous performance asymmetries for target location, and/ or distractor location, in terms of reaction time (no-reach and reach data), movement time (reach task), inattentive errors, nor distractibility errors. This result is inconsistent with the finding of an atypical right-visual field bias in a line bisection task (Sheppard et al., 1999). However, the results must be interpreted with caution because sample size was reduced with exclusion of left-handers. As there was no atypical performance asymmetry, examination of the manipulation of hand-start position (which was designed to allow investigation of whether the predicted delay reflected impairment of attention or impairment of motor preparation of movements to left targets) was not conducted.

3.6.5 Set-shifting

Set-shifting difficulties have been implicated in ADHD children by their impaired performance on the Wisconsin card sorting test and the trailmaking test (Shue & Douglas, 1992; Boucugnani & Jones, 1989). In the present study set-shifting difficulties, in terms of slowed *reaction times*, were not evident for the unmedicated ADHD children nor for the medicated ADHD children compared to their matched controls in either reach or no-reach tasks. Indeed, neither the controls nor the unmedicated and medicated ADHD children differed in terms of their reaction times when maintaining-set and changing-set in the reach task. (In the no-reach task, unmedicated ADHD children and their controls showed slower reaction times in the absence of a distractor in the change-set condition, as described in the response inhibition/ distractibility section above.) In comparison, set-shifting difficulties in terms of slower *movement time* were evident in control *and* unmedicated ADHD children in the reach task. Whilst movement time was also impaired in the controls of the medicated ADHD children when changing-set, this was not the case for the medicated ADHD children. Stimulant medication thus appeared to improve the normal effect of set-shifting on movement times, even though this was not an impairment in the (unmedicated) ADHD children relative to controls.

Effects of set-shifting were also observed in some of the error data. Both unmedicated ADHD children and their controls made more inattentive errors in the change-set condition, in both the reach and the no-reach tasks. However, unmedicated ADHD children were *not* more impaired than the controls. (In the no-reach task there was also a significant interaction between distractor and set, in which the cost associated with the absence of a distractor was evident in the change-set but not in the maintain-set condition for unmedicated and medicated ADHD children and their controls. This is discussed in the section above.) Medicated ADHD children and their controls did *not* make significantly more inattentive errors in the change-set condition in the reach task. In the no-reach task, however, medicated ADHD children and their controls made more inattentive errors in the change-set than the maintain-set condition. There was also a trend for medicated ADHD children to make *more* inattentive errors than controls in the change-set, but not in the maintain-set condition in the no-reach task.

Impulsive or premature-response errors were not influenced by changing-set in the unmedicated ADHD children. Medicated ADHD children *and* their controls, however, showed a reduction in impulsive errors when changing-set in the no-reach task. This suggests that these children are more careful and/ or less impulsive when the task has additional demands of set-changing. Results revealed that unmedicated ADHD children made *more* distractibility errors when changing-set than controls, for both reach and no-reach tasks. This deficit was not observed in the medicated ADHD children, suggesting that medication may overcome difficulties of being more distracted by distractors, when there are additional demands of set-shifting. The proportion of errors made did not change with changing-set, for any of the children.

Overall, the results of Experiments 1 and 2 suggest that set-shifting affected movement time, rather than reaction time in unmedicated ADHD children *and* controls. Unexpectedly, unmedicated ADHD children were not more impaired in movement time, and by the demands of set-shifting, than their controls. Stimulant medication appeared to improve this normal slowing of movement times in the change-set condition, because unlike their controls, medicated ADHD children did *not* show slowed movement times when changing-set. In terms of missing targets (inattentive errors), and in terms of making premature responses (impulsive errors), the extra demands of set-shifting did not impair ADHD children more than their controls. Distraction by distractors (distractibility errors), however, was greater for unmedicated ADHD children than controls when shifting-set. Again, medication appeared to resolve this difficulty. Thus it appears that the predicted deficits of set-shifting in ADHD are only partially supported, by the finding that (unmedicated) ADHD children are more distracted by distractors than controls when changing-set.

3.6.6 Correlations

Correlations conducted on data for unmedicated ADHD children revealed that there was no relationship between reaction time (reach and no-reach task), movement time, inattentive errors, distractibility errors, and impulsive errors, and behavioural measures of hyperactivity-impulsivity, impulsivity and inattentiveness as measured by the ADDES. This suggests that behavioural measures of impulsivity and inattentiveness may be measuring something different to cognitive measures of impulsivity and

inattentiveness. This is consistent with a study by Gerbing, Ahadi and Patton (1987), which showed that impulsivity as measured by self-report rating scales correlated poorly with impulsivity measured by experimental tasks such as measurements on the matching-familiar figures test.

All three error types had a positive relationship with one another, as did reaction time in the reach and the no-reach task, indicating that these may be measuring similar processes. Reaction times for no-reach and reach conditions correlated negatively with increasing age, suggesting that ADHD children get faster with age. Movement times on the other hand were positively correlated with age, suggesting that ADHD children slow down their movements with increasing age. This suggests that as children grow older they are more careful with execution of movements, while also being faster to initiate movements.

3.7 Experiment 3: Results for normal children aged 7-12 years of age; a developmental study

3.7.1 Demographic data:

Table 5 indicates the demographic details of the 35 right-handed and 5 left-handed normal children divided into groups of 7-8 year old, 9-10 year old and 11-12 year old children. One-way ANOVAs (see Appendix H) revealed that the age groups did not differ in terms of IQ ($F(2,37) = 2.38$, $p = .107$) and in mean percentile ratings for the home version of the ADDES rating scale ($F(2,30) = .308$, $p = .737$), whilst the school version was nearly significant ($F(2,28) = 3.23$, $p = .055$). This near-significant value appears to be driven by the slightly higher mean percentile rank for the 11-12 year old group.

3.7.2 Reaction time data for the reach task

The data were collapsed across start position and target location, and submitted to a three-way ANOVA with the factors of group (7-8 year olds, 9-10 year olds, 11-12 year olds), set (change-set, maintain-set) and distractor (absent, present), with repeated measures on the last two factors. Results (see Appendix H) indicated a significant

Table 5: Demographic details of 7-8, 9-10, and 11-12 year-old children

Group:	Handedness:	Mean Full Scale IQ (Standard Deviation)	Sex	ADDES - Home version Rating Scale Mean Percentile (SD)	ADDES-School version Rating Scale Mean Percentile (SD)
7-8 year-old children (n = 12)	Right = 9 Left = 3	106.3 (14.1)	Males = 3 Female = 9	52.5 (19.8)****	66.8 (25.6)***
9-10 year-old children (n = 12)	Right = 11 Left = 1	115.2 (13.8)	Males = 6 Females = 6	52.2 (20.2)**	68.9 (22.3)*
11-12 year-old children (n = 16)	Right = 15 Left = 1	104.7 (12.0)	Males = 6 Females = 10	57.8 (19.8)*	88.5 (16.8)*****

** the number of asterisks represents the number of rating scales not returned*

effect for group ($F(2, 37) = 14.82$, $p < .001$), with 7-8 year olds performing significantly slower (mean reaction time = 643 ms) than 9-10 (mean reaction time = 527 ms; $p = .003$, with Bonferroni correction) and than 11-12 year-olds (mean reaction time = 482 ms; $p < .001$, with Bonferroni correction). However, the difference between 9-10 and 11-12 year-olds was not significant ($p = .434$, with Bonferroni correction). There was also a significant main effect of distractor ($F(1,37) = 18.33$, $p < .001$), which indicated that distractors slowed children down by approximately 14 ms. There was no significant effect of set-changing ($F(1, 37) = 1.975$, $p = .168$), with children performing similarly in the maintain-set (mean = 544 ms) and the change-set condition (mean = 557.5 ms). There were also no significant interactions.

3.7.3 Movement time data for the reach task

A three-way ANOVA with factors of group (7-8 year olds, 9-10 year olds, 11-12 year olds), set (maintain-set, change-set) and distractor (absent, present), was conducted on movement time data that were collapsed across start position and target location. Results (see Appendix H) revealed that there was a significant effect of set ($F(1,37) = 15.25$, $p < .001$), with children moving approximately 39 ms slower in the change-set than the maintain-set condition. There was also a significant main effect of distractor ($F(1, 37) = 32.96$, $p < .001$), with children moving approximately 21 ms slower in the presence of a distractor, than in its absence. There was, however, no significant effect of group ($F(2, 37) = 2.157$, $p = .130$), with 7-8 year olds performing similarly (mean movement time = 366 ms) to 9-10 (mean movement time = 306 ms) and 11-12 year olds (mean movement time = 304 ms). These results must however be considered in light of the significant group x distractor ($F(2, 37) = 6.28$, $p = .004$) and set x distractor ($F(1, 37) = 6.97$, $p = .012$) interactions. Figure 5 depicts the group x distractor interaction. The data indicate that the magnitude of cost associated with the presence of a distractor gets smaller with increasing age. Follow-up ANOVAs with the factor distractor were conducted for each group. These indicated that the cost in the presence of a distractor (compared to its absence) was significant for the 7-8 year olds ($F(1,11) = 13.11$, $p = .004$), the 9-10 ($F(1,11) = 12.90$, $p = .004$) and even the 11-12 year olds ($F(1, 15) = 7.32$, $p = .016$). Figure 6 depicts the set x distractor interaction. The data show that the cost associated with the presence of a distractor is greater when changing-set than when maintaining-set. Follow-up with two ANOVAs with the factor distractor, for the maintain-set and change-set data, indicated that there was a significant effect of distractor in both the maintain-set ($F(1, 39) = 6.643$, $p = .014$) and the change-set condition ($F(1, 39) = 18.79$, $p < .001$).

3.7.4 Reaction time data for the no-reach task

Similarly to reaction time data in the reach task, reaction time data in the no-reach task (see Appendix H) indicated that there was a significant effect for group ($F(2,37) = 10.05$, $p < .001$). Post-hoc tests revealed that 7-8 year-olds (mean = 753 ms) showed longer reaction times than 9-10 year olds (mean = 613 ms; $p = .025$ with Bonferroni correction) and than 11-12 year-olds (543 ms; $p < .001$ with Bonferroni correction).

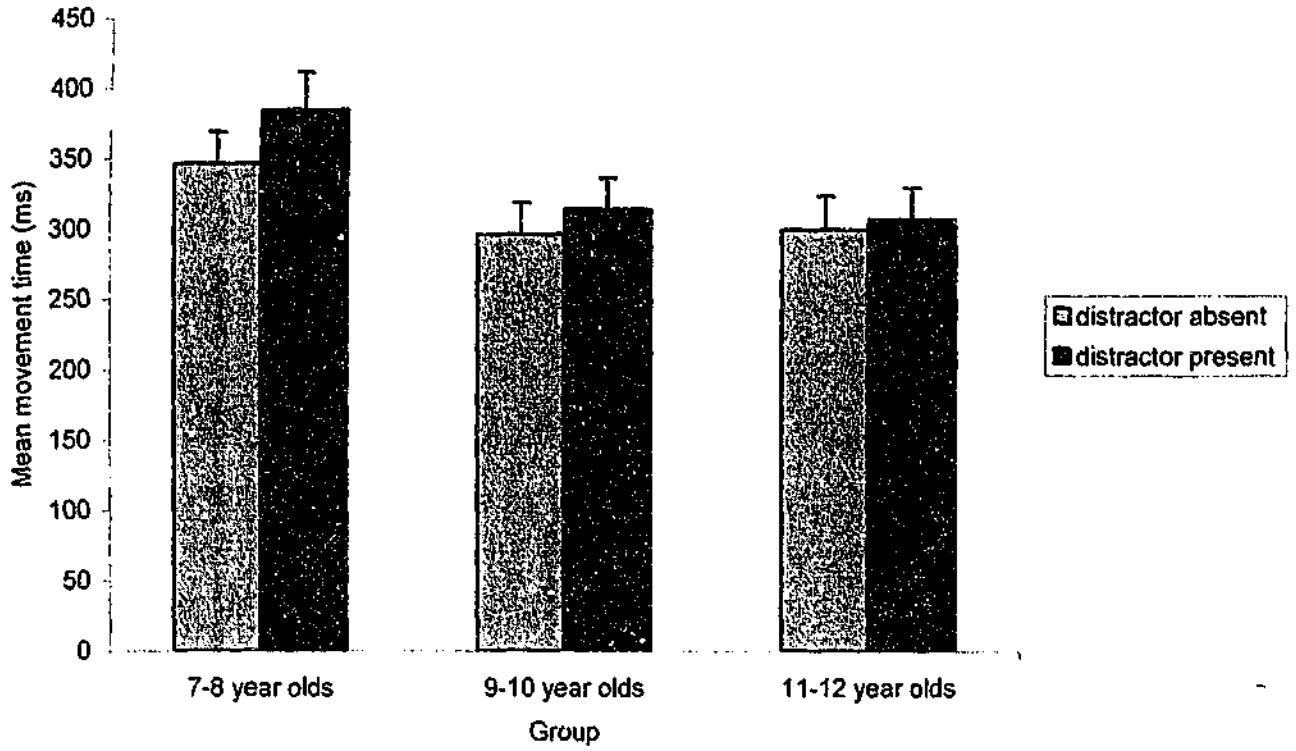


Figure 5: Mean movement time (with standard error bars) for 7-8, 9-10, and 11-12 year olds in the absence and presence of a distractor in the reach task.

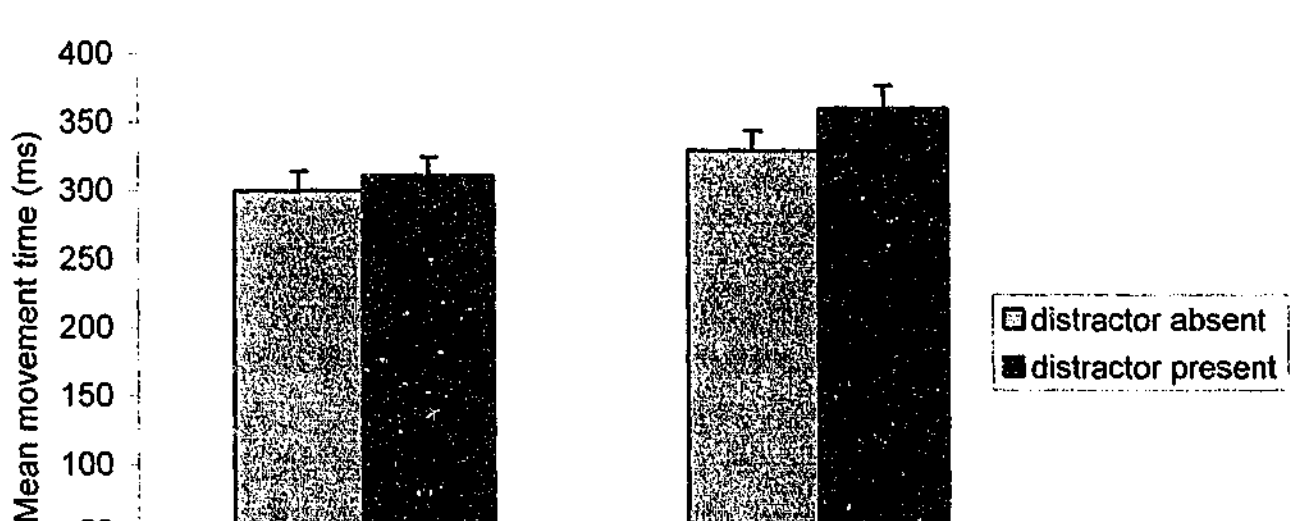


Figure 6: Mean movement time (with standard error bars) in the absence and presence of a distractor, when maintaining and changing-set.

The 9-10 year-olds did not differ significantly from 11-12 year-olds ($p = .442$ with Bonferroni correction). There was also a significant effect of distractor ($F(1,37) = 9.07$, $p = .005$), with children reacting approximately 18 ms slower in the absence of a distractor. Whilst there was no significant main effect of set ($F(1,37) = 0.611$, $p = .440$), set did interact significantly with distractor ($F(1,37) = 30.33$, $p < .001$), and there was a significant set x distractor x group interaction ($F(2,37) = 4.98$, $p = .012$). The two-way interaction appears to be driven by the slower reaction times in the absence (mean = 663 ms) than the presence (mean = 621 ms) of a distractor when changing-set, which was not evident in the maintain-set condition (distractor absent = 628 ms, distractor present = 633 ms). The three-way interaction is depicted in Figure 7. The data show that while the cost associated with the absence of a distractor appears

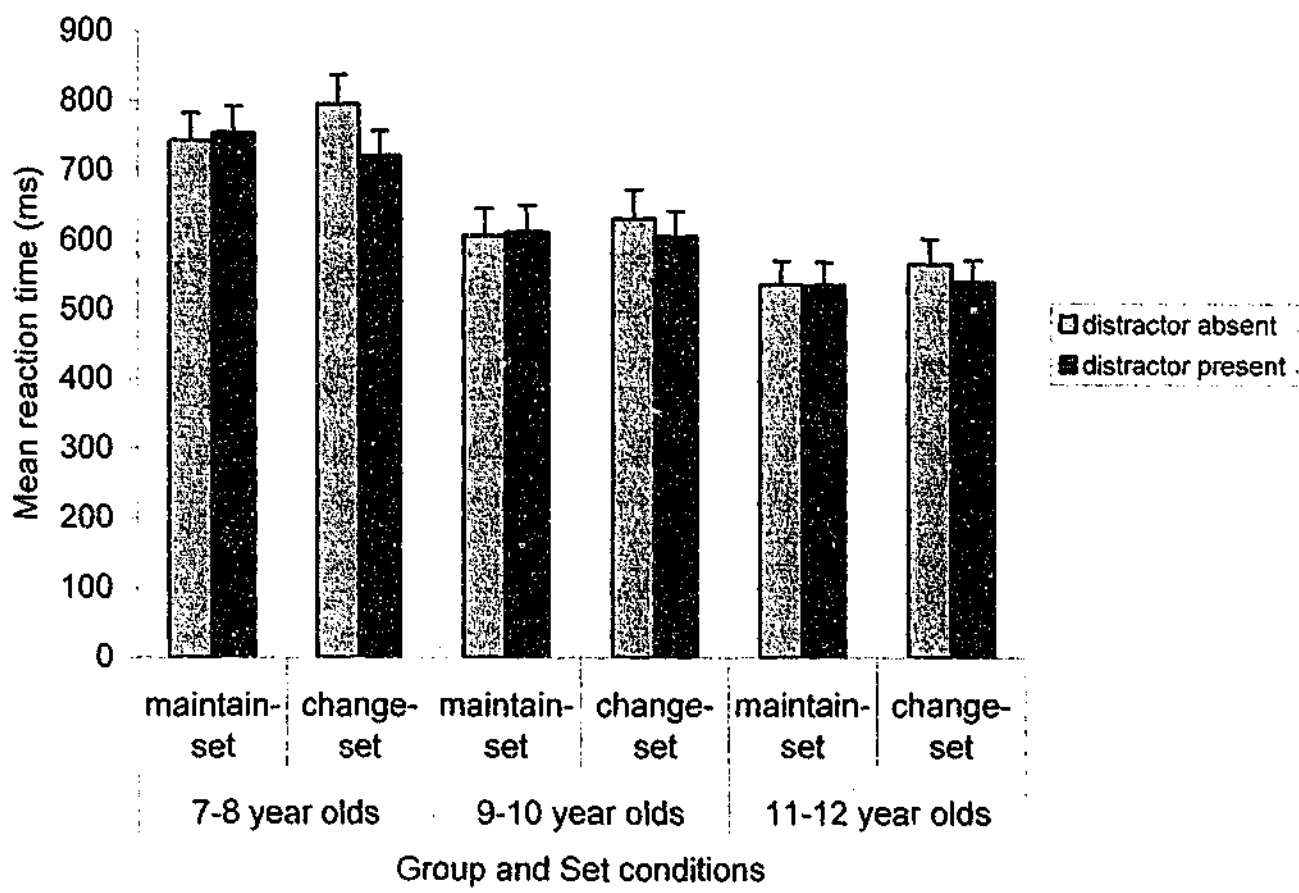


Figure 7: Mean reaction time (with standard error bars) made by 7-8, 9-10, and 11-12 year olds in the absence and presence of a distractor, in the maintain-set and change-set conditions.

to be present in the change-set but not the maintain-set condition for all groups of children, this appears to be greatest in the 7-8 year old group. Follow-up with repeated measures ANOVAs with the factors distractor (absent, present) and set (maintain-set, change-set) for each level of group, indicated that there was a significant set x distractor interaction for the 7-8 year old group ($F(1, 11) = 19.54$, $p = .001$) and the 11-12 year old group ($F(1,15) = 5.22$, $p = .037$), and a near-significant interaction for the 9-10 year old group ($F(1, 11) = 4.45$, $p = .059$).

3.7.5 Error data

3.7.5.1 Inattentive errors or misses

The mean number of inattentive errors, or misses, made in the reach and no-reach tasks were collapsed across start and target condition, and subjected to two set (maintain-set, change-set) x distractor (absent, present) x group (7-8, 9-10, 11-12 year olds) ANOVAs, with repeated measures on the first two factors (see Appendix H). Results for the reach task revealed that the mean number of inattentive errors were not affected by the presence or absence of a distractor ($F(1,37) = 2.63$, $p = .113$), with children showing similar numbers of inattentive errors in the absence (mean number of errors = .20) and presence (mean number of errors = .25) of a distractor. The effect of set was on the cusp of significance ($F(1, 37) = 3.9$, $p = .056$), with children making more inattentive errors when changing-set (mean number of errors = .29) than when maintaining-set (mean number of errors = .16). There was a significant effect of group ($F(2, 37) = 15.59$, $p < .001$), with 7-8 year olds (mean inattentive errors = .53) making more inattentive errors than 9-10 (mean inattentive errors = .08; $p < .001$ with Bonferroni corrections) and than 11-12 year olds (mean inattentive errors = .06; $p < .001$ with Bonferroni corrections). The 9-10 and 11-12 year olds did not differ significantly in the amount of inattentive errors made ($p = .99$ with Bonferroni corrections).

These results must be considered in terms of the significant set x distractor ($F(1, 37) = 10.92$, $p = .002$) and set x distractor x group interaction ($F(2,37) = 19.6$, $p < .001$). The two-way interaction appears to be driven by the greater number of inattentive errors made in the presence of a distractor when changing-set (mean difference between

target present and absent = 0.13 errors), which does not appear to be present when maintaining-set (mean difference between target present and absent = -0.03 errors). Figure 8 shows the data for the three-way interaction, which suggest that the locus of the interaction may be driven by the 7-8 year-olds showing a larger number of

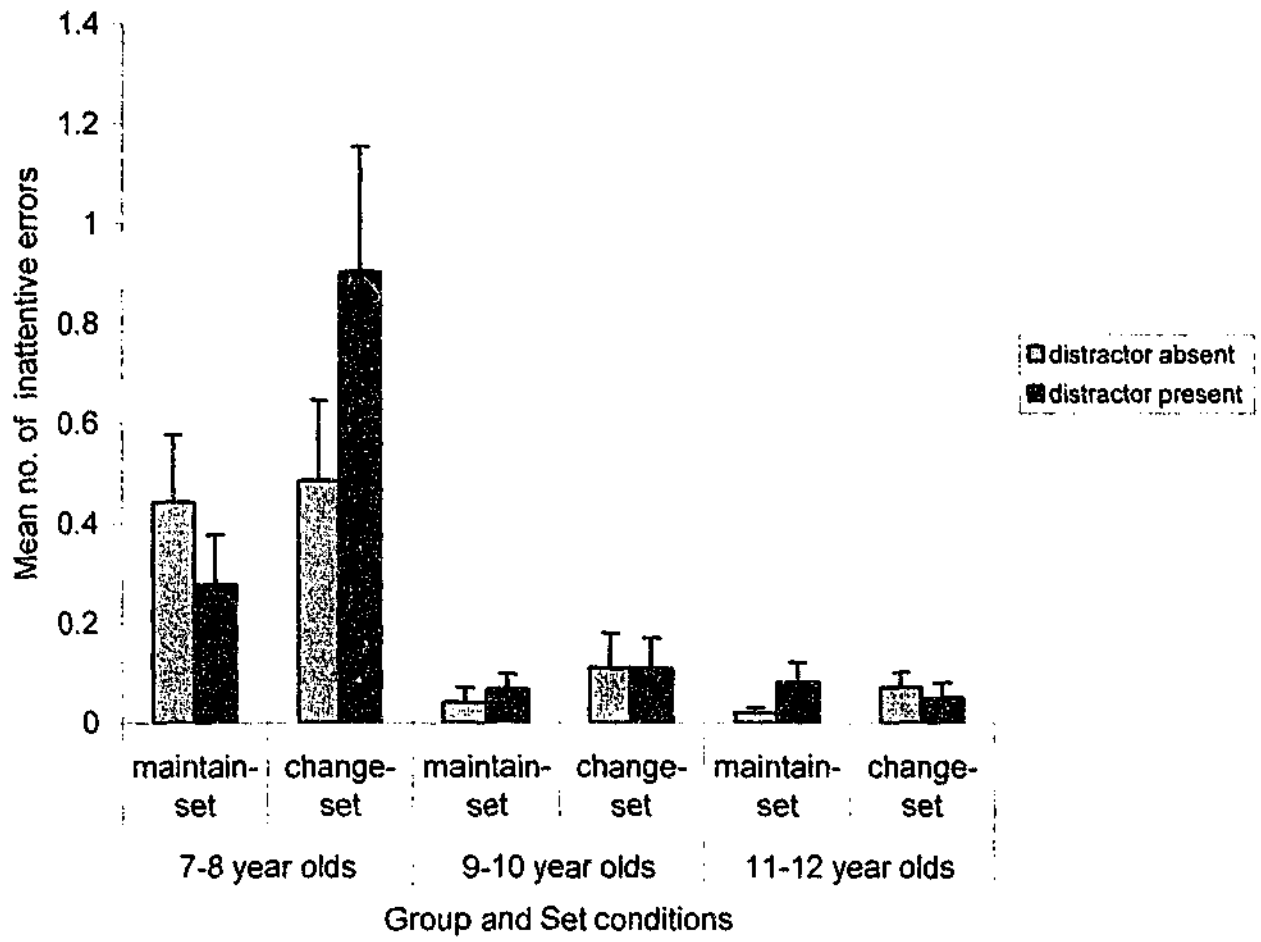


Figure 8: Mean number of inattentive errors (with standard error bars) made by the 7-8, 9-10 and 11-12 year olds in the maintain- and change-set condition in the presence and absence of a distractor.

inattentive errors made in the presence than the absence of a distractor in the change-set condition, and by the reversed pattern in the maintain-set condition. Follow up analyses, with set x distractor ANOVAs in each group, revealed a significant set x distractor interaction for the 7-8 year-old group ($F(1,11) = 19.02$, $p = .001$), which was not significant for the 9-10 year-old group ($F(1, 11) = .208$, $p = .658$), or for the 11-12 year-old group ($F(1,15) = 3.75$, $p = .072$). Analyses of simple main effects in the 7-8

year-old group revealed a significant effect of distractor in the change-set ($F(1,11) = 7.17$, $p = .021$), and in the maintain-set conditions ($F(1,11) = 6.00$, $p = .032$).

Results for the no-reach task revealed a main effect of set ($F(1,37) = 13.29$, $p = .001$), with children missing more targets in the change-set (mean number of errors = .60) than the maintain-set (mean number of errors = .22) condition, and a main effect of distractor ($F(1, 37) = 19.87$, $p < .001$) with children making more errors in the absence (mean number of errors = .58) than the presence (mean number of errors = .24) of a distractor, confirming that the apparently paradoxical main effect of distractor for the reaction time data was not a speed-accuracy trade-off. There was also a main effect of group ($F(2, 37) = 15.34$, $p < .001$), with 7-8 year olds making significantly more errors (mean number of errors = .94) than 9-10 (mean number of errors = .15; $p < .001$ with Bonferroni correction) and 11-12 year olds (mean number of errors = .12; $p < .001$ with Bonferroni correction). The 9-10 and 11-12 year olds did not differ significantly from one another ($p = 0.99$ with Bonferroni correction). These main effects must be considered in light of the significant interactions.

There were three significant two-way interactions. The significant interaction between set and group ($F(2,37) = 7.79$, $p = .002$) appears to be driven by the greater cost (increase in inattentive errors) associated with changing set for the 7-8 year olds (mean increase = 0.97 errors), compared to the 9-10 (mean increase = .06 errors) and the 11-12 year olds (mean increase = .12 errors). The significant interaction between distractor and group ($F(2, 37) = 11.72$, $p < .001$), with 7-8 year olds appears to show the greatest cost (increase in inattentive errors) in the absence of a distractor (mean increase = .9 errors), compared to the 9-10 (mean increase = .07 errors) and 11-12 year olds (mean increase = .08 errors). The third two-way interaction was between set and distractor ($F(1, 37) = 11.80$, $p < .001$), with the data indicating an increase in inattentive errors (or cost) in the absence of a distractor in the change-set condition (mean increase = .6 errors) but not in the maintain-set condition (mean increase = .05 errors). These two-way interactions must be considered in light of the significant set x distractor x group interaction ($F(2,37) = 9.81$, $p < .001$), which is depicted in Figure 9. The data indicate that while all groups showed a cost in the absence of a distractor in both change-set and maintain-set conditions, this cost is exacerbated in the 7-8 year old

group when changing-set. Follow-up, with set x distractor subanalyses for each group, indicated that the effect of set was significant in the 7-8 year old group ($F(1,11) = 8.60$, $p = .014$) but not in the 9-10 ($F(1,11) = .830$, $p = .382$) or 11-12 year old group ($F(1, 15) = 4.00$, $p = .064$). Similarly, the effect of distractor was significant for the 7-8 year old group ($F(1,11) = 13.05$, $p = .004$), but not for the 9-10 ($F(1,11) = 2.90$, $p = .117$) or 11-12 year old ($F(1, 15) = 2.74$, $p = .119$) groups. The set x distractor interaction was also only significant for the 7-8 year old ($F(1,11) = 9.11$, $p = .012$), but not the 9-10 year old ($F(1,11) = .133$, $p = .723$) or 11-12 year old ($F(1,15) = .92$, $p = .352$) groups.

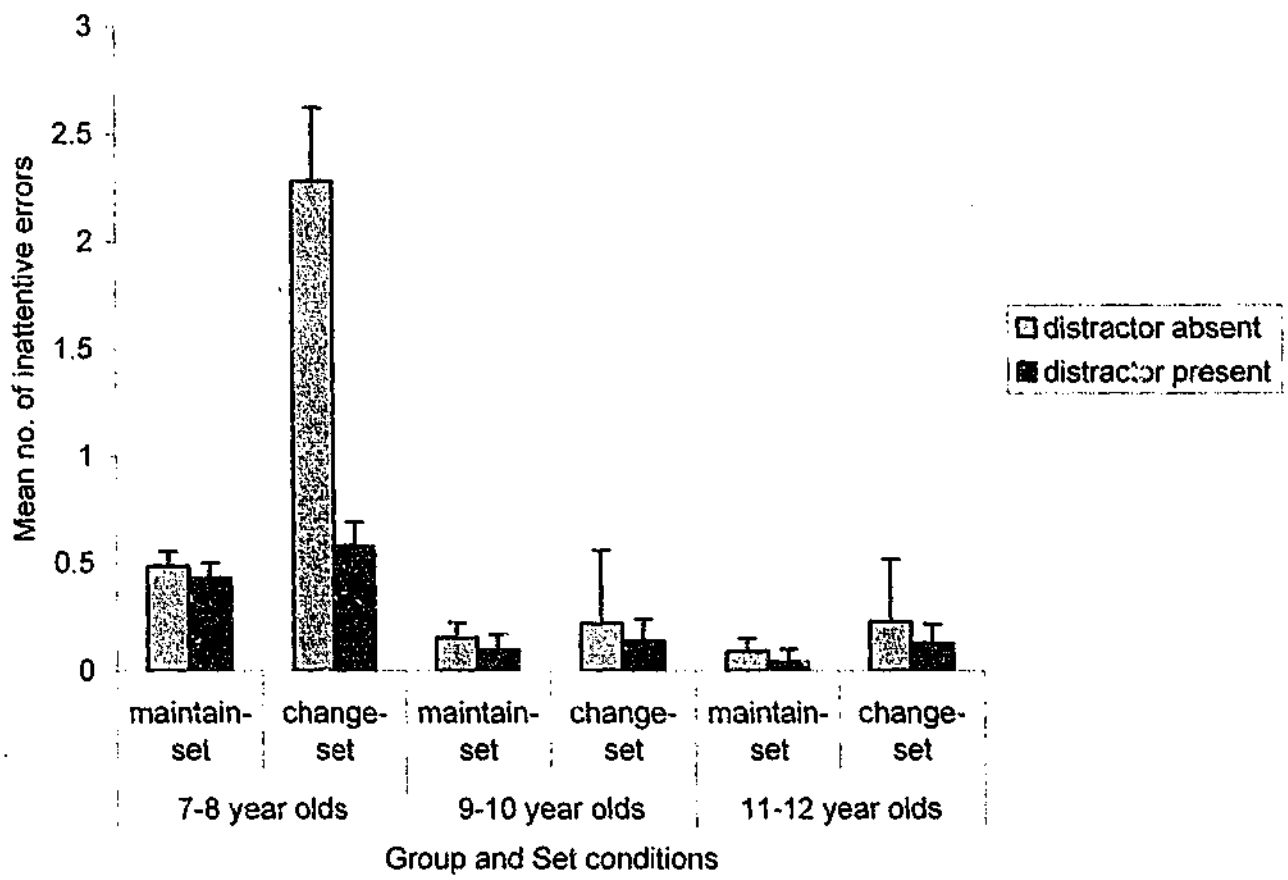


Figure 9: Mean number of inattentive errors (with standard error bars) made by 7-8, 9-10, and 11-12 year olds in the absence and presence of a distractor for the maintain-set and change-set tasks.

3.7.5.2 Impulsive errors or premature responses

Impulsive error data, or premature responses, were collapsed across start, target and distractor conditions, because these factors should have little impact on responses

made prior to stimulus presentation, and were submitted to a group (7-8, 9-10, and 11-12 year olds) x set (maintain-set, change-set) x reach (reach, no-reach) ANOVA with repeated measures on the last two factors (see Appendix H). Results revealed that impulsive errors were not affected by reach condition ($F(1,37) = .67$, $p = .418$), with children making a similar number of impulsive errors in the reach (mean number of errors = 1.41) and no-reach (mean number of errors = 1.57) tasks. There was a significant effect of set ($F(1,37) = 5.63$, $p = .023$) with children making significantly more impulsive errors in the maintain-set (mean number of errors = 1.74) than the change-set (mean number of errors = 1.25) task. There was also a significant effect of group ($F(2, 37) = 10.75$, $p < .001$), with 7-8 year-olds (mean number of errors = 3.44) making significantly more impulsive errors than 9-10 year olds (mean number of errors = 0.60; $p = .002$ with Bonferroni corrections), and than 11-12 year olds (mean number of errors = 0.44; $p < .001$ with Bonferroni corrections), who in turn did not differ significantly from one another ($p = 0.99$ with Bonferroni corrections). There were no significant interactions.

3.7.5.3 Distractibility errors

Distractibility errors, or responses to distractors, were collapsed across start position (left, centre, right) and distractor location (left, right), and analysed with a set (maintain-set, change-set) x target (absent, present) x group (7-8, 9-10, 11-12 year olds) ANOVA for the reach task, and a set (maintain-set, change-set) x group ANOVA for the no-reach task (see Appendix H).

Results in the reach task revealed a significant main effect of set ($F(1,37) = 4.25$, $p = .046$), with children making more errors in the change-set (mean number of errors = .88) than the maintain-set (mean number of errors = .60) condition. There was also a significant effect of target ($F(1, 37) = 105.31$, $p < .001$), with children making more errors in the absence of a target (mean number of errors = 1.17) than in its presence (mean number of errors = 0.30). There was also a significant effect of group ($F(2, 37) = 15.96$, $p < .001$), with 7-8 year olds making more errors (mean number of errors = 1.32) than 9-10 (mean number of errors = 0.58; $p = .001$ with Bonferroni correction) and 11-12 year olds (mean number of errors = 0.32; $p < .001$ with Bonferroni correction), who did not differ from one another ($p = .468$ with Bonferroni correction).

These results must be considered in light of the significant set x group ($F(2, 37) = 3.28$, $p = .049$) and target x group ($F(2,37) = 14.13$, $p < .001$) interactions. The set x group interaction appears to reflect the fact that 7-8 year olds show a greater cost in the change-set condition (mean cost = 0.8 errors), than the 9-10 year olds (mean cost = .04 errors) and 11-12 year olds (mean advantage = .03 errors). Follow-up with a repeated measures ANOVA for each group indicated that the only group for which the effect of set was even close to significance was the 7-8 ($F(1, 11) = 3.416$, $p = .092$) but not the 9-10 ($F(1,11) = 0.55$, $p = .819$), nor the 11-12 ($F(1, 15) = .328$, $p = .575$) year old group. The target x group interaction is depicted in Figure 10. The data indicate that the difference in error rates between the target-present and target-absent condition decreased as age increased. Repeated measures ANOVAs with the factor target revealed that the effect of target was significant for the 7-8 ($F(1, 11) = 64.89$, $p < .001$), 9-10 ($F(1,11) = 15.36$, $p = .002$) and 11-12 ($F(1, 15) = 31.12$, $p < .001$) year olds.

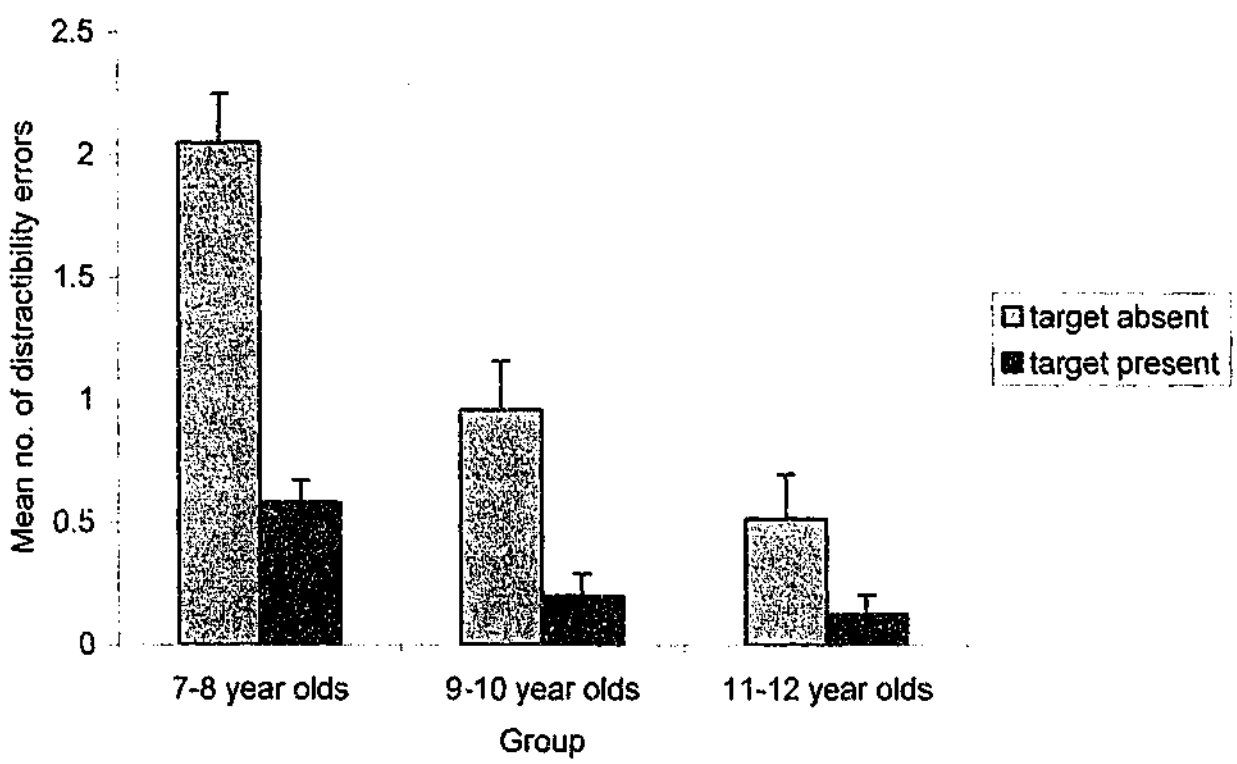


Figure 10: Mean number of distractibility errors (with standard error bars) made by 7-8, 9-10, and 11-12 year olds in the absence and presence of a target in the reach task.

Results for the no-reach task revealed that distractibility errors were affected by set condition ($F(1, 37) = 6.05$, $p = .019$), with children making more distractibility errors in the change-set (mean = 2.25) than the maintain-set condition (mean = 1.33). There was also a significant main effect of group ($F(2, 37) = 10.76$, $p < .001$), with 7-8 year olds making significantly more errors (mean number of errors = 3.33) than 9-10 (mean number of errors = 1.13; $p = .002$ with Bonferroni correction) and 11-12 year olds (mean number of errors = .91; $p < .001$ with Bonferroni correction). The 9-10 and 11-12 year olds did not differ significantly in the amount of distractibility errors made ($p = 0.99$ with Bonferroni corrections). There was also a significant set x group interaction ($F(2, 37) = 11.18$, $p < .001$), which is depicted in Figure 11. Data in Figure 11 indicate that the 7-8 year olds made more errors when changing-set, and that this cost is not evident in the other two groups of children. Follow-up with repeated measures ANOVAs with the factor of set, for each of the three groups, revealed that the effect of set was only significant for the 7-8 ($F(1, 11) = 10.15$, $p = .009$), but not for the 9-10 ($F(1, 11) = 2.81$, $p = .122$) or 11-12 ($F(1, 15) = 0.61$, $p = .808$) year olds.

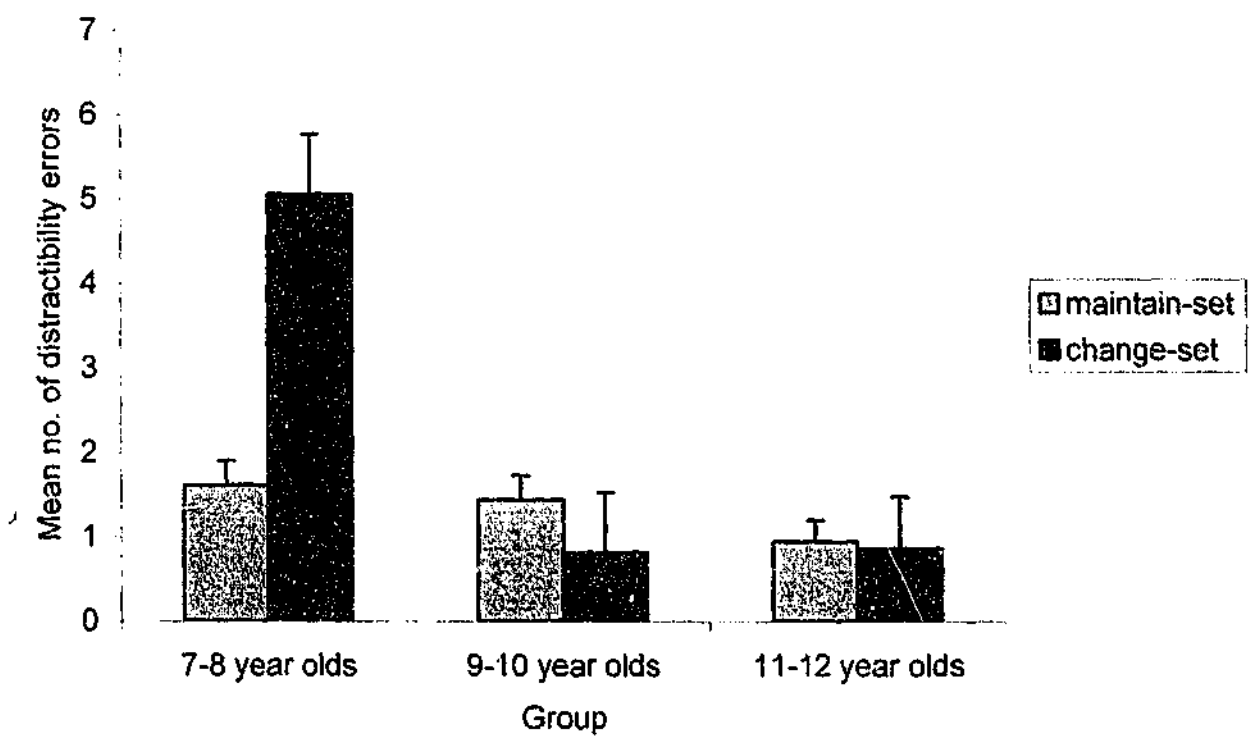


Figure 11: Mean number of distractibility errors (with standard error bars) made by 7-8, 9-10 and 11-12 year olds for maintain and change-set conditions in the no-reach task.

3.7.5.4 Proportional errors

The inattentive, impulsive and distractibility errors were converted to proportions of the total errors made by each participant, and then subjected to a group (7-8, 9-10, 11-12 year old) x set (maintain-set, change-set) x reach (reach, no-reach) x error type (inattentive, impulsive, distractibility) ANOVA (see Appendix H). Results revealed that there was no significant effect of set ($F(1, 37) = 1.72$, $p = .198$), with children performing similarly in the maintain-set (mean proportional errors = .33) and change-set (mean proportional errors = .32) conditions. There was a significant effect of reach ($F(1, 37) = 10.58$, $p = .002$), which indicates that children made errors *other* than those classified as impulsive, inattentive and distractibility errors in the reach condition, that, due to design, they were not able to make in the no-reach condition[7]. There was also a significant reach x error type interaction ($F(1.5, 56.14) = 3.76$, $p = .041$), which will not be discussed further, because it indicates which error type proportions were reduced more greatly as a result of the "other" errors.

There was a significant effect of error type ($F(2, 73.5) = 251.05$, $p < .001$), with children making a higher proportion of distractibility errors (69%) than impulsive errors (9%; $p < .001$ with Bonferroni correction) and than inattentive errors (19%; $p < .001$ with Bonferroni correction). The difference between the proportion of inattentive and impulsive errors was also significant ($p = .001$). Although there was no significant main effect of group ($F(2, 37) = .578$, $p = .556$), there was a significant error type x group interaction ($F(4, 73.5) = 6.12$, $p < .001$), which is depicted in Figure 12. Figure 12 indicates that while 9-10 year olds appear to perform like 11-12 year-olds, the 7-8 year olds appear to make a larger proportion of inattentive and impulsive errors, and a lower proportion of distractibility errors than the other two groups. Follow-up with separate one-way ANOVAs with the factor group, showed a significant effect of group for distractibility errors ($F(2,37) = 8.266$, $p = .001$), with 7-8 year olds making a significantly lower proportion of distractibility errors than both 9-10 year olds ($p = .005$ with Bonferroni correction) and 11-12 year olds ($p = .002$ with Bonferroni correction). The 9-10 and 11-12 year olds did not differ significantly ($p = 0.99$ with

[7] In the reach condition "other" errors constituted a correct release of the start-key to targets, coupled with an incorrect button-press. This type of error could not be made in the no-reach condition where there was no button-press component.

Bonferroni correction). The effect of group on the proportion of impulsive errors was not significant ($F(2, 37) = 2.47$, $p = .099$), whilst the effect of group on the proportion of inattentive errors was significant ($F(2, 37) = 5.41$, $p = .009$). The 7-8 year olds made a significantly higher proportion of inattentive errors than both the 9-10 year olds ($p = .023$ with Bonferroni corrections), and the 11-12 year olds ($p = .017$ with Bonferroni corrections). The 9-10 year olds and 11-12 year olds did not differ significantly from one another ($p = 0.99$ with Bonferroni corrections).

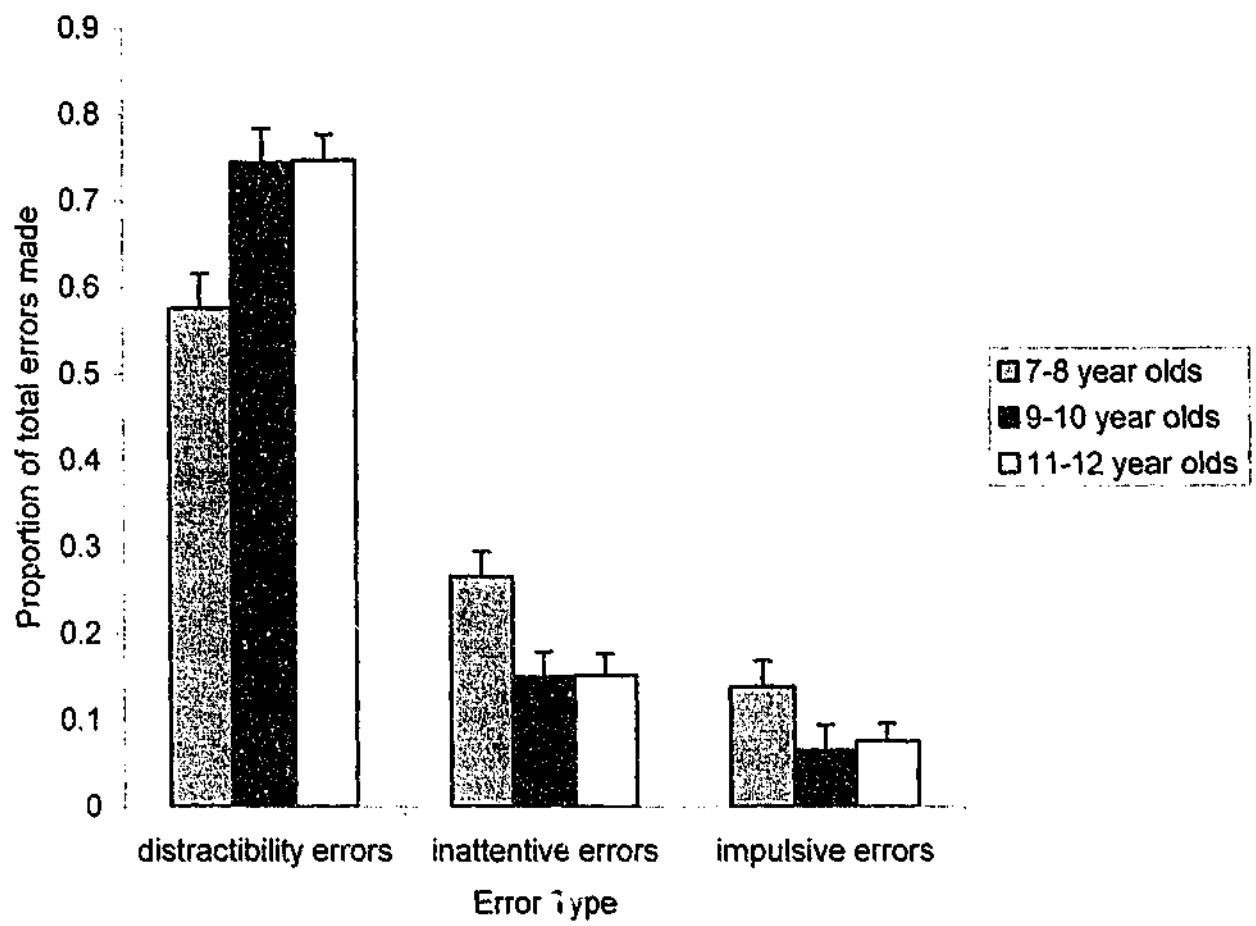


Figure 12: Proportion of distractibility, inattentive and impulsive errors made (with standard error bars) by 7-8, 9-10, and 11-12 year olds.

There was also a significant interaction between error type and set ($F(1.5, 55.4) = 5.96$, $p = .009$). Figure 13 shows the proportion of distractibility, inattentive and impulsive errors made in the maintain-set and change-set conditions. The data in Figure 13 indicate that children made a higher proportion of errors in the change-set than the

maintain-set condition for the inattentive type errors, and showed the reverse pattern of results (i.e., a higher proportion of errors in the maintain-set than the change-set condition) for the proportion of impulsive and distractibility errors. Follow-up with repeated measures ANOVAs with the factor set for each error type revealed that the ffect of set was significant for the proportion of inattentive ($F(1,39) = 10.25$, $p = .003$) and impulsive ($F(1, 39) = 11.52$, $p = .002$), but not distractibility ($F(1, 39) = 1.80$, $p = .188$) errors.

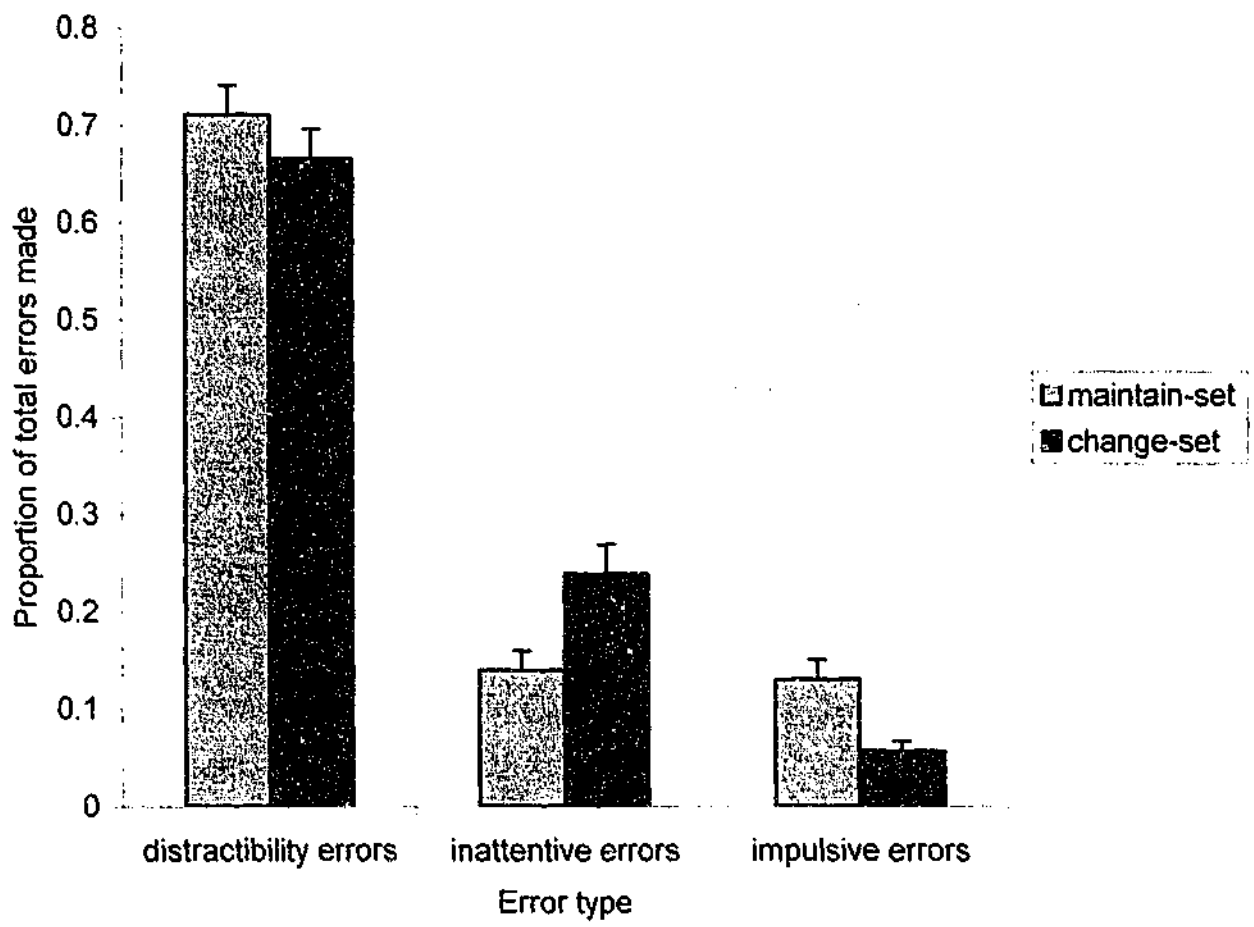


Figure 13: Proportion of distractibility, inattentive and impulsive errors (with standard error bars) made in maintain-set and change-set conditions.

3.7.6 Correlations

Correlational analysis (using Pearson's correlation coefficient) was undertaken between participant variables of age, Full Scale IQ, ADDES – home version percentile rank, ADDES – home version inattentive ratings, ADDES – home version hyperactive impulsive ratings, ADDES – school version percentile rank, ADDES – school version

inattentive ratings, ADDES – school version hyperactive-impulsive ratings, ADDES home impulsivity score (the sum of the raw scores for all questions on the rating scale pertaining to impulsivity), and ADDES school impulsivity score (again the sum of raw scores for all questions pertaining to impulsivity) and experimental variables of overall reach reaction-time, overall no-reach reaction time, overall reach movement-time, and overall inattentive, distractibility and impulsive errors.

Age was correlated negatively with reaction time in the reach task ($r = -.68$, $p < .001$), reaction time in the no-reach task ($r = -.62$, $p < .001$), movement time in the reach task ($r = -.33$, $p = .038$), inattentive errors ($r = -.63$, $p < .001$), distractibility errors ($r = -.63$, $p < .001$) and impulsivity errors ($r = -.61$, $p < .001$). Thus, children become faster in reaction time and movement time, and make less errors with increasing age. IQ did not correlate with any factors. The experimental variables of reaction time (in reach and no-reach tasks), movement time, inattentive errors, impulsive errors, and distractibility errors, were all positively correlated with one another (see Appendix H). There were no significant correlations between any of the school or home ratings on the ADDES and reaction times, movement times, inattentive errors, and distractibility errors. Impulsive errors on the other hand correlated negatively with ADDES school version percentile rank ($r = -.431$, $p = .016$), negatively with the ADDES school version hyperactivity-impulsivity scale ($r = -.463$, $p = .009$), and positively with the ADDES school impulsivity score ($r = .380$, $p = .035$). (Remember that more severe symptoms are associated with lower scores on the hyperactivity-impulsivity scaled score, inattentiveness scaled score and percentile rank; and higher scores on the impulsivity raw score.)

3.8 Discussion for Experiment 3

3.8.1 Effect of age on reaction times and movement times

Consistent with expectations, the results indicated that 7-8 year olds showed slower reaction times in both the reach and the no-reach task than the 9-10 and 11-12 year olds, who did not differ significantly. This finding is consistent with previous developmental studies, which have shown that younger children show slower reaction times than older children on simple and complex cognitive tasks (Keating & Bobbitt,

1978; Kail, 1988; Hale, 1990; Schachar & Logan, 1990). The results also indicated that 7-8 year olds did *not* show slower movement execution times than 9-10 and 11-12 year olds. This result suggests that whilst *motor planning* improves with age, and plateaus after ages 9-10, *motor execution* is well established by age 7, and does not improve substantially with age.

3.8.2 Effect of age on errors made

Results indicated that 7-8 year olds made significantly more inattentive and distractibility errors than the 9-10 and 11-12 year olds in both the reach and the no-reach tasks, while the number of these errors between 9-10 and 11-12 year olds did not differ significantly. The 7-8 year olds also made significantly more overall impulsive errors or premature responses than the 9-10 and 11-12 year olds, and again the number of these errors between 9-10 and 11-12 year olds did not differ significantly. This suggests that any improvement in inattentive, impulsive and distractibility errors, as a function of age, plateaus after the ages 9-10. The finding that improvement in children's ability to inhibit their responses to distractors plateaus after the ages 9-10 is consistent with that of Becker et al. (1987), who found that the ability to inhibit responding on a go/ no-go task did not improve significantly between ages 10 and 12 years.

Results for the reach task revealed that although all groups of children appeared to make more distractibility errors when distractors were presented in isolation than when distractors were presented in conjunction with targets, the magnitude of this cost decreased with age. This pattern of results suggests that inhibiting responses is more difficult for all children than ignoring distracting stimuli that are presented with targets, and that the magnitude of this difficulty decreases with age.

While the younger group made more of every type of error than the older groups, we are left with the question as to whether they show the same *pattern* of errors. Thus the type of errors made were examined as a proportion of the total errors made. Results indicated that the greatest proportion of errors made by all three groups were distractibility errors, and that all three groups made a greater proportion of inattentive than impulsive errors. The 7-8 year olds, however, made a significantly lower

proportion of distractibility errors than the 9-10 and 11-12 year olds. Instead the 7-8 year olds made a greater proportion of inattentive errors than the 9-10 and 11-12 year olds. Thus it appears that susceptibility to distractors is quite stable across this period of development, and that the ability to maintain vigilance improves by ages 9-10 years. The results also suggest, that ADHD children are not simply performing like younger children; that is, they do not appear to be developmentally delayed, because their pattern of errors did not resemble the pattern of errors for younger children.

3.8.3 Response inhibition/ distractibility

The above section discussed problems with ignoring distracting or irrelevant stimuli, and the ability to withhold a response, in terms of the errors made in response to distractors. The following section discusses the effects of the addition of a distractor on reaction and movement times, as well as on the number of inattentive errors made.

Distractors slowed all children's reaction times in the reach task. Results also indicated that while the presence of a distractor slowed movement times for all groups of children, the size of this cost decreased with age. The cost in movement time associated with the presence of a distractor was also greater with the additional demands of changing-set (compared with the maintain-set condition).

Due to the nature of the response in the no-reach task, the presence of a distractor did not have the desired effect of distracting participants and thereby slowing reaction times. Rather, children were slower in reaction time in the *absence* of a distractor when changing-set, and this effect appeared to be greater in magnitude for the 7-8 year-old children than for the other two groups. This result was also observed for ADHD children and their controls. Thus, the distractor appears to have acted as cue to respond, probably because a response was always required when two LEDs illuminated (in the distractor present condition), but was not always required when one LED illuminated.

The 7-8 year olds not only exhibited longer reaction times, but also an additional increase in inattentive errors made during the presence of a distractor, when required to change-set. The demands of set-changing thus appear to have resulted in the 7-8 year

olds reaching towards distractors, thereby missing targets. In addition, they showed an increase in inattentive errors in the absence of a distractor when required to maintain-set in the reach-task, and an increase in inattentive errors in the absence of a distractor when required to change-set in the no-reach task. This pattern of results in the no-reach task when changing set was also evident in the results of unmedicated ADHD, medicated ADHD and their controls in Experiments 1 and 2. Missing more targets in the absence of distractors is further evidence that the distractor may have at times acted as a cue rather than a distractor.

3.8.4 Set-shifting

Whilst children displayed slower *movement* times in the change-set than the maintain-set condition, *reaction* times in the reach and the no-reach task were not affected by set-shifting. Effects of set-shifting were also observed in the error data. Results revealed that there was a trend for children to miss more targets (i.e., make more inattentive errors) in the reach task when changing-set than when maintaining-set. In the no-reach task 7-8 year olds made more inattentive errors when changing-set, than when maintaining-set. Set also had an effect on impulsive errors, with children making more impulsive errors when maintaining-set, than when changing-set. This suggests that children are more careful and/ or less impulsive when the task is made more difficult by adding the demands of set-changing.

The 7-8 year old children also made more distractibility errors in the change-set than the maintain-set condition, for both reach and no-reach tasks. The factor of changing-set also had an effect on the types of errors made as a proportion of the total number of errors, with children showing a higher proportion of inattentive type errors when changing-set, and a higher proportion of impulsive errors when maintaining-set. This pattern of results suggests that children miss more targets due to the increase in task difficulty when changing-set, whilst also becoming more careful and/ or less impulsive, perhaps due to their perception of the level of difficulty of the task.

The expectation that younger children would be more impaired by the set-changing task than older children, as has been observed on other set-shifting tasks in the literature (e.g., Van der Meere et al., 1996), was thus partially supported by the

findings. It appears that although all children's movement times and error data were affected by set-changing, 7-8 year old children showed impairments that were not evident in the older children. Namely, they showed greater inattentive errors in the no-reach task and greater distractibility errors in both reach and no-reach tasks with the additional demands of changing-set.

3.8.5 Correlations

Correlational analyses suggested that children become faster in reaction time (reach and no-reach) and movement time, and make less inattentive errors, distractibility errors and impulsivity errors with age. Reaction time (reach and no-reach), movement time, inattentive errors, impulsive errors, and distractibility errors correlated positively, suggesting that if children perform poorly then they are both slow and error prone. Thus there does not appear to be a speed/ accuracy trade-off.

There was no significant relationship between most performance measures (i.e., reaction time in either reach or no-reach tasks, movement time, inattentive errors, and distractibility errors) and behavioural measures of hyperactivity-impulsivity, impulsivity (raw scores) and inattentiveness as measured by the home and school versions of the ADDES. This suggests that behavioural and cognitive measures of *inattentiveness* are measuring different concepts. A study by Gerbing et al. (1987) also showed that impulsivity measured by rating scales also correlated poorly with impulsivity measured by cognitive tasks, such as the matching familiar figures test. One possibility, for example, is that behavioural measures reflect *trait* and cognitive measures reflect *state* characteristics.

Impulsivity errors however, correlated negatively with overall percentile rank on the school version of the ADDES, and with scaled scores on the school version hyperactivity-impulsivity scale. Impulsive errors also showed a positive correlation with the raw score of impulsive errors from the school version of the ADDES. Lower scores on percentile rank and on scaled scores indicate greater behavioural ratings of difficulty, and higher scores for the raw scores of impulsivity ratings indicate higher behavioural impulsivity. These results therefore suggest that cognitive impulsivity is positively correlated with teacher ratings of behavioural impulsivity, hyperactivity-

impulsivity, and overall percentile rankings (which consist of scores derived from both hyperactive-impulsive and inattentive type of behaviours).

3.9 Experiment 4: Single subject design: Effects of stimulant medication on reaction time, movement time and errors in the change-set task: an on-off-off-on design

Whilst Experiments 1 and 2 indicated that medicated children do not show the deficits displayed by unmedicated children on the experimental task, the effects of medication were not studied systematically. The aim of this study was to further investigate the direct effects of stimulant medication on the reaction times, movement times and errors made by a child with ADHD, combined type.

3.9.1 Participant

MST is a right-handed boy aged 8 years and 0 months at the time of testing, who has a diagnosis of ADHD combined type without any comorbid diagnoses. He is of average intelligence, with a Full Scale IQ of 103 (as measured by the Kaufman Brief Intelligence Test; Kaufman & Kaufman, 1990), and takes 5 mg of methylphenidate three times a day (8 am, 11 am, 2 pm). He was first diagnosed with ADHD at the Royal Children's Hospital when he was 7 years of age. His home version ADDES rating scale indicated a scaled score of 4 for inattentiveness and a scaled score of 2 for hyperactivity-impulsivity, which places him at the 4th percentile overall. His school version ADDES rating scale indicated a scaled score of 10 for inattentiveness and a scaled score of 6 for hyperactivity-impulsivity, placing him at the 29th percentile overall. MST agreed to participate in this study using the change-set task from Experiments 1, 2 and 3. MST was tested on four occasions: on medication, off medication, off medication, and on medication. When MST was tested off medication, his last dose of methylphenidate was administered at 2 pm the day prior to the day of testing; when he was tested on medication, he was tested within one hour of having taken his normal dose.

3.9.2 *Apparatus and Method*

The task used was identical to the reach and no-reach set-changing tasks used in Experiments 1-3. The orders of presentation of reach and no-reach conditions and the three start positions were counterbalanced across the four sessions. Trial numbers in each block were however reduced from the original 10 to 6 for each of the six conditions (left-target-only, right-target-only, left-target-right-distractor, right-target-left distractor, left-distractor-only, right-distractor-only), resulting in a total of 36 trials per block. Trials were reduced as the task was administered on four different occasions, and prior experience with the administration of this task in children with ADHD revealed that these children often became less compliant over time (usually in the second session), claiming that the task was 'boring'. Like the children participating in the change-set task in experiments 1-3, MST was instructed to respond to green targets and to ignore any red distractors when the fixation LED was illuminated green, and the reverse, when the fixation LED was illuminated red.

3.9.3 *Results*

Data for the two sessions on-medication were combined, as were the two sessions off-medication. The reaction and movement times obtained on and off medication were subjected to paired t-tests (see Appendix I). Results indicate that MST showed significantly faster reaction times in the no-reach task when on medication (mean = 479 ms) than when off medication (mean = 741 ms; $t(143) = -8.85$, $p < .001$). Similarly, he also showed significantly faster reaction times in the reach task when on medication (mean = 502 ms) than when off medication (mean = 614 ms; $t(11) = -5.68$, $p < .001$). MST's movement times, however, did not differ significantly when he was on (mean = 293 ms) and off (mean = 307 ms) medication ($t(143) = -0.81$, $p = .418$).

Figure 14 shows the total number of inattentive, distractibility and impulsive errors made by MST in the change-set task, on and off medication. As can be seen from Figure 14, medication reduced the number of inattentive, distractibility and impulsive errors made by MST. The error type that seems to be most corrected by medication is the inattentive error type, or misses. When the number of inattentive, distractibility and impulsive errors are converted to proportions of total errors, as can be seen in Figure 15, the majority of MST's errors are distractibility, on and off medication.

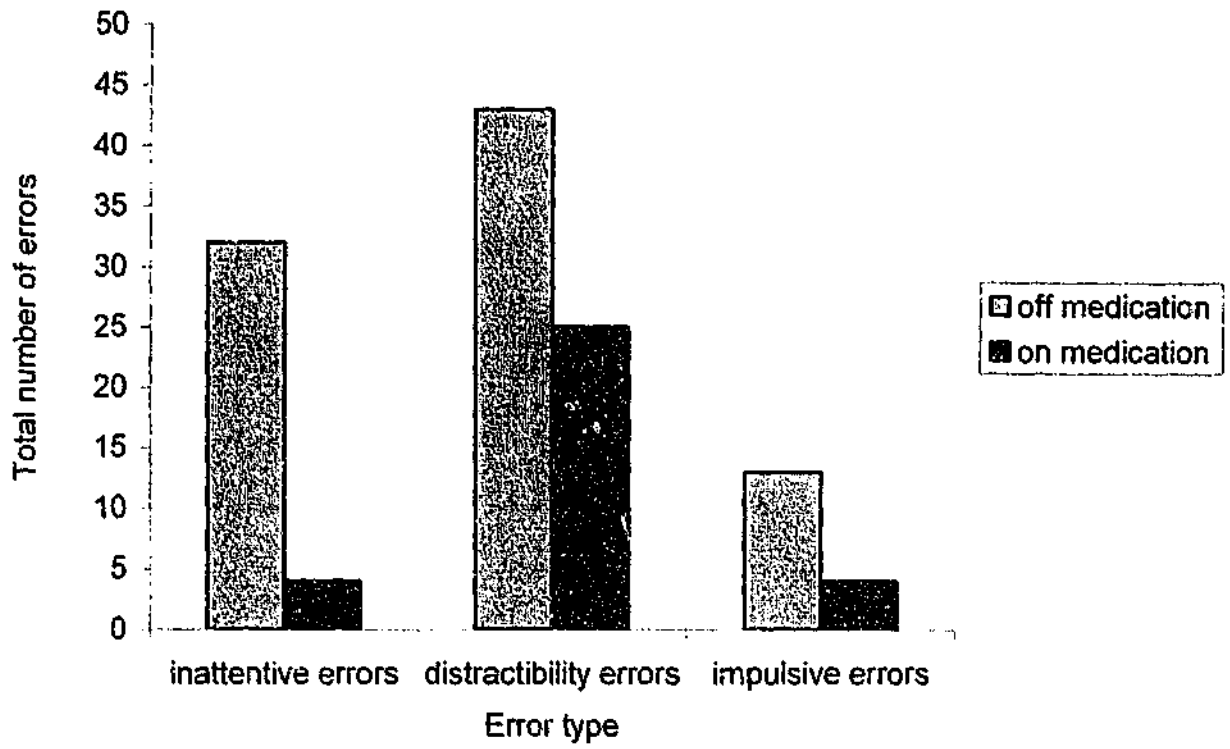


Figure 14: The total number of inattentive, distractibility, and impulsive errors made by MST on and off medication

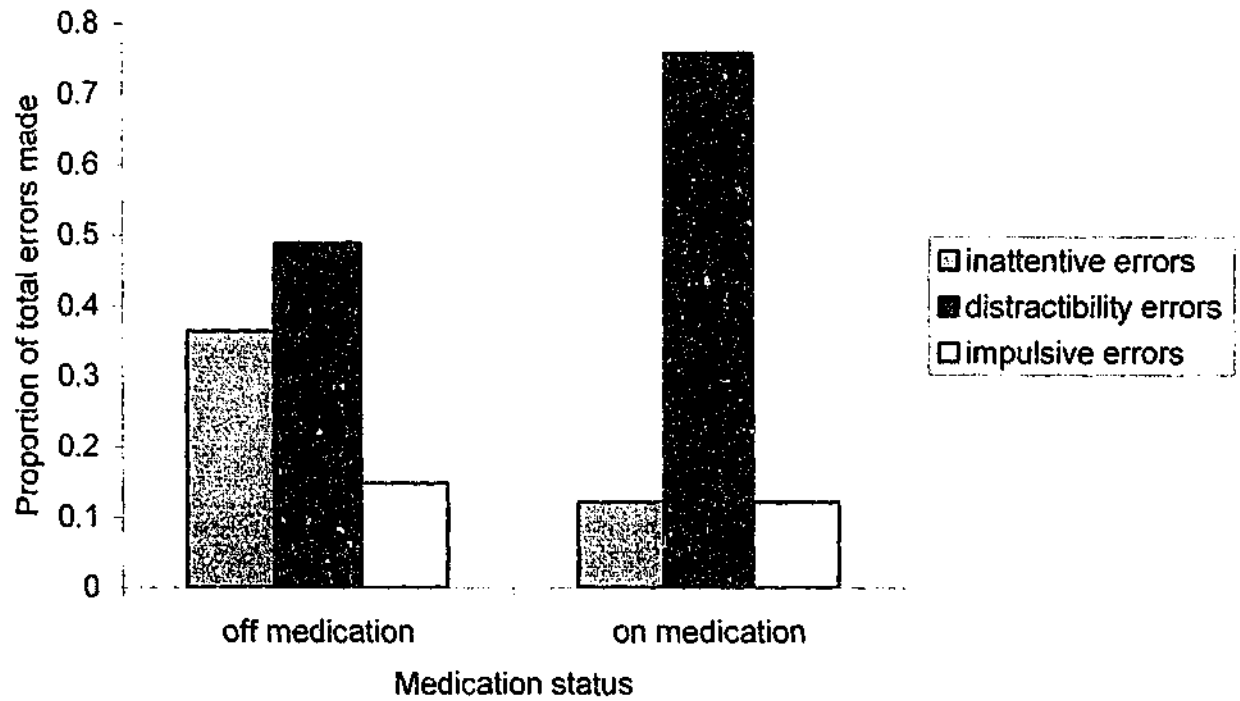


Figure 15: Inattentive, distractibility, and impulsive errors as a proportion of total errors made by MST, on and off medication

When off medication, however, MST made a smaller proportion of distractibility errors than when on medication, and instead, he made a greater proportion of inattentive errors off medication than on medication. Interestingly, MST's pattern of errors *off medication* resembles the pattern of errors made by 7-8 year normal children in Experiment 3, whilst his pattern *on medication* resembles the pattern of errors made by the older (9-12 year-old children) normal children.

3.9.4 Discussion

MST's results indicate that medication improves reaction time in both reach and no-reach tasks, but not movement time. The lack of improvement in MST's movement time may be explained by the finding in Experiment 1 that unmedicated ADHD children do not actually show any impairment in movement time compared to normals.

Medication was also shown to improve the number of distractibility, impulsive, and (especially) inattentive errors. Whilst *off* medication, MST showed a similar *pattern* of errors to the pattern of errors made by 7-8 year old normal children in Experiment 3. This *pattern* appeared to change to more closely resemble the pattern shown by older (9-12 year old) normal children in Experiment 3, when *on* stimulant medication. It therefore appears that medication does not just improve overall error rates, but alters the pattern of performance to resemble more closely that of an older child.

3.10 Experiment 5: Case study of two children diagnosed with the inattentive type of ADHD

Whilst Experiments 1 and 2 investigated the performance of children with ADHD combined type, this case study examined at the performance of two children diagnosed with ADHD inattentive type on the same task. The aim was to determine whether further study in this subgroup of ADHD would be of interest.

3.10.1 Participants

SC is a right-handed boy aged 14 years and 10 months at the time of testing, with a diagnosis of ADHD inattentive type and a comorbid diagnosis of learning disorder. He

was diagnosed by experienced clinicians, through a private paediatric outpatient unit (Cedar Court) in accordance with DSM-IV criteria. He is of average intelligence, with a full scale IQ of 106 (as measured by the Kaufman Brief Intelligence Test), and takes dexamphetamine daily. His home version ADDES rating scale indicated a scaled score of 3 for inattentiveness and a scaled score of 8 for hyperactivity-impulsivity, which places him at the 11th percentile overall. His school version ADDES rating scale indicated a scaled score of 8 for inattentiveness and a scaled score of 11 for hyperactivity-impulsivity, placing him at the 45th percentile overall. SC took no medication from the day prior to testing.

SC was matched with a right-handed control boy then aged 14 years, 9 months, who had a Full Scale IQ of 110. His Home Version ADDES rating scale indicated a score of 12 for inattentiveness, and 13 for hyperactivity-impulsivity, which places him in the 95th percentile overall. His School Version ADDES rating scale indicated a scaled score of 13 for inattentiveness, and a scaled score of 12 for hyperactivity-impulsivity, placing him at the 81st percentile overall.

CRS is a right-handed boy aged 11 years and 2 months at the time of testing who has also has a diagnosis of ADHD Inattentive type, but has no comorbid diagnoses. He was diagnosed by experienced clinicians through a public paediatric outpatient unit (Southern Health), in accordance with DSM-IV criteria. He is of high average intelligence, with a Full Scale IQ of 113 (as measured by the KBIT), and takes methylphenidate on a daily basis. CRS received his last dose of medication a day prior to testing. His home version ADDES rating scale indicated a scaled score of 3 for both inattentiveness and hyperactivity-impulsivity, placing him overall at the 1st percentile for his age. His school version ADDES rating scale indicated a scaled score of 6 for inattentiveness and 5 for hyperactivity-impulsivity, placing him at an overall 11th percentile. His ADDES profile is inconsistent with an inattentive type profile, despite his diagnosis, so results must be interpreted with caution. It is also possible, that his symptoms have changed since initial diagnosis.

CRS was matched with a right-handed control boy, aged 10 years 0 months, who was also above average intelligence with a Full Scale IQ of 112. Whilst CRS's matched

control is a year younger this should not pose any problems in the interpretation of results, because Experiment 3 indicates that whilst task performance (that is reaction time and the numbers of errors made) improves with age, it plateaus after age 9-10 years. The home version ADDES rating scale indicated a scaled score of 9 for inattentiveness, and a scaled score of 12 for hyperactivity-impulsivity, placing CRS at the 55th percentile overall. His school version ADDES rating scale indicated a scaled score of 11 for both inattentiveness and hyperactivity-impulsivity ratings, placing him at the 55th percentile overall.

3.10.2 Apparatus and Method

The apparatus and method were both identical to those in Experiments 1-3.

3.10.3 Results

Overall means for reaction time in the reach task, movement time in the reach task, and reaction time in the no-reach task were calculated for SC and his matched control, and CRS and his matched control. (Thus data were collapsed across set, start, target and distractor condition.) Figure 16 shows the reaction times and movement times for SC and his matched-control, whilst Figure 17 shows the reaction times and movement times for CRS and his matched-control. SC appeared to be slower in reaction time (reach and no-reach tasks) and movement time, compared to the matched-control. This was also true for CRS and his control, but the differences appeared rather less marked. Figure 18 shows the total number of inattentive (misses), distractibility (incorrect responses to distractor stimuli) and impulsive errors (premature responses) made by SC and his matched-control, whilst Figure 19 shows this for CRS and his matched control. As can be seen from Figure 18, neither SC nor his matched control showed any impulsive errors, due perhaps to their greater age and maturity than that of the other pair. SC did however make some inattentive errors, whilst the control child did not, and made substantially more distractibility errors than the control child. CRS made a small number of inattentive and impulsivity errors, and showed a large number of distractibility errors. His matched-control did not make any impulsive errors, a small number of inattentive errors, and some distractibility errors. Further, when the composition of distractibility errors made in the reach task was examined, both SC and CRS made a higher proportion (78% and 88% respectively) of response inhibition

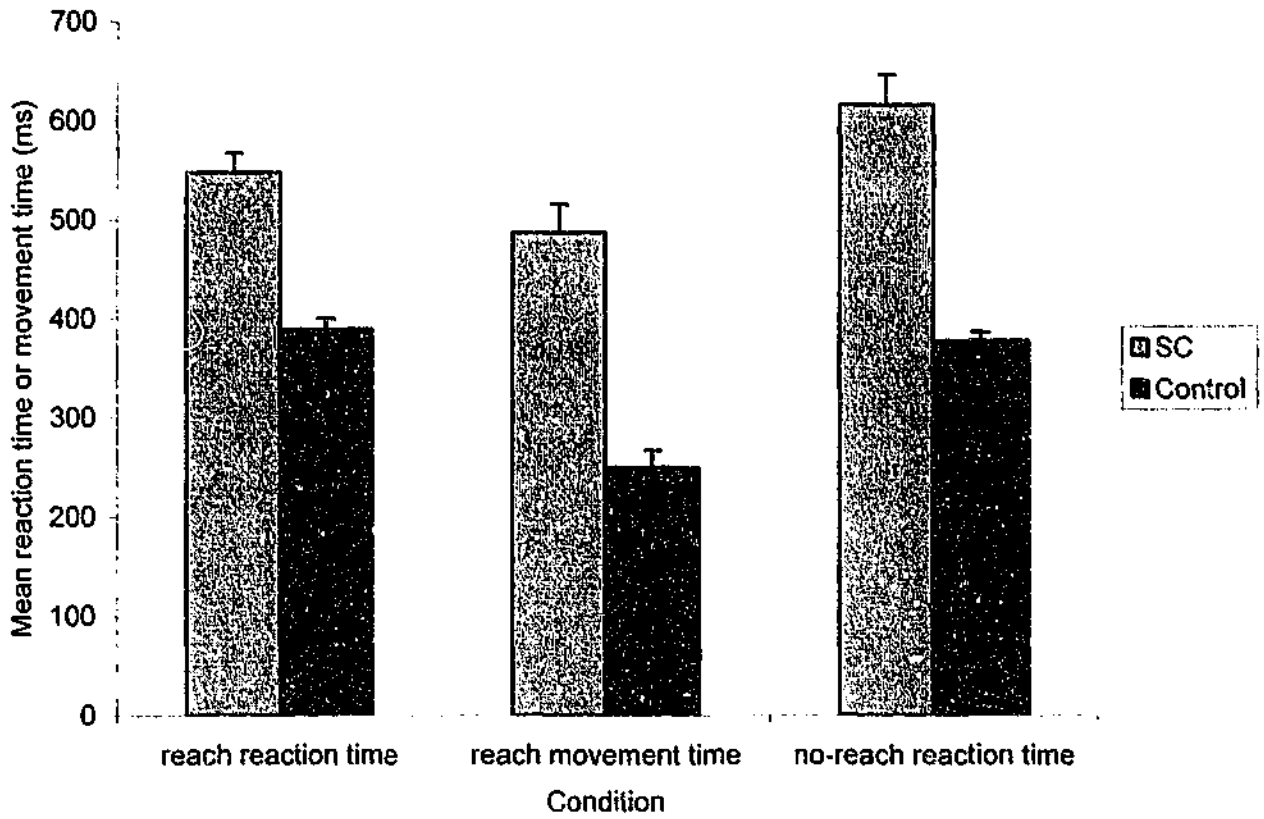


Figure 16: Mean overall reaction times and movement times in the reach and no-reach conditions for SC and his matched control. Standard error bars are shown.

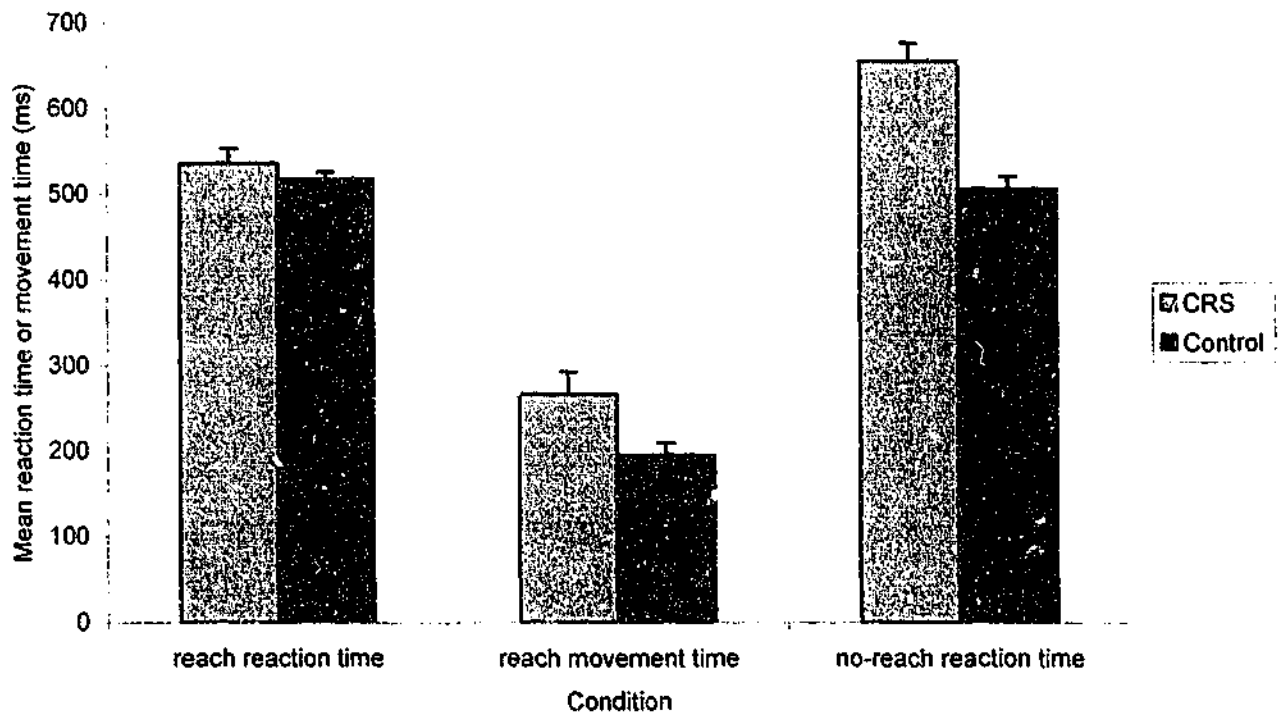


Figure 17: Mean overall reaction times and movement times in the reach and no-reach conditions for CRS and his matched control. Standard error bars are shown.

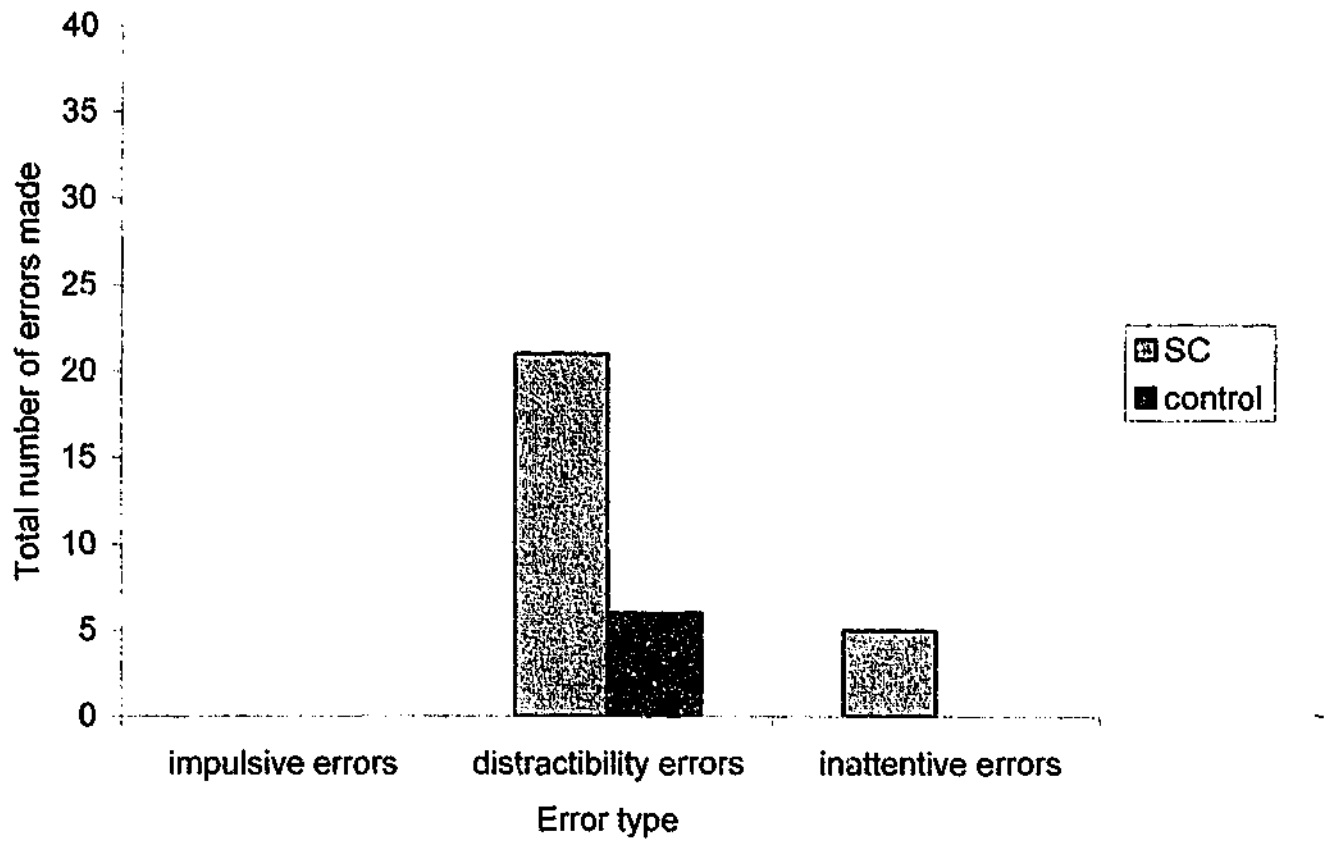


Figure 18: Total number of impulsive, distractibility and inattentive errors made by SC and his matched-control.

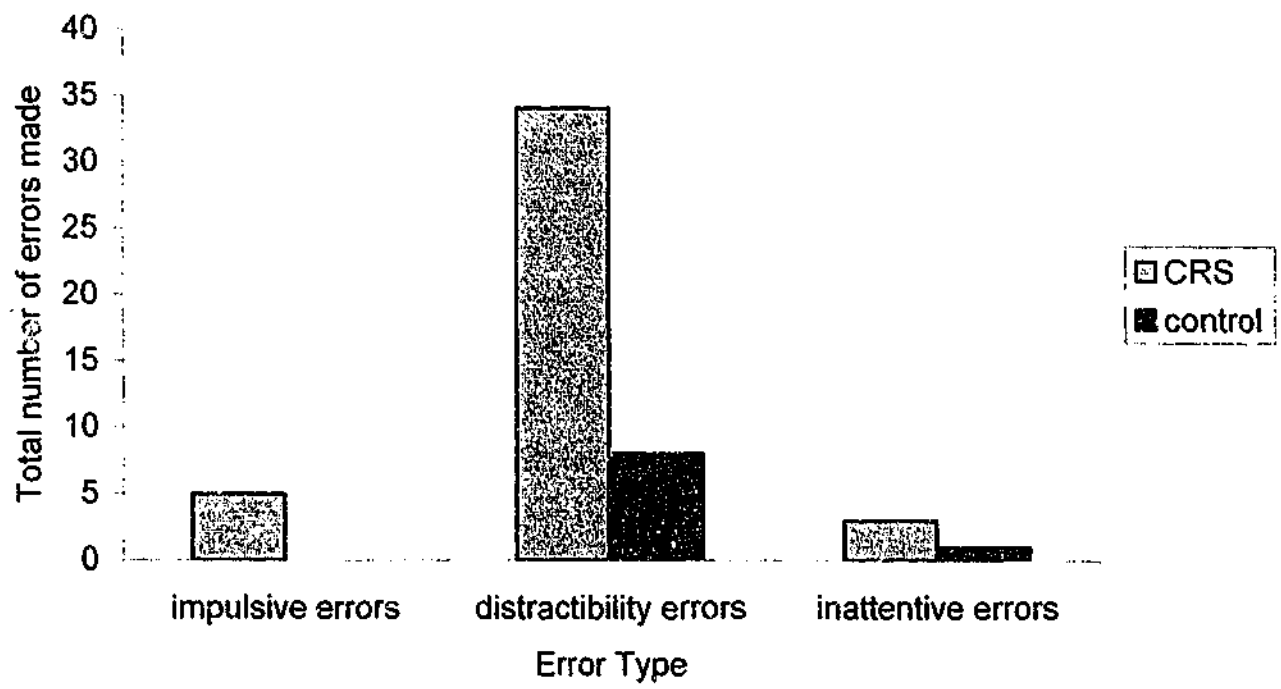


Figure 19: Total number of impulsive, distractibility and inattentive errors made by CRS and his matched-control.

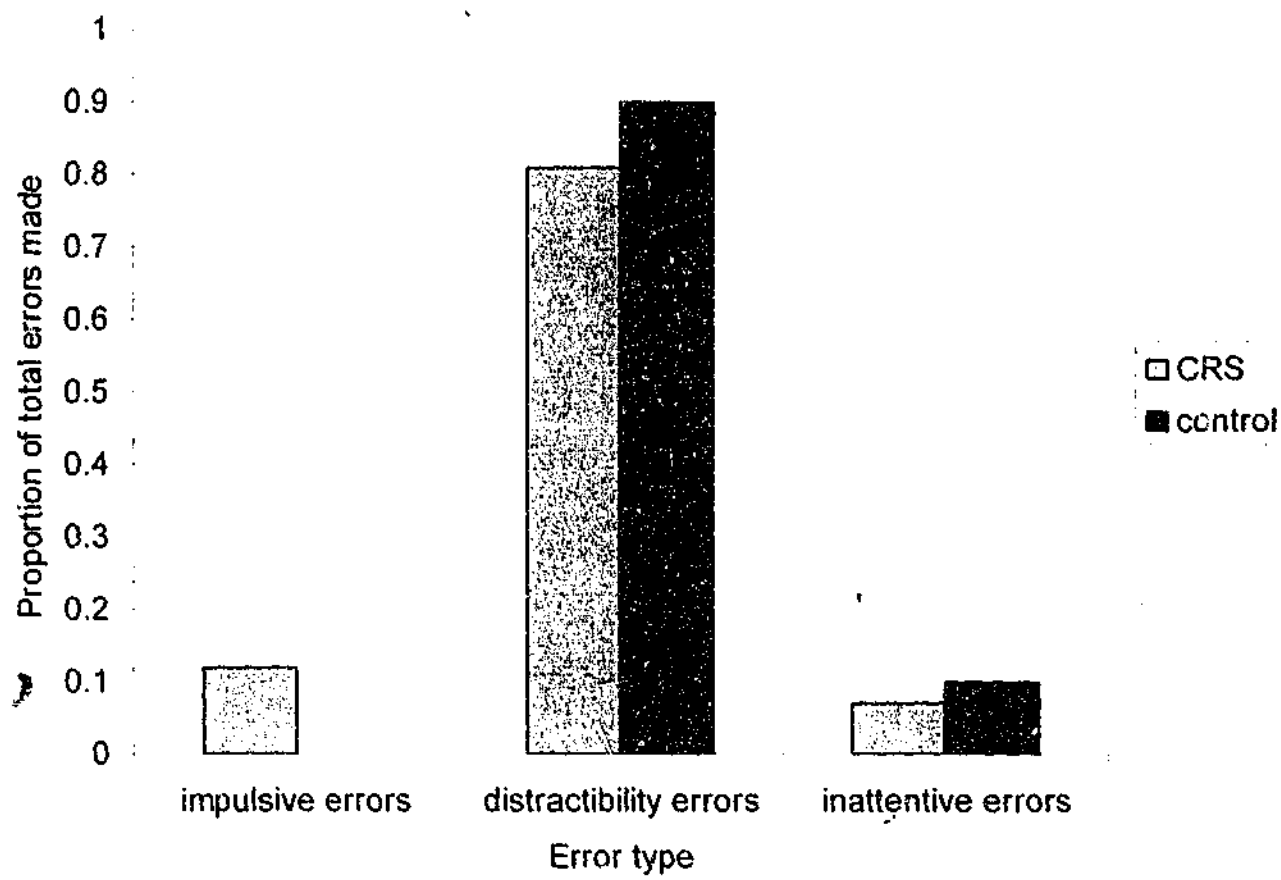


Figure 21: Impulsive, distractibility and inattentive errors as a proportion of the total errors made, for CRS and his matched-control.

3.10.4 Discussion

The data suggest that *reaction times* (in both reach and no-reach tasks) of inattentive type ADHD children may be slower than those of normal children; interestingly, this also now appeared to be the case for *movement time*. The unmedicated ADHD children in Experiment 1 did not show such deficits in movement time compared to their controls. Thus further investigation regarding movement execution problems in inattentive type ADHD children may be warranted. As younger normal children (7-8 year olds) did not differ significantly from older children in movement time in Experiment 3, it does not seem likely that the inattentive type ADHD children in this case study are lagging behind, developmentally, in terms of movement execution.

errors (errors inhibiting responses to distractors presented in isolation) than selective attention errors (errors in ignoring distractors presented simultaneously with targets). So whilst SC and CRS are classified as having problems primarily with inattention, to still make a larger they appear number of distractibility errors than inattentive errors, suggesting greatest difficulty with response inhibition.

Figures 20 and 21 show impulsive, distractibility and inattentive errors made by CRS, SC and the controls, as a proportion of the total errors made. Whilst with SC a large proportion of total errors were of the distractibility type, a small number of errors were also inattentive (18%). His matched-control only made distractibility errors. With CRS the majority of errors were of the distractibility type, though there were also a small number of inattentive (7%) and impulsivity (12%) errors.

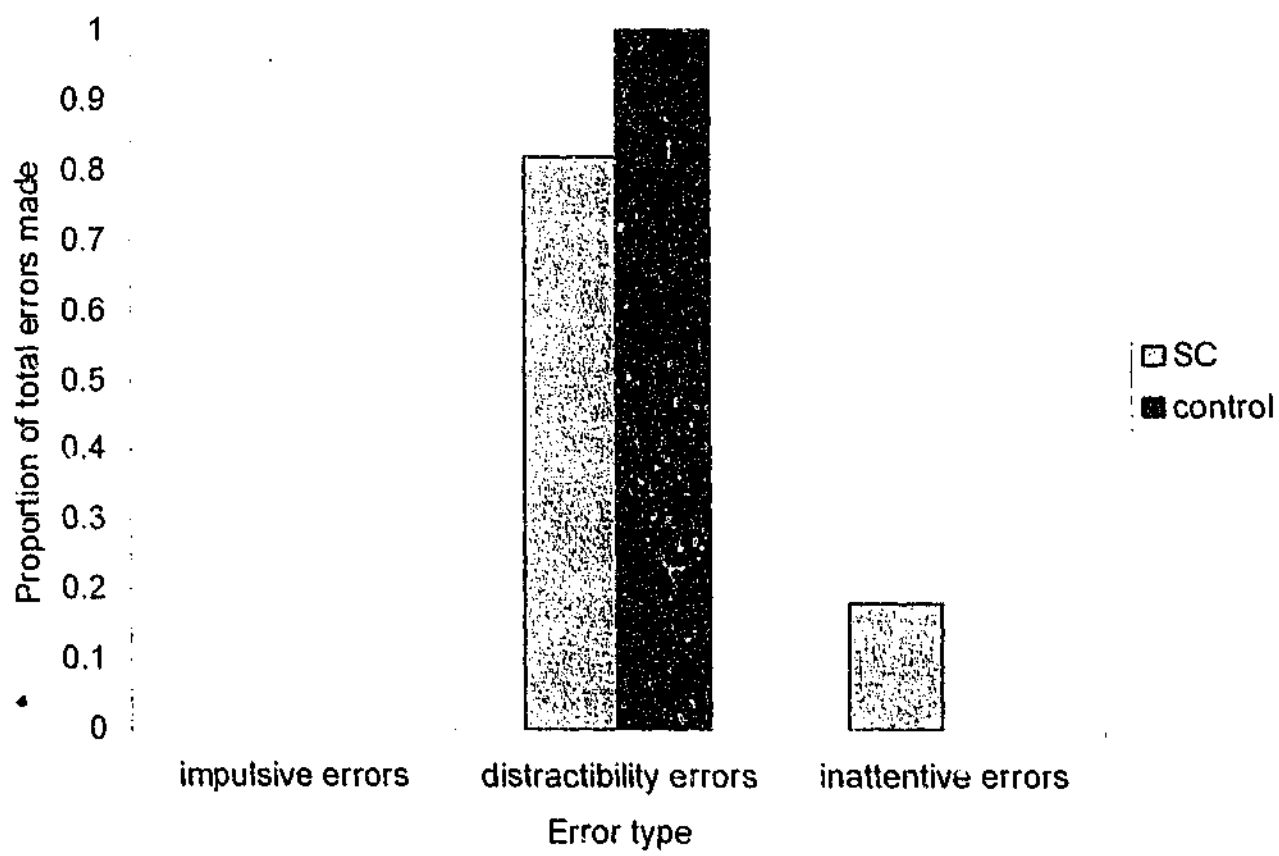


Figure 20: Impulsive, distractibility and inattentive errors as a proportion of the total errors made, for SC and his matched-control.

Although inattentive type children appeared to make more inattentive and distractibility errors (and, in the case of CRS, also more impulsive errors) than their controls, this was exacerbated for the distractibility errors. The distractibility errors that were most often made consisted of distraction by distractors presented in isolation, rather than distraction by distractors presented in conjunction with targets. This finding suggests greater difficulties with response inhibition than with selective attention in inattentive type ADHD children. Somewhat unexpectedly inattentive errors did not appear to play a major role in these children classified as having predominantly difficulties with inattention.

CHAPTER 4

STUDIES 6 - 9: BEHAVIOURAL DEFICITS IN ADHD; PARENT-, TEACHER- AND SELF-REPORT

4.1 Introduction to Studies 6 - 9

The use of behavioural rating scales plays an important role in deriving information about a child's functioning in home and school settings. It also provides the clinician with scores that yield indices of the severity of symptoms in relation to norms of children of similar age and gender. Information from multiple informants is especially important considering that DSM-IV (American Psychiatric Association, 1994) stipulates in its diagnostic criteria for ADHD that "some impairment from the symptoms is present in two or more settings (e.g., at school (or work) and at home)" (p. 84).

The ADDES Second Edition (McCarney, 1995) is the behavioural rating scale used in this thesis, and was developed to reflect DSM-IV diagnostic criteria. However, one disadvantage of this particular rating scale is that it was normed on an American, rather than an Australian, population. The ADDES was chosen because the collection of items more closely resembled DSM-IV criteria than those of other rating scales such as the Child Behavior Checklist (Achenbach, 1991), which includes only one dimension related to ADHD, consisting of items pertaining to all three core symptoms (i.e., inattention, hyperactivity and impulsivity), and the Behavior Assessment System for Children (Reynolds & Kamphaus, 1992) which includes separate subscales of attention problems and hyperactivity, but has some clear differences in item content compared to DSM-IV criteria.

When inspecting the demographic data for Experiments 1 and 2, it can be seen that teacher ratings on the ADDES appear to be more favourable overall than those of the parents. More specifically, teacher and parent ratings appear to be quite discrepant, with parents rating their ADHD children's behaviour in the clinical range, and the teachers rating their behaviour in the normal range. In order to determine whether

parent and teacher ratings were statistically discrepant, Study 6 reports paired t-test results and correlations for teacher and parent ratings of both ADHD and normal children. It has been reported in the literature that a great degree of variation may exist between parent, teacher, or adolescent reporters/ informants (Mandal, Olmi, & Wilczynski, 1999).

A meta-analysis of informant agreement regarding emotional/ behaviour problems of children revealed that the correlations between teacher- and parent-report, teacher- and self-report, parent- and self-report were low, ranging between 0.25 and 0.27 (Achenbach, McConaughy, & Howell, 1987). Correlations between parents and teachers for the symptoms of clinic-referred children and for the agreement for the diagnosis of ADHD based on diagnostic interviews were also low (Biederman, Faraone, Milberger, & Doyle, 1992; Mitsis, McKay, Schulz, Newcorn, & Halperin, 1999). Similarly, parents and children showed discrepant diagnostic information in diagnostic interviews (Jensen et al., 1999) and low correlations on behaviour rating scales (Adams, Kelley, & McCarthy, 1997). Parents have been found to report significantly more ADHD symptoms than adolescents (Hope et al., 1999). Teacher and adolescent rating scale scores have also been found to correlate poorly (Fischer, Barkley, Fletcher, & Smallish, 1993).

Although the literature reports a discrepancy between observers in ratings of behaviour (Mandal et al., 1999), it is important to determine whether self-reported behaviour in the 7-14 year old children differs from parent and teacher ratings. Unfortunately, self-report behaviour scales tend only to be available for children older than primary school age. This limitation raises the question of whether self-report questionnaires do not target younger children because they are unreliable reporters of their behaviour, possibly because of limited self-awareness. Study 7 examined ADHD children's self-report on a number of questions pertaining to their behaviour and feelings, as presented on a 0-10 visual analogue scale developed by clinicians involved in the Southern Health ADHD clinic (Graham, Lee, Morling, & Russo, u.d.). It is of interest to determine, first, whether ADHD children differed in their ratings compared to their normal matched controls (Study 7), and secondly, whether children's ratings of

questions relating to inattentive and hyperactive-impulsive type behaviour correlate with parent and teacher ratings of inattentive and hyperactive-impulsive behaviour on the ADDES (Study 8). Consistent with the poor interrater reliability reported in the literature (e.g., Mandal et al., 1999), the relationship between parent/ teacher and children's ratings of behaviour was expected to be poor. In addition, Study 9 examined the relationship between self-report items and the experimental variables of Experiments 1 and 3.

4.2 Study 6: Discrepancy of parent and teacher ratings for ADHD and normal children

4.2.1 Method

4.2.1.1 Participants

The same 27 ADHD and 65 normal children reported in the Method section in Chapter 3 participated in this study. Unlike Experiments 1-3, children were not excluded if they were diagnosed with the inattentive type of ADHD, or had low IQs, as this was not deemed important for this study.

4.2.1.2 Materials and Procedure

Parents and teachers of both ADHD children and normal children rated their child's inattentive and hyperactive-impulsive behaviours on the ADDES rating scale, as described in the Method section of Chapter 3.

4.2.2 Results

Paired t-tests and Pearson's r correlations were conducted between parent and teacher ratings of each ADHD child on the ADDES inattentive scale, ADDES hyperactive-impulsive scale, and the ADDES overall percentile ranking (see Appendix J). As not all the parents and teachers returned the rating scales, these cases were excluded from the data analyses. Data for the normal children were also analysed in this manner.

Results indicated that, overall, parents give higher problem counts than the teachers for children diagnosed with ADHD. Parent ratings of their ADHD children resulted in a significantly lower overall percentile rank (i.e., more severe symptoms) on the ADDES (mean = 4th percentile), compared to teacher ratings (mean = 30th percentile; $t(24) = -5.28$, $p < .001$). Scaled scores on the inattentiveness scale revealed lower scores (more severe symptoms) reported by parents (mean = 2.2) than teachers (mean = 7.4; $t(24) = -7.86$, $p < .001$). Similarly scaled scores on the hyperactivity-impulsivity scale revealed lower scores (again more severe symptoms) reported by parents (mean = 2.9) than teachers (mean = 7.5; $t(24) = -5.551$, $p < .001$). In addition, the correlational analyses revealed that there were no significant correlations between parent and teacher ratings of ADHD children, on any of the measures of the ADDES.

Results for the normal children also indicated that parent ratings resulted in a significantly lower overall percentile rank (mean = 63rd percentile) than teacher ratings (mean = 78th percentile; $t(49) = -4.10$, $p < .001$). Scaled scores on the inattentiveness scale were significantly lower for parents (mean = 10.96) than teachers (mean = 12.1; $t(49) = -3.65$, $p = .001$), as were scaled scores on the hyperactive-impulsivity scale (mean parent score = 11.1, mean teacher score = 11.9; $t(49) = -2.69$, $p = .01$). Correlational analyses for parent and teacher ratings of the normal children on measures of the ADDES, revealed that parent and teacher-rated percentile ranks ($r = .32$, $p = .024$), inattentive scaled scores ($r = .34$, $p = .016$), and hyperactive-impulsive scaled scores ($r = .37$, $p = .008$) were all positively correlated. Similarly, home hyperactivity-impulsivity scaled scores and school overall percentile ranks ($r = .33$, $p = .019$), home inattentiveness scaled scores and school overall percentile ranks ($r = .31$, $p = .028$), and school hyperactivity-impulsivity scaled scores and home overall percentile ranks ($r = .30$, $p = .037$), were all positively correlated.

4.2.3 Discussion

The results indicated that parent and teacher behavioural ratings for both ADHD and normal children on the ADDES were significantly discrepant, with parents reporting more problematic behaviour than teachers. Similarly, there was a lack of correlation between parent and teacher rating on the ADDES for ADHD, but not for the normal

children. This suggests that ADHD children may show less stable, more inconsistent behaviour at home and school than normal children. It is possible that the results were affected by the fact that many of the ADHD children take medication while at school; thus they may have showed less inattentive and hyperactive-impulsive type behaviours at school. As children cannot receive late (in the day) doses of psychostimulants due to the possibility of sleep-disturbance, parents, on the other hand, would spend more time with their children when they are not affected by medication; thus children may show more inattentive and hyperactive-impulsive behaviour at home. A short-coming of the rating scale is that it does not specify whether ratings of behaviour are to be conducted for children on or off medication.

The finding that normal children were also rated as displaying less problematic behaviours when judged by teachers than by parents suggests that teachers and parents tend to show different tolerance of problem behaviours (Mandal et al., 1999), or that the children are generally better behaved at school. On the other hand, it is also possible that the observed differences across informants, instead of stemming from different behaviours exhibited by the child in different environments, may rather be a product of poor psychometric properties of the ADDES, or the fact that the norms used to obtain scaled scores and percentile ranks are based on an American population. The mean teacher overall percentile rankings of the normal children were much higher than the average 50th percentile (at the 78th percentile), which suggests that either the sample of normal children were better behaved than on average, or that perhaps the American norms, from which these percentile ranks were derived do not accurately reflect behaviour ratings by Australian teachers.

Whilst McCarney (1995) does not report the number of false positives or negatives associated with using the ADDES for the diagnosis of ADHD, Bussing, Schuhmann, Belin, Widawski and Perwien (1998) have found that the ADDES yields a substantial number of false negatives; using the 15th percentile as a cut-off, the ADDES home version failed to identify 42% of children meeting diagnostic criteria for ADHD from a population of special education students in Florida. It appears that the validity of the ADDES as a screening measure requires further research.

It seems unlikely that the discrepancy between parent and teacher ratings reflects the fact that the children had situation-specific, or "home-specific" ADHD, because they had been diagnosed by experienced clinicians according to DSM-IV criteria (which stipulates that ADHD symptoms have to be present in multiple settings).

4.3 Study 7: Self-report in ADHD and normal children

4.3.1 Method

4.3.1.1 Participants

Participants were the same as those described in Study 6.

4.3.1.2 Materials and Procedure

Children filled out a self-report visual analogue scale (see Appendix K) that was developed by clinicians of the ADHD clinic at Southern Health (Graham et al., u.d.). The scale consisted of 22 questions about mood and behaviour, and answers were recorded by participants putting a cross on a line that ranged from 0 at one end to 10 at the other. Children were instructed that "these are some questions about the kind of person you are and your feelings. Read the question and put a cross (X) on the line where you think your answer would go". The responses of 25 of the 27 ADHD children (two children did not complete the self-report scale) and their matched controls were subjected to independent t-tests to ascertain whether ADHD children differed significantly from control children in self-report on any of the items.

4.3.2 Results

Means for the ADHD and control children on each of the 22 items are given in Table 6. Results for each of the independent t-tests are in Appendix J. As can be seen from Table 6, children with ADHD rated themselves significantly lower than the controls for twelve of the items. ADHD children did not rate their mood significantly differently from controls. However, they did report a significantly greater negative self-perception, and a significantly greater negative view of how others perceive them. Children with ADHD liked reading and maths significantly less than controls, and reported that they had messier handwriting, more difficulty keeping their rooms tidy,

less friends, got into more trouble at home and school, and had greater difficulty concentrating, sitting still and following directions. These results suggest that children with ADHD are able to self-report ADHD-related symptoms such as difficulties with concentration, restlessness/ difficulty sitting still, and following directions.

Table 6: Mean ratings for ADHD and control children for the 22 items of the self-report questionnaire. Significant differences (according to independent t-tests) are denoted by "sig" ($p < .05$).

	GROUP	Mean	Std. Deviation	Independent t-test results
HAPPY	clinical	6.8400	2.9429	
(10 =happy)	control	7.6800	1.6130	
ANGRY	clinical	5.7800	3.7447	
(10 =not angry)	control	6.1400	2.8922	
WORRY	clinical	4.8000	3.9078	
(10 = not worried)	control	5.9000	1.7678	
FEAR	clinical	6.9200	3.4177	
(10 = not scared)	control	6.8000	2.5000	
SELF PERCEPTION	clinical	6.0800	3.0369	sig.
(10 = good person)	control	7.7200	1.9044	
OTHER PERCEPTION	clinical	5.5000	3.2787	sig.
(10 = good person)	control	8.3000	1.4790	
READING	clinical	4.7800	4.5164	sig.
(10 = like reading)	control	7.6600	3.1581	
DRAWING	clinical	9.1400	2.6869	
(10 = like drawing)	control	7.8200	2.4744	
MATHS	clinical	4.2800	4.3948	sig.
(10 = like maths)	control	7.2200	3.2018	
WRITING	clinical	4.5600	3.6552	sig.
(10= neat handwriting)	control	6.6800	2.1741	
TIDY ROOM	clinical	3.5600	4.0551	sig.
(10 = tidy bedroom)	control	5.9800	3.1440	
FRIENDS	clinical	7.6800	3.3969	sig.
(10 = have friends)	control	9.3400	1.2309	

LOSE THINGS	clinical	5.0600	4.0371	
(10 = do not lose things)	control	4.9400	2.8296	
BULLIED	clinical	5.3600	4.2020	
(10 = not bullied)	control	7.0400	3.1554	
TROUBLE HOME	clinical	3.1600	3.6364	sig.
(10 = no trouble)	control	5.1800	2.4447	
TROUBLE SCHOOL	clinical	5.4000	3.5824	sig.
(10 = no trouble)	control	7.2600	2.9337	
NO THINK	clinical	4.1400	3.9331	
(10 = do not do things without thinking)	control	5.0600	3.0968	
CONCENTRATE	clinical	3.7800	4.0622	sig.
(10 = not difficult to concentrate)	control	6.4400	2.7813	
TALK	clinical	6.6800	4.3178	
(10 = talk a lot)	control	6.9400	2.7322	
SIT STILL	clinical	4.4000	4.4253	sig.
(10 = not difficult to sit still)	control	7.2200	3.3853	
WORDS MIX	clinical	6.1400	3.6444	
(10 = do not mix up words)	control	6.1000	2.9651	
DIRECTIONS FOLLOW	clinical	6.5800	4.0612	sig.
(10 = can follow directions)	control	8.6800	1.6948	

4.3.3 Discussion

Although it has been documented that ADHD adolescents' self-report ratings on rating scales distinguish them from normal adolescents (Robin & Vandermay, 1996), self-report rating scales typically do not target children. The present results indicate that children with ADHD are also able to self-report greater ADHD-related symptoms such as difficulties with concentration, restlessness/ difficulty sitting still, and following directions, compared with age-matched controls.

The self-report measure indicated that children with ADHD reported more negative self-perception and a more negative view of how they thought others perceived them, which may be indicative of low self-esteem. Consistent with this suggestion are

reports that children with ADHD (McDougal, 1999; Alexander, 2000) and adolescents with ADHD (Slomkowski, Klein, & Mannuzza, 1995; Pennington, 2001) score lower than normal children on a variety of measures of self-esteem. Children with ADHD also reported getting into more trouble at home and school, and having messier handwriting and bedrooms than as reported by control children. In addition, they liked reading and maths less than controls, perhaps due to difficulties in persisting in activities that require mental effort (which is included in DSM-IV diagnostic criteria). Reports of having less friends than controls may also reflect the documented social problems in ADHD. The literature has documented that relative to other children, children with ADHD have few friends and experience high rates of peer rejection (Olson, 1996). Several potential explanations for the social problems of children with ADHD have been proposed, including deficits in social knowledge, attributional style and social reasoning (Olson, 1996).

4.4 Study 8: Correlations between self-report and parent and teacher ADDES ratings.

4.4.1 Method

4.4.1.1 Participants

Participants were the same as those indicated in the Method section in Studies 6 and 7.

4.4.1.2 Materials and Procedure

Scores on the returned school and home versions of the ADDES (see the Method section in Chapter 3 for details) and scores on eleven items that were deemed to reflect ADHD symptomatology on the self-report visual analogue scale (see Appendix K) were subjected to two correlational analyses, one for the scores of normal children and one for the scores of ADHD children. The eleven items were chosen due to their correspondence with DSM-IV diagnostic criteria (they were not necessarily those that distinguished ADHD and normal children in Study 7), and are as follows:

1 concentration difficulty: inattention criterion, "has difficulty sustaining attention in tasks or play activities"

2 do things without thinking: inattention criterion, "often fails to give close attention to details or makes careless mistakes in schoolwork, work or other activities", and impulsivity criteria: "often blurts out answers before questions have been completed" and "often interrupts or intrudes on others"

3 difficulty sitting still: hyperactivity criteria, "often fidgets with hands or feet or squirms in seat" and "often leaves seat in classroom or other situations in which remaining seated is expected"

4 difficulty following directions: inattention criterion: "often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace."

5 loses things: inattention criterion, "often loses things necessary for tasks or activities"

6 talks a lot: hyperactivity criterion: "often talks excessively"

7 in trouble at home: possibly related to the criterion "some impairment from the symptoms is present in two or more settings"

8 in trouble at school : possibly related to the criterion "some impairment from the symptoms is present in two or more settings"

9 messy handwriting: inattention criterion: "avoids, dislikes or is reluctant to engage in tasks that require sustained mental effort"

10 dislikes reading: inattention criterion: "avoids, dislikes or is reluctant to engage in tasks that require sustained mental effort"

11 dislikes maths: inattention criterion, "avoids, dislikes or is reluctant to engage in tasks that require sustained mental effort"

4.4.2 Results

Significant correlations for the ADHD children are shown in Table 7. Only two of the eleven self-report item scores correlated significantly with school or home version ADDES scores. *Reading* was positively correlated with *teacher inattentiveness ratings on the ADDES*, indicating that better attention is associated with a greater liking of reading. *Talking a lot* was negatively correlated with *overall percentile ranks on the*

parent ADDES, suggesting that talking more is associated with lower percentile ranking, and thus more problem behaviour, as rated by parents.

Reading correlated positively with *maths*, and *doing things without thinking* correlated positively with *having trouble sitting still*. This pattern of results suggests that a dislike of reading is likely to be reported in conjunction with a dislike of maths, and reports of a greater likelihood of doing things without thinking are likely to be reported in conjunction with greater difficulties in sitting still. *Getting into trouble at school*

Table 7: Pearson's correlations (r), significance levels (p), and number of cases (n), for self-report items and ADDES measures for children with ADHD

	Reading	Talk	Sit still	FSIQ	Trouble home
Maths	r = .58 p = .002 n = 25	-	-	-	-
No think	-	-	r = .47 p = .017 n = 25	-	r = .40 p = .046 n = 25
Lose things	-	-	-	-	r = .40 p = .049 n = 25
Trouble school	-	-	-	r = -.44 p = .03 n = 25	-
ADDES (school) inattentive scale	r = .50 p = .012 n = 24	-	-	-	-
ADDES (home) inattentive scale	-	-	-	r = .43 p = .036 n = 24	-
ADDES (home) overall percentile rank	-	r = -.41 p = .04 n = 24	-	-	-

was negatively correlated with *IQ*, suggesting that ADHD children with higher IQs are more likely to report getting into trouble at school. *IQ* was also positively correlated with *parent inattentive ratings on the ADDES*, suggesting that children with higher IQs are likely to be rated as displaying better attention, by their parents. Ratings of getting into trouble at home were positively correlated with ratings of losing things and doing things without thinking.

The significant correlations for the normal children shown in Table 8 indicate that only two of the self-report item scores correlated with ADDES scores. *Concentration* was positively correlated with *percentile ranks on the school version ADDES*, and *sitting still* was positively correlated with *percentile ranks on the home version ADDES*, and with *parent inattentiveness ratings*, as well as with *teacher hyperactivity-impulsivity ratings*. This suggests that children who score higher in overall percentile rank (as rated by teachers) report better concentration. Similarly, children who score higher in percentile rank (better behaviour, as rated by parents), and/ or higher (i.e., less severe behaviour) on parent-rated inattention, and/ or higher on teacher reported hyperactivity-impulsivity (better behaviour) also report less difficulty with sitting still.

Reading, maths and *following directions* were positively correlated with *neat writing*; *losing things* was positively correlated with *concentration* and with *sitting still*. Thus, neater handwriting was associated with a greater liking of reading and maths and greater reported ability to follow directions. Reports of greater difficulty concentrating and sitting still were associated with a greater likelihood of losing things. *Talking a lot* was positively correlated with both *concentration* and *not thinking*, suggesting that self-reported ability to concentrate and to think before acting, are both associated with the tendency to talk a lot. *Getting into trouble at school* was positively correlated with *getting into trouble at home*, suggesting that if children report that they get into trouble at home, they are also likely to report that they get into trouble at school. *Getting into trouble at home* was positively correlated with *losing things* and with *sitting still*, whilst *getting into trouble at school* was positively correlated with *not thinking* and *concentration*. Thus, children who reported that they got into greater

Table 8: Pearson's correlations (r), significance levels (p), and number of cases (n), for self-report items and measures on the ADDES for normal children

	Neat writing	Concentrate	Sit still	No think	Trouble home
Reading	r = .35 p = .005 n = 65	-	-	-	-
Maths	r = .29 p = .02 n = 65	-	-	-	-
Follow directions	r = .37 p = .002 n = 65	-	-	-	-
Lose things	-	r = .38 p = .002 n = 65	r = .27 p = .028 n = 65	-	r = .48 p = .000 n = 65
Talk	-	r = .27 p = .029 n = 65	-	r = .30 p = .014 n = 65	-
Trouble school	-	r = .39 p = .001 n = 65	-	r = .31 p = .012 n = 65	r = .42 p = .001 n = 65
Sit still	-	-	-	-	r = .29 p = .018 n = 65
ADDES (home) overall percentile rank	-	-	r = .32 p = .017 n = 57	-	-
ADDES (school) overall percentile rank	-	r = .30 p = .029 n = 54	-	-	-
ADDES (home) inattentive scale	-	-	r = .33 p = .012 n = 57	-	-
ADDES (school) hyperactive-impulsive scale	-	-	r = .296 p = .03 n = 54	-	-

trouble at home also reported greater difficulties with sitting still and a greater likelihood of losing things. Children who reported getting into greater trouble at school also reported greater difficulties with concentration and a greater likelihood of doing things without thinking.

4.4.3 Discussion

Although there were significant correlations between some of the self-report items, there was poor agreement between child and teacher/ parent ratings overall. For ADHD children, only reading and talking a lot were significantly correlated with teacher and parent ratings, respectively. Agreement was also low between child and teacher/ parent ratings for normal children; only concentration and sitting still were significantly correlated with teacher/ parent ratings. Findings of poor agreement between child and teacher/ parent ratings, and poor agreement between teacher and parents (in Study 6) are consistent with reports of poor interrater reliability reported on a variety of assessment instruments in the ADHD literature (e.g., Mandal et al., 1999). These findings suggest that in order to get a more accurate picture of the elements of a child's behaviour, it is better not to rely on just one informant. However, the lack of concordance between informants makes it difficult to base an ADHD diagnosis on data derived from behavioural rating scales, and serves as a caution to research that bases ADHD diagnoses on rating scale data, rather than clinician-based diagnoses. Further, these results suggest that perhaps there is a need for the assessment of a child's behaviour to be made by the clinician observing the child in various settings, such as at school, in the clinic, and at home.

4.5 Study 9: The relationship between self-report and experimental variables

4.5.1 Method

4.5.1.1 Participants

Children were the same as those that participated in Experiments 1 and 3 (in Chapter 3).

4.5.1.2 Materials and Procedure

Scores from the experimental measures (movement time, reaction time, inattentive, impulsive and distractibility errors) from Experiments 1 and 3 were investigated in terms of their relationship with the eleven self-report items from Section 4.4 above. Cases in which self-report data were missing were excluded from the analyses.

4.5.2 Results

Results for the unmedicated ADHD children (see Appendix J) revealed that there was a positive correlation between distractibility errors (inability to inhibit responses to in-task distractor stimuli) and neat handwriting ($r = .59$, $p = .033$), which suggests that children who report neater handwriting, paradoxically, also tend to make more distractibility errors. Concentration was negatively correlated with both no-reach and reach reaction times ($r = -.81$, $p = .001$; $r = -.63$, $p = .022$, respectively), which suggests that ADHD children who report better concentration also have faster reaction times in the reach and no-reach tasks. Reaction time in the reach task also correlated positively with getting into trouble at school ($r = .77$, $p = .002$). Thus, the less trouble children reported getting into at school, the slower their reaction times on the reach task.

Results for the normal children (see Appendix J) indicated that writing was positively correlated with inattentive errors ($r = .37$, $p = .021$) and with distractibility errors ($r = .31$, $p = .049$). Thus children who made more inattentive and distractibility errors also reported that they had neater handwriting. Losing things was negatively correlated with reaction time in the reach task ($r = -.37$, $p = .02$), reaction time in the no-reach task ($r = -.45$, $p = .003$), inattentive errors ($r = -.38$, $p = .015$), and distractibility errors ($r = -.34$, $p = .03$). Thus children who reported that they were less likely to lose things also made less inattentive and distractibility errors, and demonstrated faster reaction times in both reach and no-reach tasks. Concentration was negatively correlated with movement time ($r = -.38$, $p = .015$), reaction time in the no-reach task ($r = -.42$, $p = .007$), inattentive errors ($r = -.38$, $p = .017$), and distractibility errors ($r = -.35$, $p = .029$). Thus children who reported better concentration also made less inattentive and

distractibility errors, and showed faster reaction times in the no-reach task, and faster movement times in the reach task.

4.5.3 Discussion

The results indicated that there were significant correlations between items on the self-report questionnaire and the experimental variables. ADHD children who reported greater difficulty with concentration were slower in reaction times (in both reach and no-reach tasks), and normal children who reported more difficulty with concentration were also slower in reaction times (in the no-reach task). In addition, these normal children, who reported greater difficulty with concentration, also made more inattentive and distractibility errors and were slower in movement time. Paradoxically, both normal and ADHD children who reported having neater handwriting also made more distractibility errors (and in the case of normal children, also made more inattentive errors). It is possible that children who write more neatly tend to concentrate on the manner (neatness), rather than on the content of the task. The focus on *how* they write may be a form of distraction from *what* they write. If this is indeed the case, the finding that they missed more targets, and were less able to inhibit their responses to distractors, does not appear to be quite so paradoxical.

4.6 Conclusion

The focus of this Chapter was to investigate the behavioural deficits in ADHD that are reported by parents, teachers and the ADHD children themselves in the form of rating scales. In accordance with the literature, it was found that the concordance between teacher, parent and child informants was quite low. Compared to parents, teachers tended to over-rate both ADHD and normal children's behaviour. Children with ADHD were found to be able to report their problems relating to ADHD symptomatology, low self-esteem, and social problems when they were compared to controls on a self-report visual analogue scale. Further, some of the items on the self-report scale correlated with experimental variables. These results suggests that children with ADHD can be reliable reporters of their behaviour, and highlights the importance of using multiple informants including the children themselves, when trying to get an accurate overview of the child's behaviour and difficulties. These

findings also highlight the importance of not basing ADHD diagnoses blindly on rating-scale scores.

CHAPTER 5:

EXPERIMENTS 10 AND 11: PERCEPTUAL ASYMMETRIES IN NORMAL CHILDREN AND CHILDREN WITH ADHD

5.1 Introduction to Experiments

Studies of line bisection, dichotic listening, and various tachistoscopic tasks have been used to assess perceptual asymmetries, and to draw inferences about hemispheric lateralization, in adults and children. In studies of horizontal line bisection, where participants are required to mark the mid-point, right-handed adults tend to bisect lines slightly to the left of their true centre (Bowers & Heilman, 1980; McCourt & Olafson, 1997), although this bias has not been found by all investigators (Nielsen, Intriligator, & Barton, 1999; Werth & Poeppel, 1988). In dichotic listening tasks, two different auditory stimuli are presented to the left and right ears simultaneously. A right ear advantage (REA), that is, superior report of right compared to left ear items, has been found in normal individuals for processing verbal stimuli such as words and syllables (Ley & Bryden, 1982). This REA is believed to result from left hemisphere lateralization for verbal processing. Emotional stimuli, on the other hand, are preferentially detected in the left ear (Freeman & Traugott, 1994), possibly reflecting right hemisphere lateralization for emotion.

Perceptual asymmetries in vision have traditionally been studied using tachistoscopic tasks, in which stimuli are presented rapidly and unilaterally to the left or right visual field (and therefore, to the corresponding right and left hemispheres, respectively). These asymmetries have also been reproduced in free-viewing tasks, although in the latter, stimuli are not transmitted exclusively to a single hemisphere. It has been demonstrated that right-handed adults attend consistently more to leftward features of a variety of facial and visuospatial stimuli than to those on the right (e.g., Luh, Redl, & Levy, 1994). The free-viewing tasks typically use pairs of stimuli in which each stimulus is a mirror reversal of the other, and where the salient feature (such as the smile on a face) is on the left in one of the pair and on the right in the other. Participants tend to select the stimulus with the salient feature on the left-hand side

more than the stimulus with the salient feature on the right-hand side (e.g., David, 1989; Luh et al., 1994).

Right-handed adults have been found to recognize faces (e.g., Rhodes, 1985), and base judgements of gender (e.g., Luh et al., 1994) and emotion (e.g., David, 1989; Luh et al., 1994), more via leftward than rightward features of the face. This leftward bias can be affected by the type of emotion to be judged (Magnussen, Sunde, & Dyrnes, 1994) and by handedness, with left-handers showing reduced or atypical asymmetries (e.g., David, 1989; Luh et al., 1994). Bias for leftward features has also been observed for non-facial stimuli, such as judgements of brightness and numerosity (Nicholls, Bradshaw, & Mattingley, 1999), and somewhat less consistently for shape (see Nicholls et al., 1999; cf. Luh et al., 1994).

The mechanisms underlying these auditory and visual perceptual asymmetries are not clearly understood. The traditional *structural model* of perceptual asymmetry (Kimura, 1967) postulates that contralateral auditory/ visual brain areas are more activated during some of these perceptual asymmetry tasks; verbal stimuli presented to the right ear/ right visual field have direct access to processing centres in the left hemisphere, whereas left ear/ left visual field stimuli have to be transferred across the corpus callosum to reach speech processing areas in the left hemisphere. Similarly, nonverbal stimuli presented to the left ear/ left visual field would have direct access to non-verbal, right hemisphere processing, but would have to cross the corpus callosum to reach verbal processing areas in the left hemisphere.

Alternatively, an *attentional model* has been proposed to account for normal perceptual asymmetries (Kinsbourne, 1970). Rather than structural constraints, this model focuses on selective attention and hemispheric activation mechanisms. Because verbal material evokes activity in the language areas of the left hemisphere, attention is directed contralaterally to stimulus material on the right. Nonverbal stimuli, on the other hand, evoke predominantly right hemisphere activity, so that attention is directed preferentially to the left. In line with this, Mattingley and colleagues (Mattingley et al., 1995; Mattingley, Bradshaw, Nettleton, & Bradshaw, 1994; Mattingley, Bradshaw, Phillips, & Bradshaw, 1993) found that patients with left unilateral neglect due to right

hemisphere damage demonstrated a pronounced rightward bias in line bisection, face-processing, and brightness judgement tasks. It appears that in these right-hemisphere-damaged patients, right-hemisphere activation by the task is not enough to compensate for the lesion, and thus a rightward (left hemisphere) bias prevails. This rightward bias has been found to persist even after the resolution of other clinical symptoms of neglect (Mattingley, Bradshaw, Bradshaw, & Nettleton, 1994).

Perceptual asymmetry tasks have also been administered in a variety of clinical populations. In adults with schizophrenia, for example, a reduction in the normal REA in dichotic listening tasks has been found (e.g., Bruder et al., 1995) which may be interpreted as indicating abnormal left hemisphere functioning in schizophrenia. Jaeger, Borod and Peselow (1987) reported that depressed patients showed a smaller-than-normal leftward bias in making judgements of emotion (happiness), supporting a postulated right hemisphere dysfunction in depression. Similarly, David (1993) observed reduced leftward-bias in the tachistoscopic presentation of happy-sad faces in depressed patients, and no significant left or rightward bias in schizophrenic patients.

As outlined in Chapter 2, perceptual asymmetries in individuals with ADHD have also been observed. Specifically, a right-visual field advantage has been found in studies of line bisection (e.g., Sheppard et al., 1999; cf. Ben-Artsy et al., 1996) and in studies of target cancellation (e.g., Voeller & Heilman, 1988a; Adelstein, 1995; cf. Ben-Artsy et al., 1996) in children with ADHD. Studies utilizing dichotic listening tasks in children and adolescents with ADHD have, however, typically failed to observe any differences of lateralization in children with ADHD compared to normal controls, when using (left hemisphere activating) syllables (Oie, Rund, Sundet, & Bryhn, 1998), words (Davidson & Prior, 1978; Manassis, Tannock, & Barbosa, 2000) and (right hemisphere activating) emotional stimuli (Manassis et al., 2000). Those studies which have demonstrated anomalies in perceptual biases are consistent with the view that ADHD reflects predominantly *right-sided* frontal-striatal system dysfunction (Heilman, Voeller, & Nadeau, 1991; Castellanos et al., 1996). This is consistent with various neuroimaging studies (reviewed in Chapter 2) that found when compared to normals, individuals with ADHD show right hemisphere hypoarousal (Lou et al., 1989; Zametkin et al., 1990; cf. Zametkin et al., 1993).

Given this previous research on pathologies of hemispheric asymmetry, it is important to ascertain how children with ADHD perform on free-vision perceptual bias tasks, which have not been administered in this population to date. As perceptual asymmetries in chimeric tasks have been predominantly explored in normal *adults*, the corresponding study of developmental differences in *children* must first be considered. Young and Ellis (1976) conducted a tachistoscopic study of face recognition with children aged 5, 7 and 11 years. The children were briefly presented with faces to their left or right visual field, and were then asked to indicate whether a comparison face was the same as or different to the face they had seen. Similarly to adults, a right hemisphere/ left visual field advantage was found for all groups of children, suggesting no developmental changes in visual field preference with age. In another tachistoscopic study, Young and Bion (1979) demonstrated that 5-11 year-old children also showed a left visual field advantage for judgements of quantity.

Levine and Levy (1986) used chimeric face stimuli in free-viewing conditions in right-handed children in kindergarten and grades 1, 2, 4, 6, 8, 10 and 12. Chimeric stimuli consisted of pairs of faces, one the mirror image of the other. Only half of each face was smiling, and participants had to specify the "happier" face (either the one with the smile on the left or the one with the smile on the right). Results indicated that all age-groups demonstrated a leftward bias and that there was no significant difference in the magnitude of the bias scores across age-groups. Nevertheless, the authors drew attention to the apparently smaller leftward bias scores in kindergarteners.

Chiang, Ballantyne and Trauner (2000) also used free-viewing chimeric stimuli to investigate judgements of affect (happy faces), gender, quantity and shape (roundedness) in 6-7, 9-10, and in 14-16 year-old right-handed children. They found that, averaged across all tasks, all age-groups displayed a significant leftward bias. However, the presence or extent of the leftward bias depended on the task. Unlike the results of Levine and Levy (1986), Chiang and colleagues found no significant leftward bias in judgements of happiness in the 6-7 year-old group. Despite the similar sample sizes in each group, Chiang and colleagues had fewer stimuli than Levine and

Levy (24 versus 36), and employed a combination of cartoon and photographic-face-stimuli (Levine and Levy used photographic faces only). Similarly, the leftward bias for judgements of gender (femininity) was significant in the 9-10 and 14-16 year old, but not in the 6-7 year old children. In contrast, a leftward bias for numerosity judgements was observed in all age-groups, whereas judgements of shape (roundedness) elicited no significant leftward bias in any age-group.

In summary, past research has indicated that children with ADHD may show anomalous lateralized perceptual biases in letter cancellation (Adelstein, 1995; Voeller & Heilman, 1988a) and line bisection (Sheppard et al., 1999) tasks. Such anomalous lateralization/ perceptual bias is consistent with the postulated right-hemisphere abnormality in ADHD (e.g., Heilman et al., 1991). Importantly, however, this is by no means a universal finding (see Ben-Artsy et al., 1996; Adelstein, 1995; Manassis et al., 2000). Thus, further investigation of anomalous lateralization in children with ADHD using free-vision chimeric tasks is warranted. Since free-viewing perceptual bias tasks have not been studied extensively in a developmental context, it is also important that they be validated in a normal sample of children. This is even more important in view of the inconsistent findings of age effects in previous studies of children (Levine & Levy, 1986; Chiang et al., 2000).

The aim of Experiment 10 was to clarify developmental differences in free-viewing judgements of happiness, as well as to explore judgements of facial resemblance and brightness in normal children aged 7-12 years. Consistent with the study of Levine and Levy (1986), photographic rather than cartoon stimuli were used in the face tasks. In Experiment 11, free-viewing judgements of happiness, facial resemblance, and brightness were investigated in children with ADHD, combined type.

5.2 Experiment 10

Three different free-viewing chimeric stimuli that have previously been observed to induce leftward biases in normal right-handed adults (Mattingley, Bradshaw, Nettleton et al., 1994; Mattingley et al., 1993) were administered to children aged between 7 and 12 years. In the *face-matching task* participants had to choose whether a face

comprising left-left, or right-right composites most closely resembled the original full-face photograph. In the *chimeric faces task* participants indicated whether a composite face with the smile on the left, or a composite face with the smile on the right, looked happier. In the *grey scales task,* participants indicated which of two rectangles, one with the dark end on the left and the other with the dark end on the right, appeared darker overall. In line with findings of the tachistoscopic face-recognition task of Young and Ellis (1976), a leftward bias was expected in the *face-matching task.* In line with the findings of Levine and Levy (1986) and Chiang et al. (2000), a leftward bias was also predicted for the *chimeric faces task.* No studies have investigated the *grey scales* task in children, so the prediction of a leftward bias was based solely on studies of normal adults (Mattingley et al., 1994b; Nicholls et al., 1999). As there is discrepancy in the literature regarding the developmental trajectory of perceptual biases (Chiang et al., 2000; cf. Levine & Levy, 1986), the effect of age on perceptual bias was further explored in this study.

5.2.1 Method

5.2.1.1 Participants

Fifty-two right-handed children aged between 7 years and 12 years of age, recruited mainly from local primary schools, participated in this experiment. (All of these children also participated in Experiment 3.) Children were divided into three groups: 7-8 year olds (8 boys and 9 girls), 9-10 year-olds (10 boys and 7 girls), and 11-12 year-olds (9 boys and 9 girls). A one-way ANOVA (see Appendix L) revealed that there was no significant difference in Full Scale IQ (FSIQ) for the three groups (7-8 year-old children's mean FSIQ = 103.7, 9-10 year-old children's mean FSIQ = 111.9, and 11-12 year-old children's mean FSIQ = 103.8, $F(2,49) = 2.425$, $p = .099$).

5.2.1.2 Materials and Procedure

As in Experiments 1-3, each child's full scale IQ was measured using the Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1990), which, depending on the age of the child, took between 15- 40 minutes to administer.

Eighteen different faces were photographed with neutral expressions to serve as stimuli for the *face-matching* task (see Appendix M for sample stimuli), based on the method of Gilbert and Bakan (1973); for a more detailed description see Mattingley et al. (1993) Briefly, each photograph was divided along its midsagittal axis and recombined to form left-left and right-right composites. The normal photograph was positioned at the top of each stimulus card, and the two composites were placed directly underneath. Each photographic stimulus was 5.5 cm in height and 4.2 cm in width. The vertical positions of the composites (middle/ bottom) were counterbalanced, such that there were two stimulus cards for each poser, resulting in 36 stimuli in total.

Materials for the *chimeric faces* task (see Appendix M for sample stimuli) were generated from two photographs of ten peoples' faces, as described in detail by Mattingley et al. (1993). Briefly, one photograph was of the person smiling, and the other was of the same person with a neutral expression. Each photograph was divided along its midsagittal axis and recombined to form two different mirror-image chimeras, one in which the smiling half was on the left (and the neutral on the right), and one in which the smiling half was on the right (and the neutral on the left). Each chimera was then paired with its mirror image, and the two chimeras were positioned in vertical alignment in the centre of a stimulus card. Each face was approximately 8 cm in height and 6 cm in width. The vertical positions of the pairs on the stimulus card (top/ bottom) were counterbalanced, resulting in four pairs of chimeric stimuli for each face. Thus, there were 40 stimulus pairs in total.

The *grey scales* stimuli (see Appendix M for sample stimuli) were produced using a computer graphics package, and then printed onto separate sheets of white A4 paper (see Mattingley et al., 1994b). Each stimulus was a rectangular strip, with a thin black outline. The height of each strip was 32 mm, and there were eight different widths varying between 110 and 268 mm. The length of the stimuli was varied between trials to discourage the use of a standard response. Each strip consisted of a continuous scale of grey shades ranging from black at one end to white at the other. Each A4 sheet contained two strips of equal width, one above the other, with the dark end of each strip on opposite sides of the page. On half the trials, the dark side of the top rectangle

was on the left, and on the other half the dark side of the top rectangle was on the right, making 32 pairs of stimuli in total.

Stimuli were placed in front of participants, who indicated which of the two composite faces more closely resembled the original (asymmetric) face in the *face-matching* task; which of the two faces looked happier in the *chimeric faces* task; and which of the strips appeared darker in the *grey scales* task. The stimuli in each task were counterbalanced so that any consistent response bias (e.g., always choosing the bottom item) would result in a mean bias of zero. The order in which the three tasks were performed was also counterbalanced. There was no time limit for completion of the tasks, but participants were encouraged to make a judgement based on immediate apprehension rather than a lengthy inspection. If participants could not decide between stimuli, they were required to guess. Responses were recorded and defined as left-biased if participants selected the left-left composite face (*face matching*); the face with the smile on the left (*chimeric faces*); or the strip with the dark end on the left (*grey scales*).

5.2.2 Results

An asymmetry score was calculated by subtracting the number of leftward responses from the number of rightward responses, and then dividing by the total number of items, for each task. Scores, therefore, could range from –1 to +1, with negative scores indicating a leftward bias and positive scores indicating a rightward bias.

Three separate, one-way ANOVAs (see Appendix L) were performed on the asymmetry scores, one for each of the three tasks, with the single factor of age (7-8, 9-10, 11-12 years). There was no significant effect of age in the face-matching task ($F(2,49) = 1.133$, $p = .330$), the chimeric faces task ($F(2,49) = 2.981$, $p = .06$[8]), or the grey scales task ($F(2,49) = 1.421$, $p = .251$). Data were therefore collapsed across age, and single-sample t-tests were conducted for each of the three tasks to determine whether asymmetry scores differed significantly from zero (no bias). Results indicated a significant leftward bias for the face-matching task (mean asymmetry score = -.0588,

[8] The near-significant p-value reflects a somewhat greater leftward bias in the 9-10 than the 7-8 and the 11-12 year-old group

(S.D. = .20), $t(51) = -2.172$, $p = .035$, two-tailed), and for the chimeric faces task (mean asymmetry score = -.1731, (S.D. = .45), $t(51) = -2.799$, $p = .007$, two-tailed), but not for the grey scales task (mean asymmetry score = -.0577, (S.D. = .32), $t(51) = -1.288$, $p = .203$, two-tailed). Although the asymmetry score for the grey scales task was numerically only fractionally smaller than that for the face-matching task, the standard deviations reveal greater variability in asymmetry scores in the grey scales task.

In further analyses, participants were classified as showing a leftward bias, rightward bias, or no bias, based on their observed asymmetry scores in the three tasks. Examination of Table 8 reveals that the majority of children displayed leftward biases in all three tasks.

Table 8: The number of 7-12 year-old children (and percentage in brackets) showing leftward, rightward and no biases in face matching, chimeric faces and grey scales tasks.

	Face-matching task	Chimeric faces task	Grey Scales task
Leftward bias	28 (54%)	35 (67%)	27 (52%)
Rightward bias	16 (31%)	14 (27%)	18 (35%)
No bias	8 (15%)	3 (6%)	7 (13%)

Chi-squared tests were conducted on the frequencies of leftward and rightward biases. There were significantly more individuals with a leftward bias in the face-matching task ($\chi^2_1 = 3.27$, $p = .048$, one-tailed, on the *a priori* assumption of a greater frequency of leftward biases), and in the chimeric faces task ($\chi^2_1 = 9.00$, $p = .002$, one-tailed). However, no such difference was found in the grey scales task ($\chi^2_1 = 1.8$, $p = .116$, one-tailed).

Differences between the magnitudes of the perceptual biases shown in these tasks are further evident from Figure 22, which depicts histograms of participants' scores in the face-matching, chimeric faces and grey scales tasks. In line with the non-significant

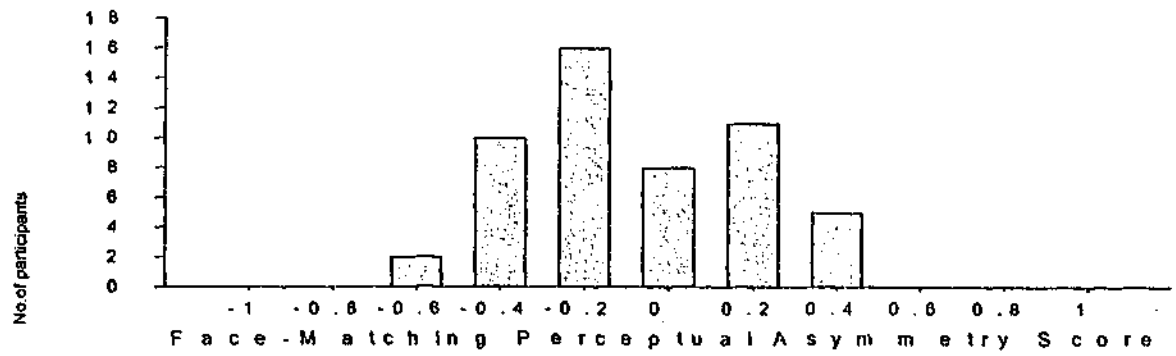
mean asymmetry score for the grey scales task, inspection of Figure 22c reveals that a small number of participants had extreme rightward biases, which increased the overall standard deviation of the group (thus reducing the likelihood of a significant effect for this task). In contrast, despite the similar mean asymmetry score for the face-matching task, fewer participants had such extreme rightward biases. Figure 22a shows a much tighter distribution centred around 0 (no bias), which indicates that the face-matching task is less discriminating of perceptual biases in this group compared with the other two tasks. The chimeric faces task yielded a strong leftward bias overall, and most participants showed this direction of bias.

5.2.3 Discussion

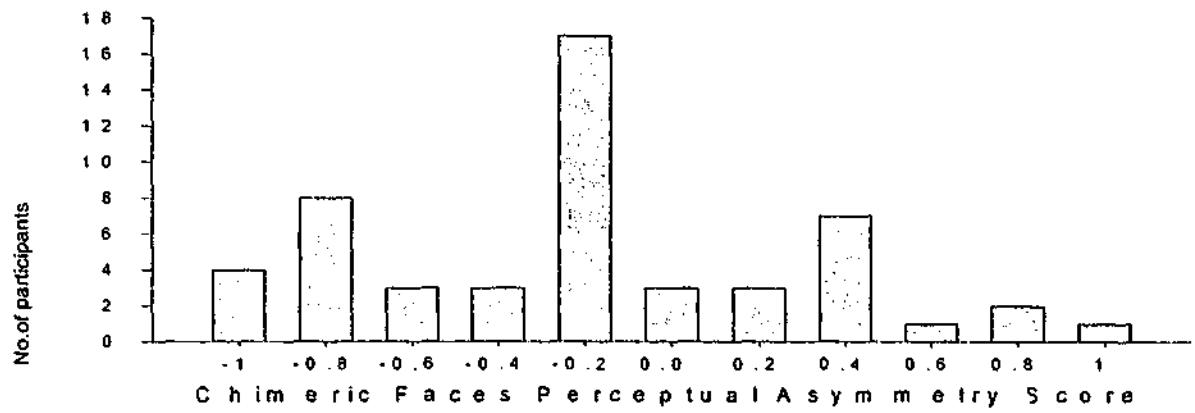
The aims of this study were to examine free-viewing perceptual biases in a large sample of normal, school-aged children, and to determine whether such biases are influenced by age. Results indicated that normal right-handed children, like normal right-handed adults (e.g., Luh, Rueckert, & Levy, 1991), show a bias for leftward features when making judgements of affect (happiness) in the chimeric faces task, and when making judgements of resemblance, in the face-matching task. This is consistent with Levine and Levy's (1986) findings of a leftward bias in primary-school-aged children when making judgements of affect in free-viewing conditions, and with the tachistoscopic study of face recognition in children by Young and Ellis (1976). Results also indicated that there was no significant effect of age on the magnitude of perceptual biases, a result that is also consistent with Levine and Levy's (1986) study. This is in contrast with the findings of Chiang et al. (2000), who found differences in the strength of perceptual bias for affect between 6-7 and 9-10 year olds. This may be due to differences in the stimuli used in the two studies; stimuli used in this study more closely resembled those of Levine and Levy (photographic face-stimuli), than those of Chiang et al. (who used fewer stimuli, and included a combination of cartoon and photographic face-stimuli).

The chimeric faces task was better at discriminating perceptual biases than the face-matching task. This is consistent with Luh, Rueckert, and Levy (1991) who found a larger and more consistent bias in adults with face stimuli, when emotion was a

a



b



c

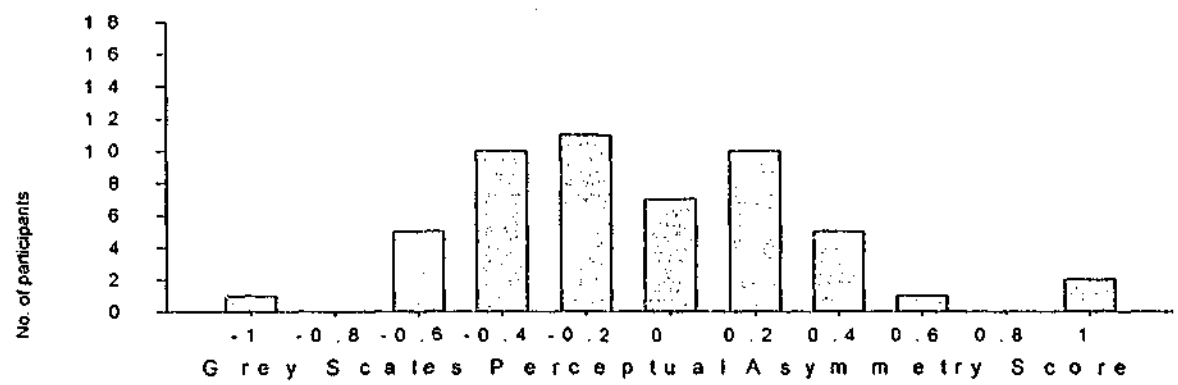


Figure 22: Histograms showing the number of normal children as a function of their performance (perceptual asymmetry score) on the face-matching task (a), chimeric face task (b), and the grey scales task (c). (Note that 1.0 on each x axis represents scores ranging between 0.81 and 1.00; 0.8 represents scores ranging between 0.61 and 0.80; 0.6 represents scores between 0.41 and 0.60; 0.4 represents scores between 0.21 and 0.40; 0.2 represents scores between 0.01 and 0.21; 0 represents scores of 0 (no bias); and the same range of scores applies to the negative scores.)

component in the judgement, compared to when gender was a component in the judgement. Similarly, Mattingley et al. (1993) found larger asymmetry scores for their chimeric faces task than the face-matching task, for both normal adults and left neglect patients. It is possible that this difference is due to the greater difficulty associated with comparing three stimuli (face-matching) than with comparing two stimuli (chimeric faces). It is also possible that the presence of an emotional (happy) expression augments right hemisphere involvement in face processing tasks (Magnussen et al., 1994).

Brightness judgements, though eliciting a strong leftward bias in normal adults (Mattingley, Bradshaw, Nettleton et al., 1994; Nicholls et al., 1999), revealed only a slight (and non-significant) leftward bias in children. This is inconsistent with adult studies, which suggest that the grey scales task elicits greater and more consistent asymmetry scores than the chimeric faces task (Mattingley, Bradshaw, Nettleton et al., 1994). Chiang et al. (2000) also found no significant leftward bias for their (non-facial) processing of shape (roundedness), but a significant leftward bias for numerosity judgements, in children. Taken together, these findings suggest that the hemispheric asymmetry for face processing emerges earlier during development than for other, non-facial judgement tasks.

5.3 Experiment 11

In Experiment 11 the same perceptual bias tasks were administered to right-handed children diagnosed with ADHD (combined type). It was predicted that if these children suffer from predominantly right hemisphere frontal-striatal dysfunction (Heilman et al., 1991; Castellanos et al., 1996), they should exhibit a reduced (or absent) leftward bias (cf. the findings for normal children in Experiment 10). Based on previous behavioural studies of ADHD (Voeller & Heilman, 1988; Adelstein, 1995; Sheppard et al., 1999) it is possible that a reversed *rightward bias* would be found.

5.3.1 Method

5.3.1.1 Participants

Twenty-three right-handed children with a diagnosis of ADHD (combined type), recruited mainly through child psychiatric outpatient settings, participated in this experiment. (Most of these children also participated in either Experiment 1 or 2.) Diagnoses were made by experienced clinicians in accordance with DSM-IV diagnostic criteria (American Psychiatric Association, 1994). The children were between 7 and 14 years of age, and the majority (15/23, or 65%) also had comorbid diagnoses: five children had oppositional defiant disorder (ODD), two children had a language disorder, two children had both ODD and a language disorder, two children had a learning disorder, one child had both learning and language disorders, one child had both language disorder and Tourette's syndrome, one child hand an anxiety disorder, and one child had both a learning and anxiety disorder. This is consistent with previous reports of the prevalence of comorbidities in children diagnosed with ADHD, which range from 50-80% (e.g., Tannock, 1998). Data for one child were excluded on the basis of lower than average IQ (< 80). Of those children prescribed stimulant medication (either methylphenidate or dexamphetamine), nine received their typical dose of medication before testing (1 – 4 hours). The other 13 children were tested off medication, where the last dose was administered at least 16 hours before testing so that any residual effects of medication would have been minimal.

Demographic details for the children are given in Table 9. Separate one-way ANOVAs (see Appendix L) revealed that the unmedicated and medicated children did not differ significantly in IQ, as measured by the Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1990; $F(1,20) = .167$, $p = .687$); age, $F(1,20) = 0.006$, $p = .940$; or on any of the measures of the Attention Deficit Disorder Evaluation Scale (ADDES; McCarney, 1995).

5.3.1.2 Materials and Procedure

The materials and procedures used were identical to those of Experiment 10. In addition, the school and the home versions of the attention deficit disorder evaluation scale (ADDES; McCarney, 1995), which is a behaviour rating scale based on DSM-IV

criteria, was filled out by teachers and parents of all children. Scoring of the ADDES results in scaled scores of inattention and hyperactive-impulsive behaviour, and an overall percentile ranking (based on American norms).

Table 9: Demographic details of medicated and unmedicated right-handed ADHD combined type children

	Unmedicated ADHD children (n = 13)	Medicated ADHD children (n = 9)
Mean Age (Standard Deviation (SD) in brackets)	10.2 (1.9)	10.3 (2.5)
Sex	Males = 10, Females = 3	Males = 8, Females = 1
Mean Full Scale IQ (SD in brackets)	99.8 (8.2)	101.4 (11.1)
Home rating scale – inattentive scale	2.2 (2.1)*	2.3 (2.4)
Home rating scale- hyperactivity/impulsivity scale	2.6 (2.0)*	3.3 (2.8)
Home rating Scale – percentile ranking	2.9 (3.7)*	5.7 (10.0)
School rating scale – inattentive scale	7.7 (1.9)***	7.6 (4.1)
School rating scale – Hyperactivity/impulsivity scale	8.2 (2.7)***	8.0 (4.5)
School rating scale – percentile ranking	29.7 (16.5)***	37.7 (30.0)

* the number of asterisks represents the number of unreturned rating scales

5.3.2 *Results*

As in Experiment 10, an asymmetry score was calculated for each task by subtracting the number of leftward responses from the number of rightward responses and then dividing by the total number of items. Single-sample t-tests revealed that the 22 ADHD children had a significant *leftward* bias on the face-matching task (mean asymmetry score = -0.0883, (S.D. = 0.14), $t(21) = -2.875$, $p = .009$), and the chimeric faces task (mean asymmetry score = -0.1773 (S.D. = 0.26), $t(21) = -3.160$, $p = .005$), but not on the grey scales task (mean asymmetry score = -0.1051 (S.D. = 0 .37), $t(21) = -1.337$, $p = .195$). Although the mean asymmetry score for the grey scales task was only fractionally different from that for the face-matching task, the standard deviation was larger for the former, implying greater variability in asymmetry scores for the group.

Table 10 shows the number and percentage of participants with leftward, rightward, and no biases, for all three tasks. A significantly greater number of participants showed a leftward bias in the face-matching task ($\chi^2_1 = 5.76$, $p = .027$, two-tailed), but not in the chimeric faces task ($\chi^2_1 = 4.26$, $p = .064$, two-tailed), or the grey scales task ($\chi^2_1 = 1.80$, $p = .262$, two-tailed)[9].

Table 10: The number (and percentage) of right-handed ADHD combined type participants (n = 16) showing leftward, rightward and no bias in face matching, chimeric faces and grey scales tasks.

	Face-matching task	Chimeric faces task	Grey Scales task
Leftward bias	16 (72.7%)	14 (63.6%)	13 (59.1%)
Rightward bias	5 (22.7%)	5 (22.7%)	7 (31.8%)
No bias	1 (4.5%)	3 (13.6%)	2 (9.1%)

[9] Note that assessing the one-tail probability did render the chimeric faces but not the grey scales score significant

As half of the participants were taking stimulant medication, results are also shown separately for unmedicated and medicated ADHD children. Figures 23 and 24 show histograms for unmedicated and medicated ADHD children on the face-matching, chimeric faces, and grey scales tasks. Qualitatively, histograms for the two groups of children do not appear to differ substantially in terms of response patterns. Compared to the normal children, ADHD children appear to show even less extreme rightward bias scores on the three tasks.

Table 11 shows the mean asymmetry scores for unmedicated and medicated ADHD children. Both groups showed a leftward bias on all three tasks, with the medicated group showing a stronger bias. One-way ANOVAs on the asymmetry scores of unmedicated and medicated ADHD children revealed that there was no significant difference between the groups (medicated versus unmedicated) in the face-matching task ($F(1, 20) = 2.24$, $p = 0.150$), the chimeric faces task ($F(1,20) = 0.331$, $p = 0.572$), or the grey scales task ($F(1,20) = 0.122$, $p = 0.730$). The absence of a significant difference may, however, be a reflection of the relatively small number of participants in each group.

Table 11: Mean asymmetry scores (with Standard Deviations in brackets) for medicated and unmedicated ADHD (combined type) children in face-matching, chimeric faces, and grey scales tasks.

	Unmedicated ADHD group	Medicated ADHD group
Face-matching task	- .0511 (SD = .11)	-.1420 (SD = .18)
Chimeric faces task	-.1500 (SD = .26)	-.2167 (SD = .28)
Grey scales task	-.0817 (SD = .39)	-.1389 (SD = .36)

5.3.3 Discussion

Results revealed that children with ADHD do not demonstrate the rightward bias previously observed in line bisection and letter cancellation tasks (Sheppard et al., 1999; Voeller & Heilman, 1988a) when processing faces and when making brightness judgements in free-viewing conditions. However, this could be due in part to

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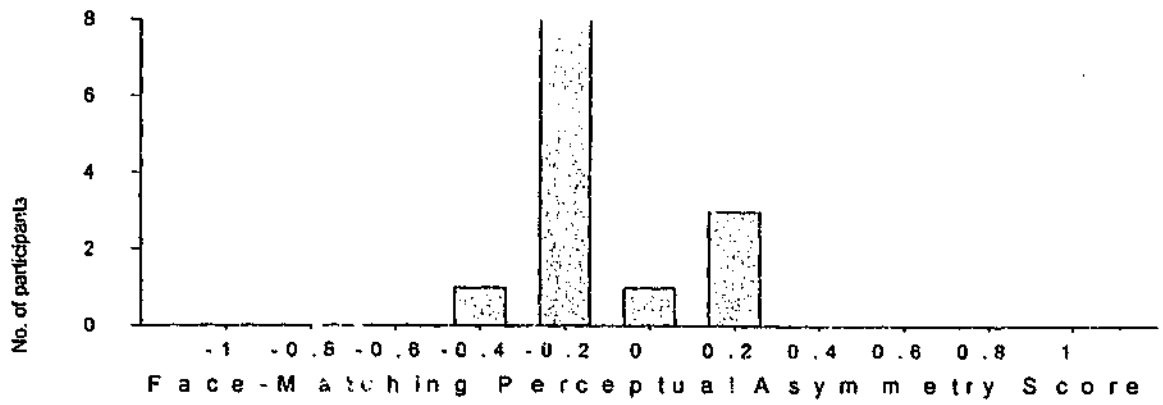

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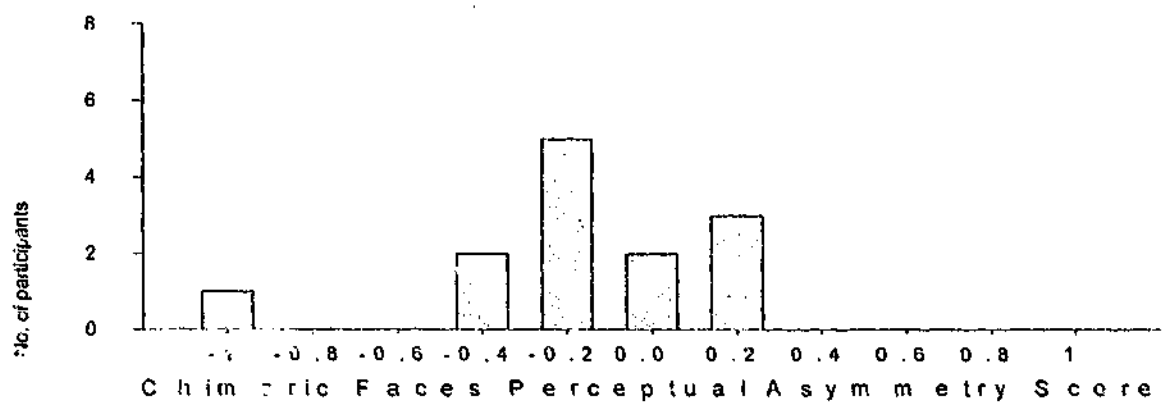

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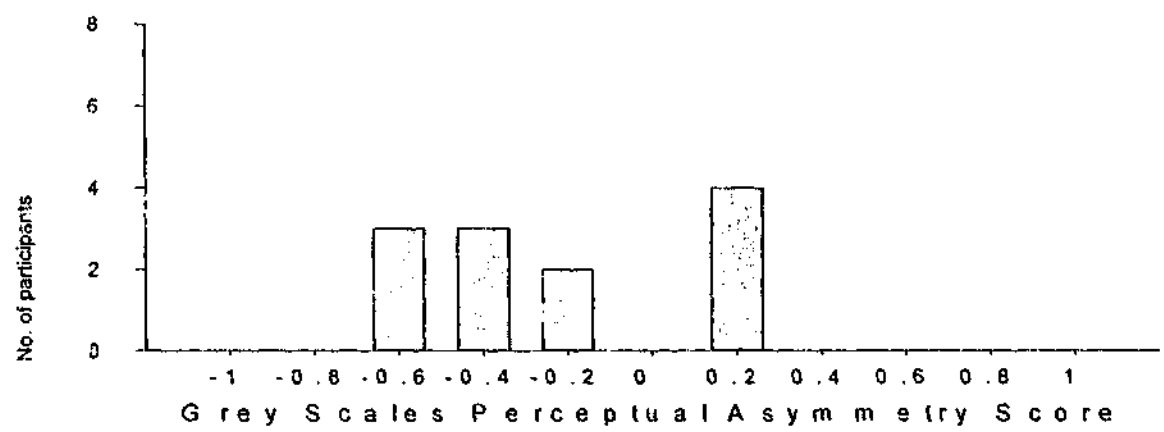
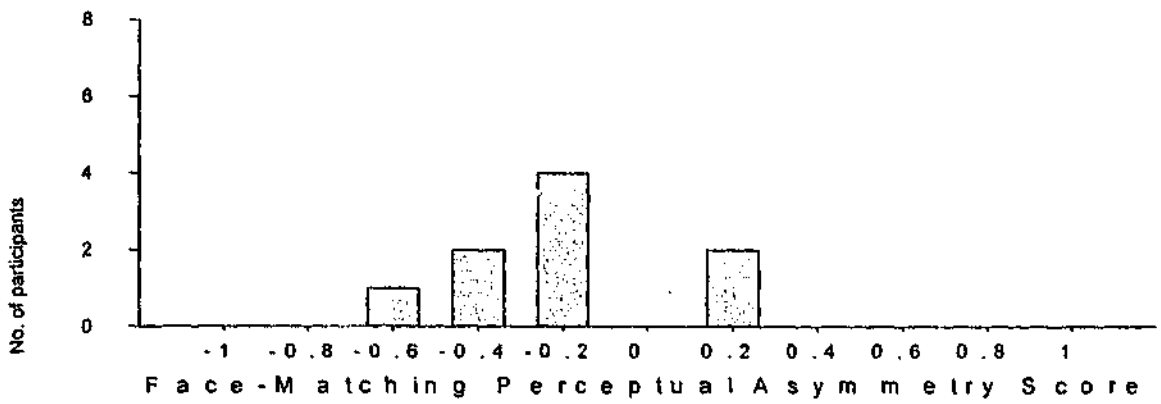


Figure 23: Histograms showing the number of unmedicated ADHD children as a function of their performance (perceptual asymmetry score) on the face-matching task (a), chimeric faces task (b), and the grey scales task (c). (Note that 1.0 on each x axis represents scores ranging between 0.81 and 1.00; 0.8 represents scores ranging between 0.61 and 0.80; 0.6 represents scores between 0.41 and 0.60; 0.4 represents scores between 0.21 and 0.4; 0.2 represents scores between 0.01 and 0.21; 0 represents scores of 0 (no bias); and the same range of scores applies to the negative scores.)

a



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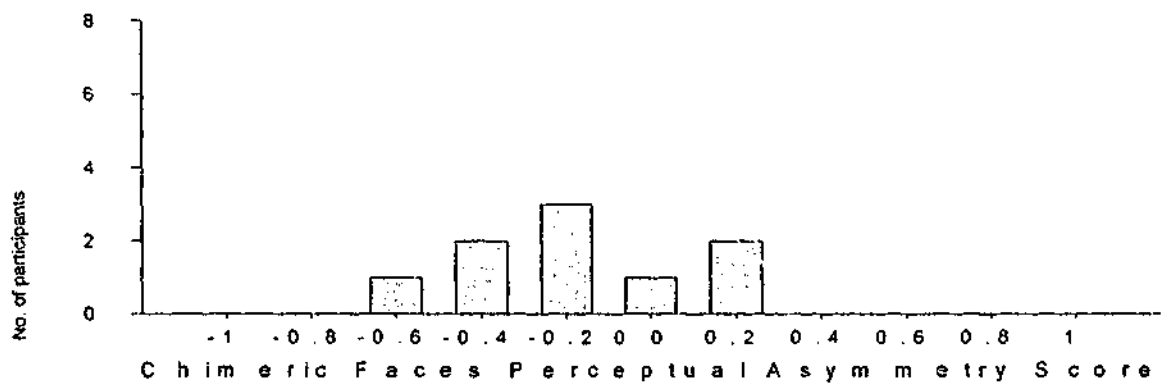

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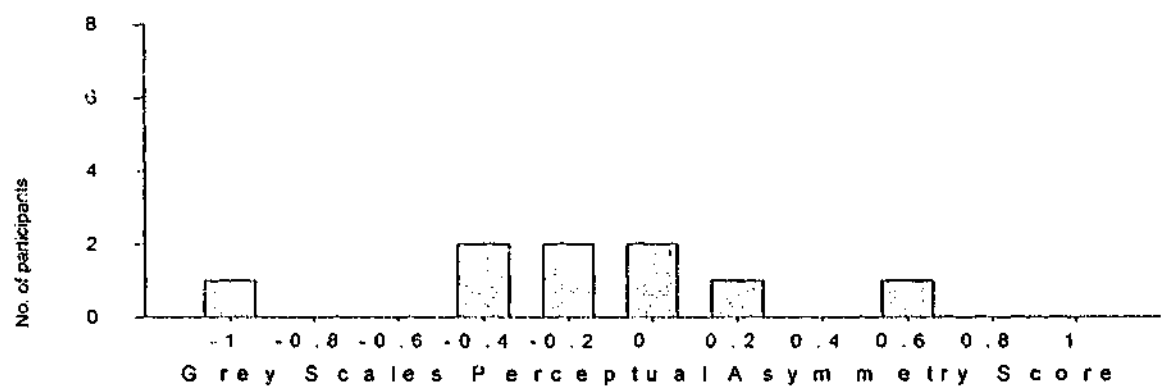


Figure 24: Histograms showing the number of medicated ADHD children as a function of their performance (perceptual asymmetry score) on the face-matching task (a), chimeric faces task (b), and the grey scales task (c). (Note that 1.0 on each x axis represents scores ranging between 0.81 and 1.00; 0.8 represents scores ranging between 0.61 and 0.80; 0.6 represents scores between 0.41 and 0.60; 0.4 represents scores between 0.21 and 0.4; 0.2 represents scores between 0.01 and 0.21; 0 represents scores of 0 (no bias); and the same range of scores applies to the negative scores.)

differences in comorbid diagnoses for the sample of ADHD children used in this study. A study by Malone, Couitis, Kershner, and Logan (1994) found that ADHD children with comorbid learning disorders largely accounted for the finding of a rightward bias on a letter cancellation task. In the present study only four of the ADHD children had comorbid learning disorders.

In this study, children with ADHD performed similarly to the normal children in Experiment 10, demonstrating a significant leftward bias for face-matching and chimeric faces tasks. The non-significant leftward bias for the grey scales task, which was observed in both normal and ADHD children, probably reflects greater variability between participants in this task. This suggests that the perceptual bias tasks employed in this study consistently show different magnitudes of lateralization in both normal and ADHD children, and that the processing of these stimuli may be dependent on distinct mechanisms. Consistent with this, Mattingley and colleagues (Mattingley et al., 1993; Mattingley, Bradshaw, Nettleton et al., 1994) examined lateral biases on facial and non-facial perceptual tasks in clinical and non-clinical adults, and found no significant correlations between scores on the different tasks.

A comparison of those children who were medicated with stimulant medication and those who were not failed to reveal any significant results, perhaps due to the small sample size in each group. Inspection of the data suggests that despite non-significant results, the medicated ADHD children tended to have larger leftward asymmetry scores than both unmedicated ADHD children and normal controls, which may perhaps be of statistical significance in a larger study. If this is indeed shown in future studies, this "improvement" of normal perceptual asymmetry will be consistent with a study of line-bisection (Sheppard et al., 1999), which indicated that stimulant medication "improved"/ normalized anomolous line-bisection performance.

It is possible that finding normal lateralization in children with ADHD is also due to the fact that the chimeric tasks measure different functions to line-bisection and letter cancellation tasks. In support of this, although Mattingley et al. (1994) found strong positive correlations between standard clinical tests of line bisection and cancellation in a group of right hemisphere patients with neglect, they found only low correlations

between scores on the chimeric faces and grey scales tasks, and scores on the standard clinical tests.

Whereas line bisection and letter cancellation tasks require manual responses, the free-viewing tasks used in this study are purely "perceptual" in nature, requiring only a verbal response. Letter cancellation and line bisection tasks also require *active spatial exploration*, whereas the perceptual tasks used in this study involve a comparative judgement of just two stimuli (three in the case of the face-matching task). In view of the absence of anomalous perceptual biases in ADHD children found in the present study, those findings that have previously been interpreted as lateralized attention deficits, or as visual field differences in selective attention, may in fact reflect abnormal *intentional (motor) responses*.

CHAPTER 6

EXPERIMENTS 12 AND 13: BIMANUAL COORDINATION IN CHILDREN WITH ADHD AND THEIR CONTROLS

6.1 Introduction to Experiments

As reviewed in Chapter 2, deficits in both fine and gross motor skills have been reported in children with ADHD (Piek et al., 1999; Doyle et al., 1995). Although deficits are not apparent in ADHD using simple motor tasks such as finger-tapping (Seidman et,al., 1995), they become apparent with more complex motor tasks such as those requiring replication of coordinated sequences of movement (Carte et al., 1996). Similarly, although patients with Huntington's disease are reported to be able to perform simple unimanual (and bimanual) movements, they may be impaired in performing more complex unimanual tasks including sequential movement, and in performing complex bimanual tasks where movement of the two limbs differ (Johnson et al., 2000). Patients with schizophrenia (Bellgrove et al., 2001) and Parkinson's disease (Johnson et al., 1998) have also been found to experience difficulties performing complex bimanual tasks. These deficits in bimanual coordination have been interpreted as reflecting dysfunction of the basal ganglia, and the subsequent effects on its output areas, particularly the supplementary motor area (SMA; Johnson et al., 1998; Johnson et al., 2000).

The SMA is thought to be involved in the control of voluntary movement, particularly bimanual coordination, with reported observations that lesions to the SMA (and the corpus callosum) result in deficits in bimanual coordination (Cunnington, Bradshaw, & Iansek, 1996). Cunnington et al. (1996) outline various neurophysiological and clinical studies that suggest that the SMA is involved in the coordination of bimanual tasks. Such findings include electric stimulation studies, which show that unilateral stimulation of the SMA elicits responses on both sides of the body (e.g., Fried et al., 1991), neuroimaging studies that show greater SMA activity for bilateral than unilateral movements (e.g., Kristeva, Keller, Deecke, & Kornhuber, 1979), and studies that show greater SMA involvement for asymmetric bimanual tasks where hands are

rotated in opposite directions, rather than symmetric bimanual tasks where hands are rotated in identical directions (e.g., Uhl, Lindinger, & Kornhuber, 1993).

Coordinated bimanual movement is more than a simple simultaneous production of two separate and individually different unimanual movements, otherwise one could execute any given pair of unimanual movements simultaneously, with neither being distinguishable from the unimanual movements (Rogers, Bradshaw, Cunnington, & Phillips, 1998). This is demonstrated by the ease of performing the unimanual movement of patting one's head, and that of rubbing one's stomach, compared to the difficulty in performing these two unimanual movements simultaneously. Typically, bimanual performance degrades as the movements of the two limbs increasingly differ (Rogers et al., 1998). This is evident in the differences in performance of in-phase and out-of-phase bimanual movements. In-phase movements typically involve symmetrical hand movements, with for example, the right hand moving clockwise in a circular motion and the left hand moving anti-clockwise in a circular motion (e.g., Johnson et al., 1998; Johnson et al., 2000). This movement involves homologous muscle groups active simultaneously; it is relatively easy to perform because the timing of the hands is identical and a common programming element may be involved (Johnson et al., 2000). Out-of-phase bimanual movements, however, typically involve asymmetrical movements, with each hand being at a different point in the movement cycle, so that there is a phase difference between the two hands. Out-of-phase movements result in homologous muscles being active sequentially rather than simultaneously and are much more difficult to produce (Johnson et al., 2000). In healthy adults, out-of-phase bimanual movements have been found to revert to the easier symmetrical in-phase movements, especially at faster movement speed (Rogers et al., 1998).

Although many studies have examined motor coordination in ADHD, few studies have specifically examined bimanual movement in ADHD. The grooved pegboard test, where participants are required to place pegs both unimanually and bimanually in a board within a specified time period, is one task that allows examination of bimanual movement (Lezak, 1983). Pegboard studies have discriminated schizophrenic patients from controls in terms of greater impaired bimanual pegboard scores (Heinrichs,

Ruttan, Zakanis, & Case, 1997); however, studies comparing individuals with ADHD to controls have only found impaired bimanual scores in preschoolers (Mariani & Barkley, 1997), and not adolescents (Oie & Rund, 1999; Reeve & Schandler, 2001).

In Experiment 12, children with ADHD and their controls performed bimanual in-phase and out-of-phase movements. Half of the trials were conducted at a fast pace (2 Hz) and half at a slow pace (1 Hz), with a metronome acting as a cue for speed. It was predicted that if children with ADHD had problems with bimanual coordination they would be significantly more impaired than controls in performing both in-phase and out-of-phase movements, particularly at a faster speed. In Experiment 13 the effect of stimulant medication on the performance of in-phase and out-of-phase movements was explored in a child with ADHD, using an off-on-on-off single-subject design.

6.2 Experiment 12: Bimanual coordination in unmedicated ADHD children compared to controls

6.2.1 Method

6.2.1.1 Participants

Twelve boys with ADHD combined type and their matched controls participated in this experiment. All boys were aged between 8 years and 14 years of age, with a mean age of 11 years. Only four of the twelve ADHD boys had no comorbid diagnoses. The remaining eight boys had the following comorbid diagnoses: two boys with language disorder, one boy with anxiety, two boys with behavioural problems (oppositional defiant disorder), two boys with both language disorder and learning disability, and one boy with both language disorder and behavioural problems (oppositional defiant disorder). This ratio of comorbid diagnoses is consistent with reports of prevalence rates of comorbid diagnoses in children with ADHD that range between 50-80% (Tannock, 1998). Seven of the children with ADHD were recruited from a public paediatric outpatient unit (Southern Health), and the other five had previously participated in Experiments 1 or 2. The controls were recruited through friends and colleagues. All children with ADHD were tested off medication, where the last dose

was administered at least 16 hours before testing; thus any residual effects of medication would have been minimal. Table 12 indicates the demographic details for the ADHD children and their matched controls. One-way ANOVAs (see Appendix P) indicated that ADHD children and controls did not differ in terms of age ($F(1, 22) = 0.283$, $p = .600$) or full scale IQ ($F(1, 22) = 2.80$, $p = .109$). Children also performed in the expected directions on the Attention Deficit Disorder Evaluation Scale (ADDES; McCarney, 1995), with ADHD children scoring lower on the school and home scaled scores and percentile rankings than control children.

6.2.1.2 Materials and Apparatus

As in Experiments 1-3, each child's full scale IQ was measured using the Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1990), which, depending on the age of the child, took between 15- 40 minutes to administer. The school and the home version of the attention deficit disorder evaluation scale (ADDES; McCarney, 1995) was filled out by teachers and parents of all children. Scoring of the ADDES generates scaled scores of inattention and hyperactive-impulsive behaviour, and an overall percentile ranking.

A detailed description of the apparatus can be found in Johnson et al. (1998). The apparatus is shown in Figure 25, and consists of a pair of cranks, comprising two wheels (26 cm in diameter) mounted side-by-side. Each wheel had a knob set 8 cm from the axis of rotation. Participants were seated with the cranks directly in front of them, centred on the participant's midline. Movement of left and right hands was recorded via separate data channels, and was sampled at 200 Hz. A code-wheel and optical decoder unit measured the position of each wheel in degrees. The angular displacement was measured for each hand, and from this mean and standard deviation measures of the relative positions of the hands were derived. An electronic metronome was used to indicate the target velocity of movement.

6.2.1.3 Procedure

Each participant performed three blocks of each condition. Note that one ADHD boy only completed two blocks of each condition because he refused to perform the third

Table 12: Demographic details of the ADHD children and their controls.

	ADHD children	Control children	1-way ANOVA p-values
Handedness	Right = 11 Left = 1	Right = 11 Left = 1	-
Mean age (standard deviation, SD)	11.00 (1.7)	11.35 (1.6)	.600
Mean full scale IQ (SD)	98.33 (10.2)	106.83 (14.4)	.109
ADDES – home version Mean inattentive scaled score (SD)	2.63 (2.2)*	11.58 (1.9)	.000
ADDES – home version Mean hyperactive-impulsive scaled score (SD)	3.81 (1.4)*	12.25 (1.7)	.000
ADDES – home version Mean overall percentile ranking (SD)	4.64 (3.8)*	70.75 (20.1)	.000
ADDES – school version Mean inattentive scaled score (SD)	7.56 (3.5)***	11.63 (1.8)****	.011
ADDES – school version Mean hyperactive-impulsive scaled score (SD)	7.22 (3.6)***	12.00 (1.6)****	.004
ADDES – school version Mean overall percentile ranking (SD)	30.33 (28.5)***	71.63 (17.2)****	.003

* the number of asterisks represents the number of rating scales not returned

block (not surprisingly, this boy also had a comorbid diagnosis of oppositional defiant disorder). The order of presentation of the four conditions, in-phase slow movements, in-phase fast movements, out-of-phase slow movements, and out-of-phase fast movements, was counterbalanced (see Appendix N). A metronome speed of 1 Hz signalled the slow target speed and a speed of 2 Hz signalled the fast target speed, with participants instructed to rotate the wheels once for every beat of the metronome.

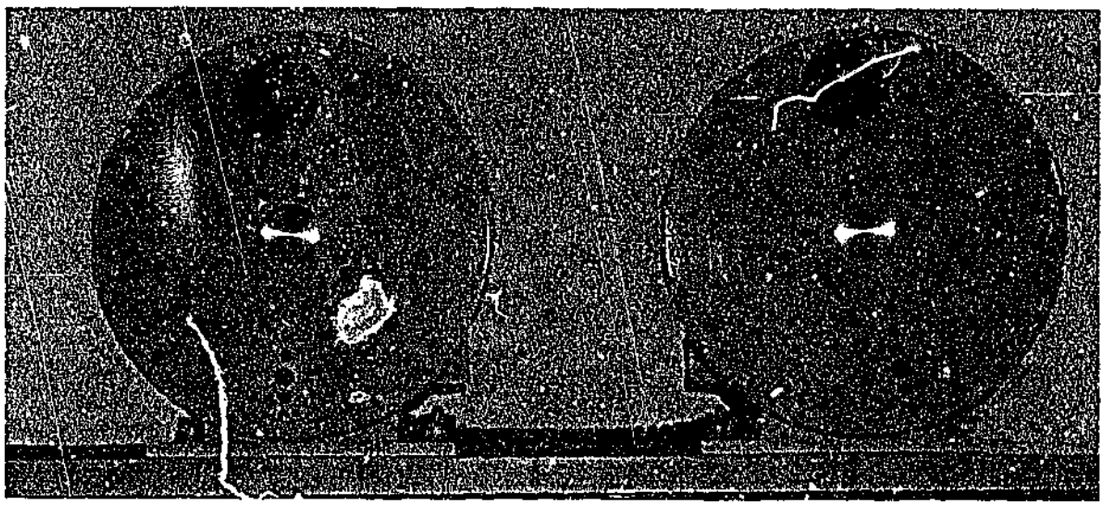


Figure 25: The cranks apparatus.

Participants always moved their right-hand in a clockwise direction and their left-hand in an anti-clockwise direction. For the in-phase movements, participants positioned their hands at the top of the wheels and attempted maintain the 0° phase difference between the hands throughout the movement (see Appendix O). For the out-of-phase movements participants positioned their right hand at the top, and their left hand at the bottom of the wheel, and tried to maintain the 180° phase difference between the hands throughout the movement (see Appendix O). Each movement was recorded for twenty seconds at 200 Hz, in this way the hand-position was monitored every 5 ms. Participants participated in a general practice session, followed by specific practice for each condition. The task took approximately 30 minutes to administer.

6.2.1.4 Data Analysis

The data were analysed as in Johnson et al. (1998) and Rogers et al. (1998). The first and last five seconds of the movement recordings were excluded, leaving the mid ten-second segment for data analysis.

Phase histograms

The difference between the hands was calculated every 50 ms and placed into one of 24 data bins, each of which represented 15° segments of the movement cycle. Phase histograms were plotted to represent the movement performance of each group. Perfect performance in the in-phase task was a score of 0°, and perfect performance in the out-of-phase task was a score of 180°. Scores on the left side of zero indicated that the left hand was leading the right, and vice versa.

From the displacement data, velocity was derived to determine the velocity of the crank at each 50 ms interval. From these displacement and velocity data, four dependent variables were calculated:

(a) Variation in coordination pattern

Variation in the coordination pattern measures the ability to maintain a constant, stable relationship between the two hands. It is the standard deviation of the difference (in degrees) between the right and left hand over time and measures the variability of the difference between the left and right hands. Lower scores indicate better performance.

(b) Accuracy in coordination pattern

Accuracy in the coordination pattern is a measure of the relationship between the two hands over time, giving the difference in degrees between actual and target phase angle. Therefore, for both in- and out-of-phase movements, a perfect score is zero, at which target performance and actual performance are equivalent.

(c) Variation in velocity

Variation in velocity indicates the variability of movement velocity, as represented by the standard deviation. Lower scores indicate consistent, well-controlled movements.

(d) Accuracy of velocity

Accuracy of velocity measures the difference between the target velocity (fast = 2 Hz, slow = 1 Hz) and the actual velocity. Negative scores denote movements that are slower than the target speed, while positive scores denote movements that are faster than the target speed.

Correlations

The experimental data of the ADHD children and their controls were examined separately for correlations with ADDES scaled scores of inattention, scaled scores of hyperactivity-impulsivity and overall percentile ranks.

Two separate group (ADHD, controls) x speed (slow, fast) x hand (left, right) mixed-factorial ANOVAs were conducted for the accuracy and variation in velocity data for the in-phase and out-of-phase tasks. Similarly, two group x speed ANOVAs were used to analyze the accuracy and variation in coordination pattern data for the in-phase and out-of phase tasks.

6.2.2 Results

6.2.2.1 Results for the in-phase task

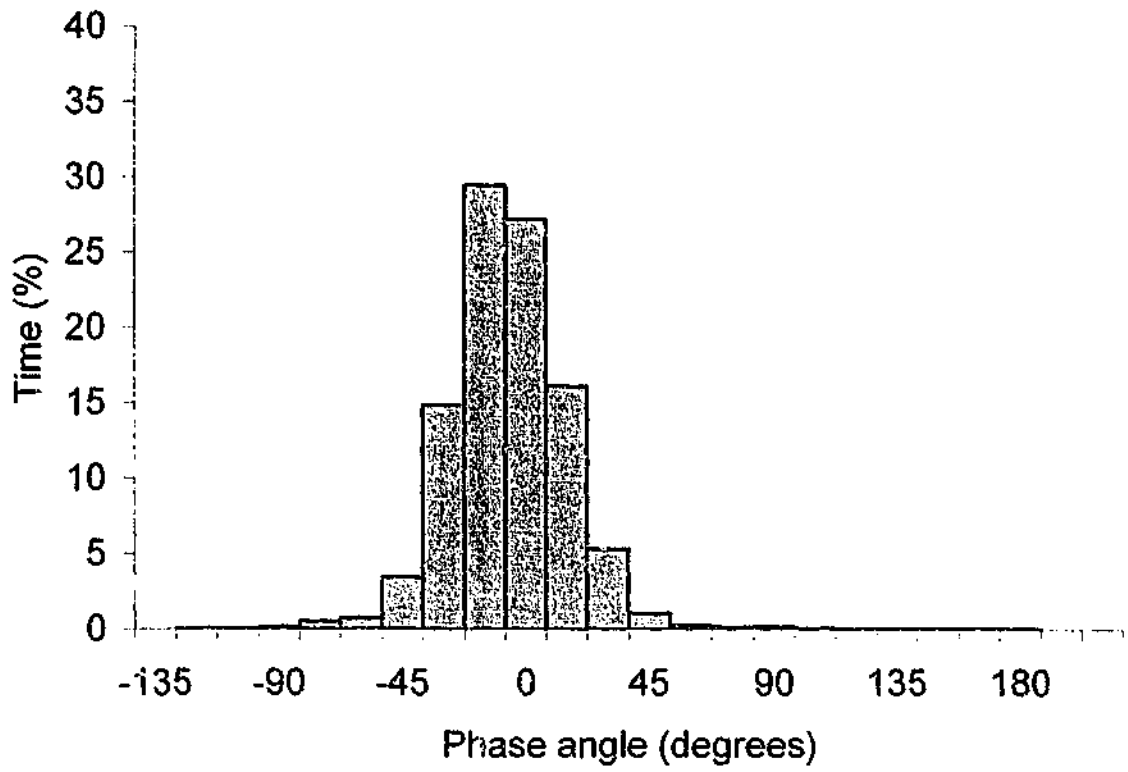
Phase histograms

The phase histograms in Figures 26 and 27 indicate that both groups performed the required movement for most of the time, at both slow and fast speeds (most scores were around zero). Children with ADHD, however, were much more variable, spending a lower proportion of time in the correct in-phase relationship (evident by the spread of data on the histograms). They were also less accurate than controls at both speeds (evident by the reduced height of the histogram at zero).

Variation in coordination pattern

There was a significant main effect of group ($F(1,22) = 15.72$, $p = .001$) with ADHD children (39°) showing more variable movements than the controls (22°). Movements at the fast speed (38°) were also significantly more variable than at the slow speed

a



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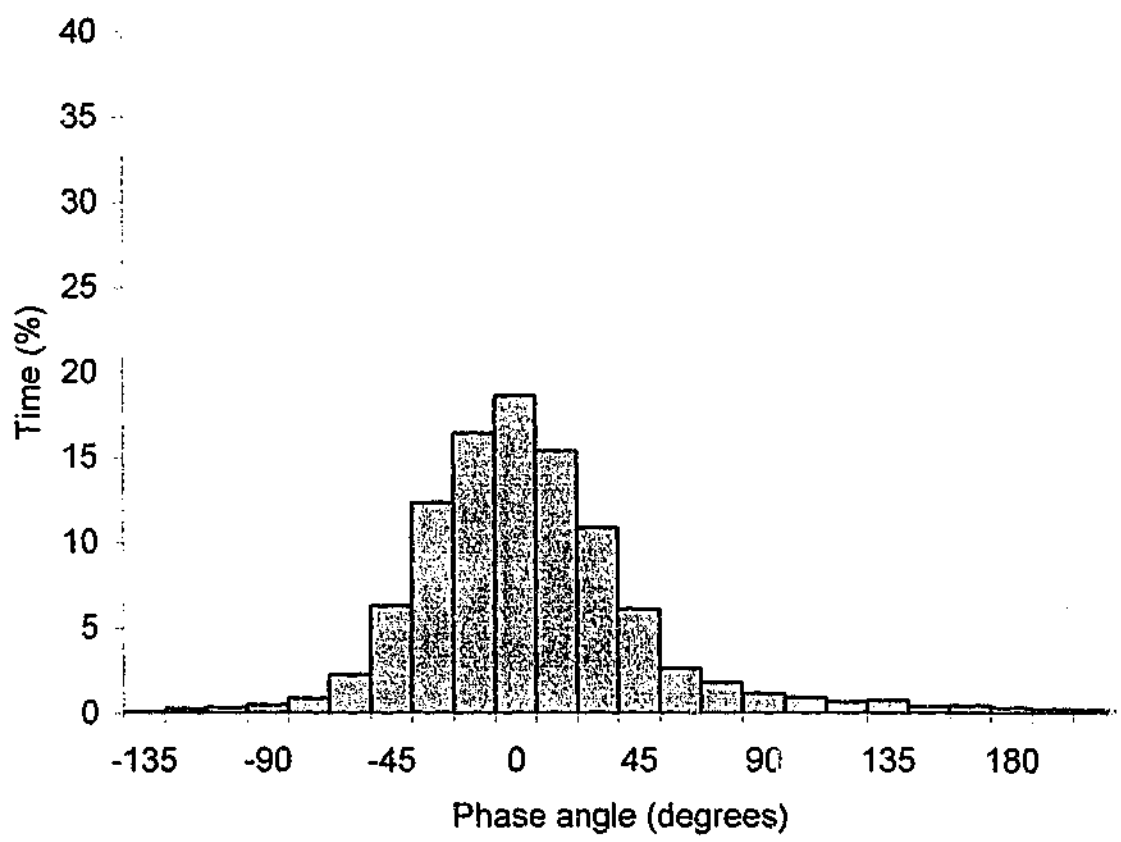
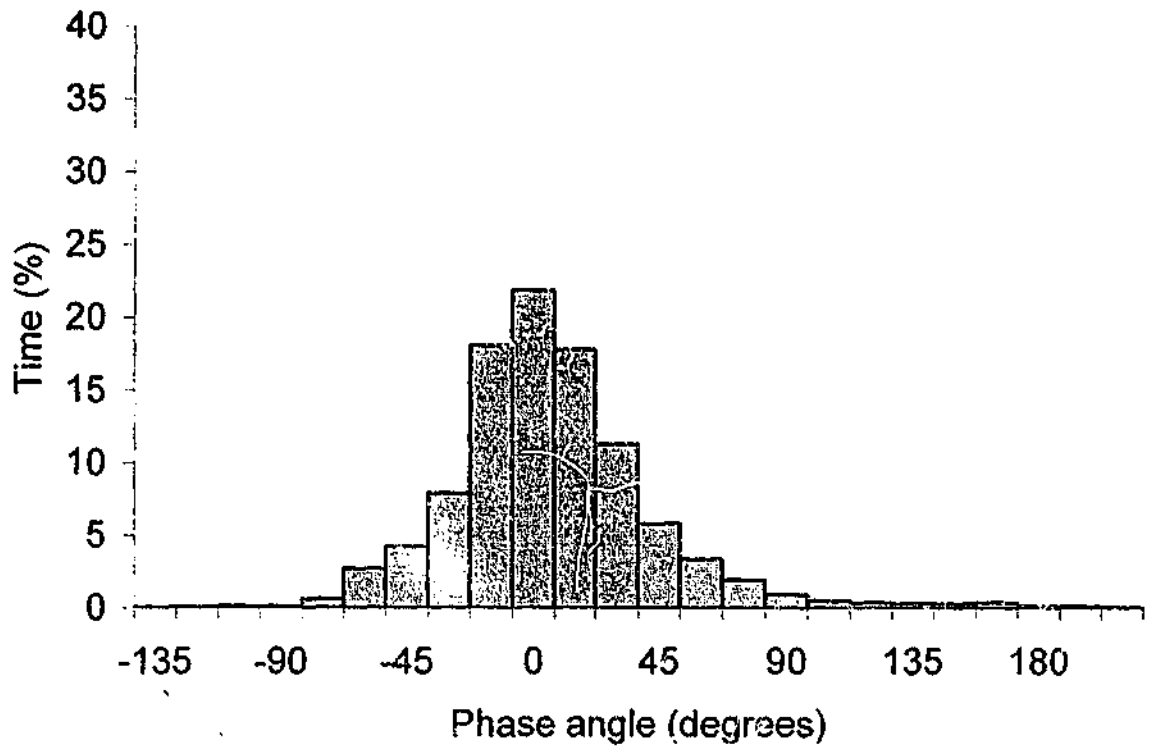


Figure 26: In-phase histograms for a) control children and b) children with ADHD at the slow speed

a



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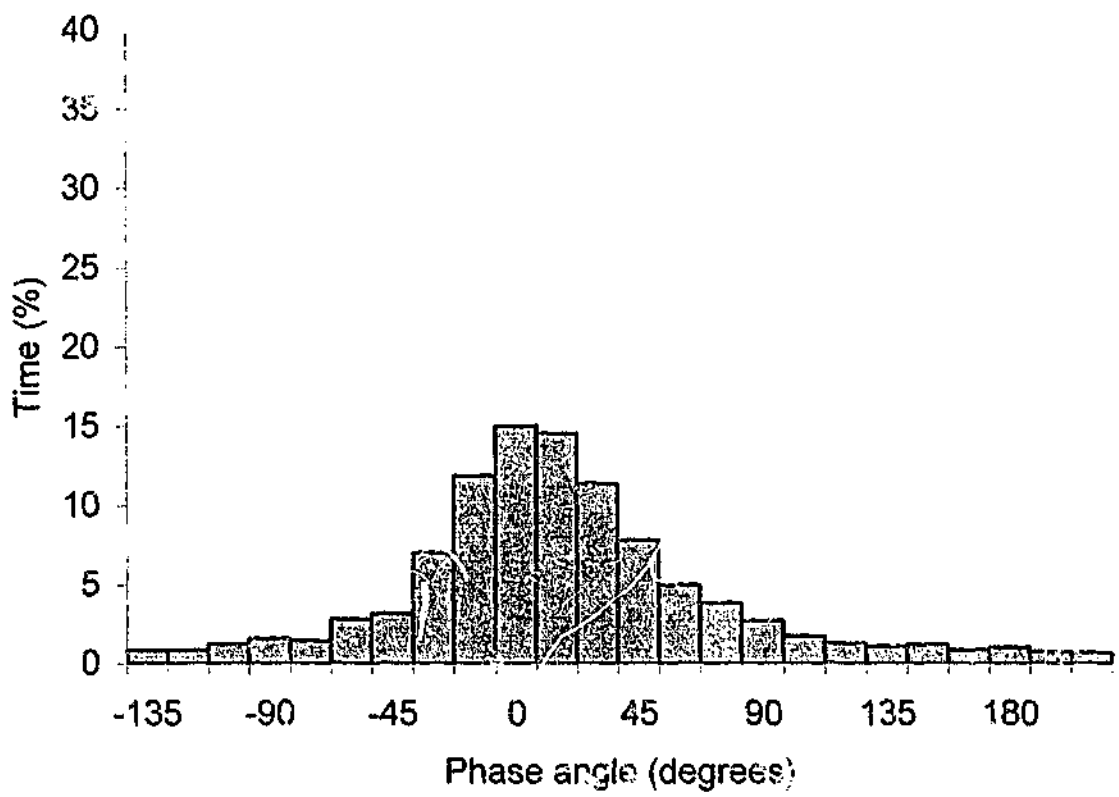


Figure 27: In-phase histograms for a) control children and b) ADHD children at the fast speed

(23°; $F(1,22) = 22.57$, $p < .001$) for all participants. There was no significant interaction.

Accuracy of coordination pattern

The ADHD children (28°) did not perform the in-phase task as accurately as the control group (14°; $F(1, 22) = 6.60$, $p = .018$). All children were significantly less accurate at the fast speed (27°) than the slow speed (16°; $F(1, 22) = 8.531$, $p = .008$). There was no significant interaction between group and speed.

Variation in velocity

The ADHD children (SD $\pm$ 0.50 Hz) were significantly more variable in velocity than controls (SD $\pm$ 0.24 Hz: $F(1,22) = 9.62$, $p = .005$). All participants were significantly more variable with their left hand (SD $\pm$ .39 Hz) than their right (SD $\pm$ .35 Hz; $F(1,22) = 17.93$, $p < .001$). This main effect must be interpreted in light of the significant hand x group ($F(1,22) = 6.47$, $p = .019$) and speed x hand ($F(1,22) = 11.42$, $p = .003$) interactions. The former interaction appears to be driven by the greater variability in velocity of ADHD children with their left compared to their right hands (left hand = SD $\pm$ .54 Hz, right hand = SD $\pm$ .47 Hz) compared to the control children (left hand = SD $\pm$ .25 Hz, right hand = SD $\pm$ .23 Hz). The significant speed x hand interaction appears to reflect greater variability in velocity for the left than the right hand, at the fast (left hand = SD $\pm$ .44 Hz, right hand = SD $\pm$ .36 Hz) but not the slow speed (left hand = SD $\pm$ .34 Hz, right hand = SD $\pm$ .35 Hz). These two-way interactions must be interpreted in light of the significant three-way speed x hand x group interaction ($F(1, 22) = 5.15$, $p = .033$). The effects of speed and hand on variation in velocity are plotted separately for the ADHD and normal children in Figure 28. It appears that control children are more variable at a fast than slow speed, and that ADHD children are more variable with their left hand at a fast speed. Follow-up with separate speed x hand subanalyses for ADHD and control children revealed that control children showed a near-significant effect of speed ($F(1,11) = 4.68$, $p = .053$). In contrast, ADHD children showed a significant effect of hand ($F(1, 11) = 15.52$, $p = .002$) and a significant speed x hand interaction ($F(1, 11) = 11.15$, $p = .007$). Further subanalyses

of this interaction indicated a significant effect of hand at a fast ($F(1,11) = 24.8$, $p < .001$) but not at a slow ($F(1,11) = 0.58$, $p = .461$) speed.

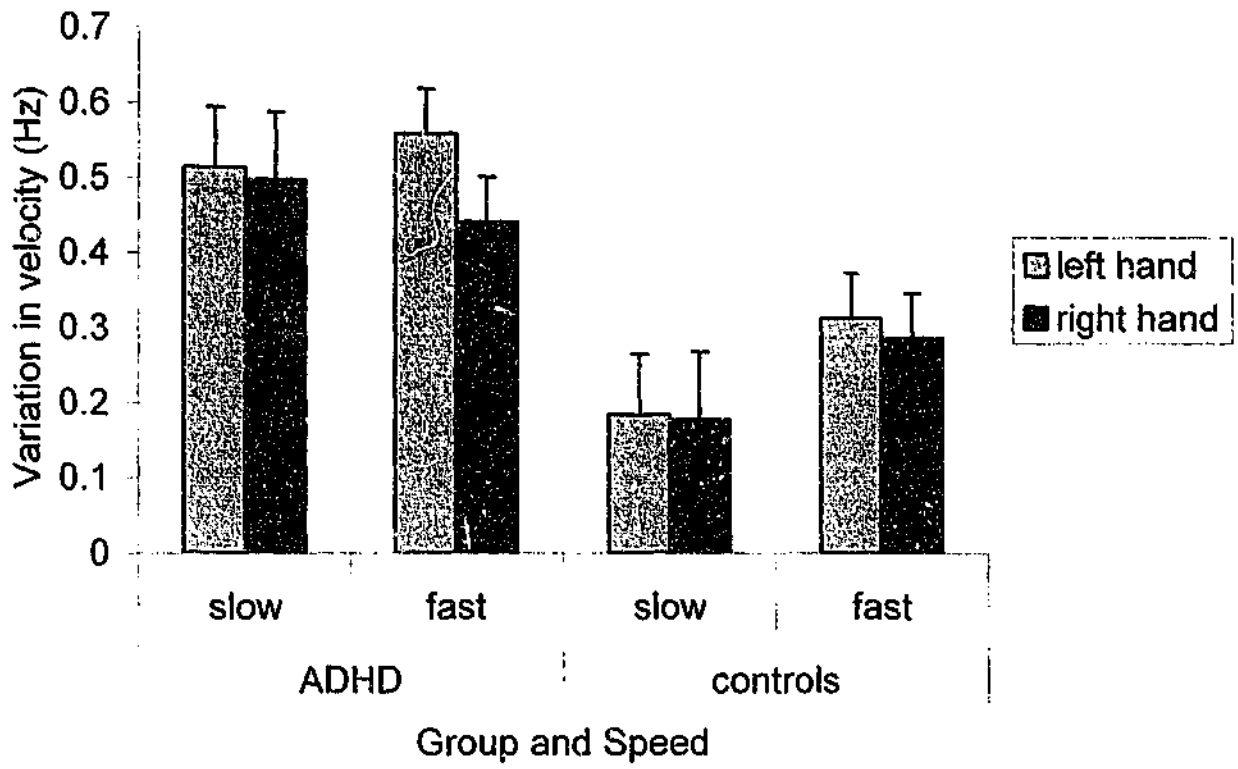


Figure 28: Variation in velocity for ADHD and control children at slow and fast speeds, for the left and the right hand. Standard error bars are shown.

Accuracy of velocity

ADHD children were able to perform this task at the same velocity as controls. There was a trend for both groups to perform the in-phase movements too fast, particularly at the fast (+.16 Hz) compared to the slow (+.03 Hz) speed ($F(1, 22) = 4.13$, $p = .052$). There was also a trend for the effect of hand ($F(1, 22) = 3.81$, $p = .064$), reflecting faster movements than the target velocity with the left hand (+.079 Hz) compared to the right hand (+ .048 Hz).

Correlations with ADDES scores

No significant correlations were found between any of the measures of the ADDES for in-phase movements of ADHD children. For the normal children scaled scores for

inattentiveness on the home ADDES version correlated negatively with accuracy of coordination at the slow speed ($r(12) = -.713$, $p = .009$), and accuracy in coordination at the fast speed correlated negatively with overall percentile rank on the home ADDES version ($r(12) = -.681$, $p = .015$). Variation in velocity for the right hand at fast speed correlated negatively with both scaled scores of inattentiveness ($r(8) = -.846$, $p = .008$) on the school ADDES version, and overall percentile rank ($r(8) = -.809$, $p = .015$) on the school ADDES version. Thus normal children whose behavioural measures showed better scores on home ratings of (in)attention and overall better home rated behaviour also tended to perform more accurately in coordinating in-phase movements at fast and slow speeds. Similarly, children with better school ratings of (in)attention, and overall better school rated behaviour, also tended to perform less variably in velocity using the right hand to make in-phase movements at the fast speed.

6.2.2.2 Results for the out-of-phase task

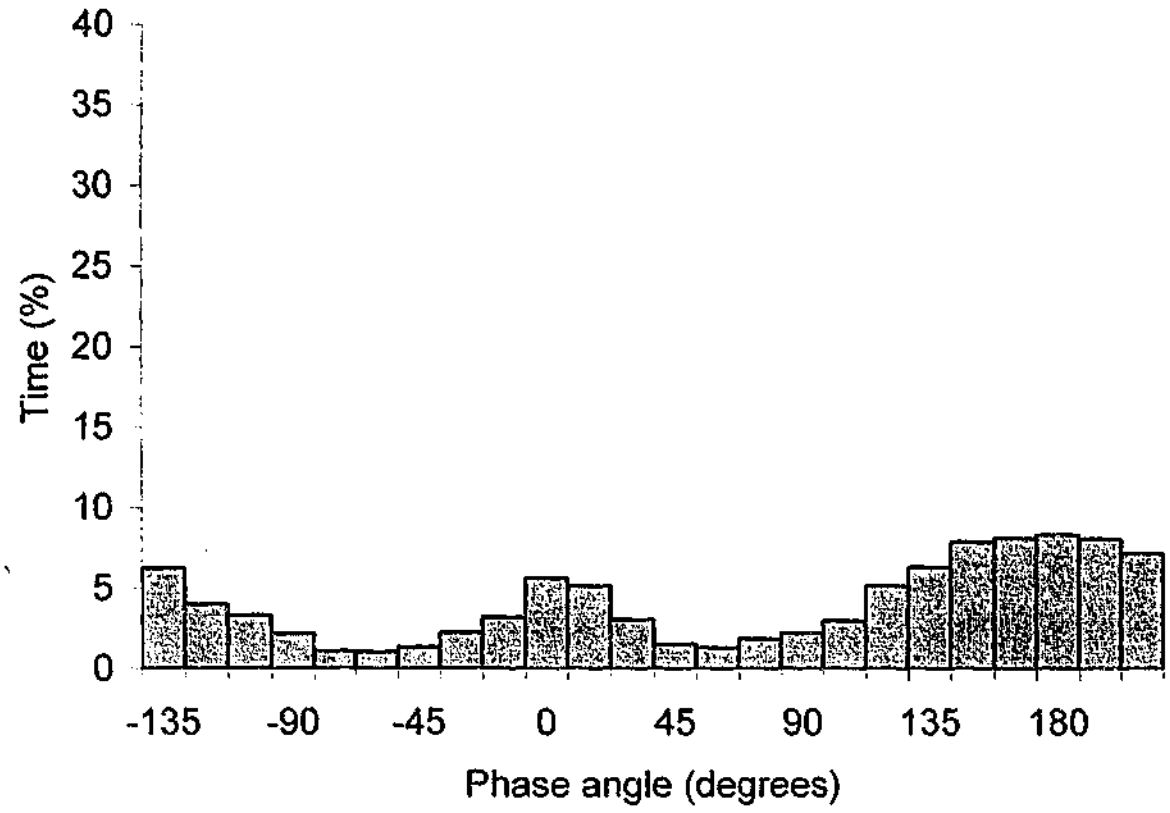
Phase histograms

The phase histograms depicted in Figures 29 and 30 indicate that, at the slow speed, both controls and ADHD children had difficulties performing the out-of-phase movements (depicted by the flat peak at 180°, and another peak at 0°, which indicates inappropriate in-phase movement). Similarly, at the fast speed, both controls and ADHD children had difficulties performing the out-of-phase movements. The controls appeared to perform slightly better than the ADHD children at the fast speed; they showed a short, wide-spread peak around 180°, whereas the ADHD children showed a relatively flat distribution.

Variation in coordination pattern

The ADHD children (63°) were significantly more variable in their movements than control children (44°; $F(1,22) = 8.95$, $p = .007$). In addition, all participants performed movements at the fast speed (63°) more variably than at the slow speed (44°; $F(1,22) = 22.26$, $p < .001$).

a



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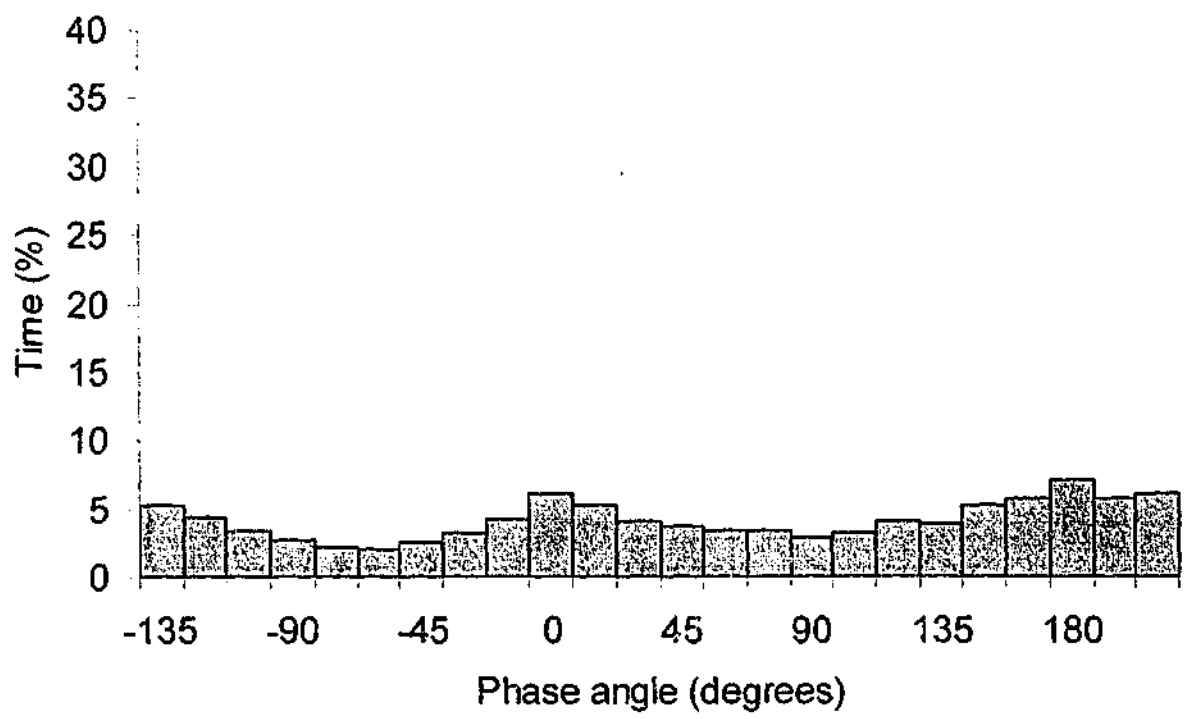
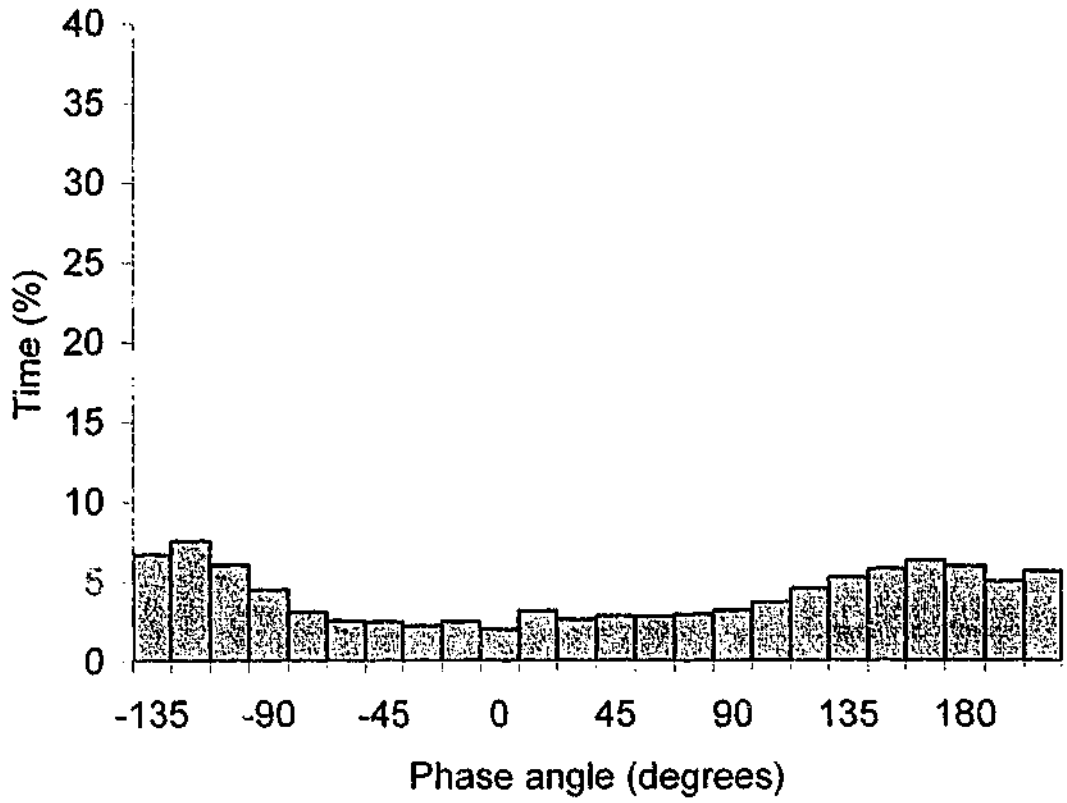


Figure 29: Out-of-phase histograms for a) control children and b) children with ADHD, at the slow speed

a



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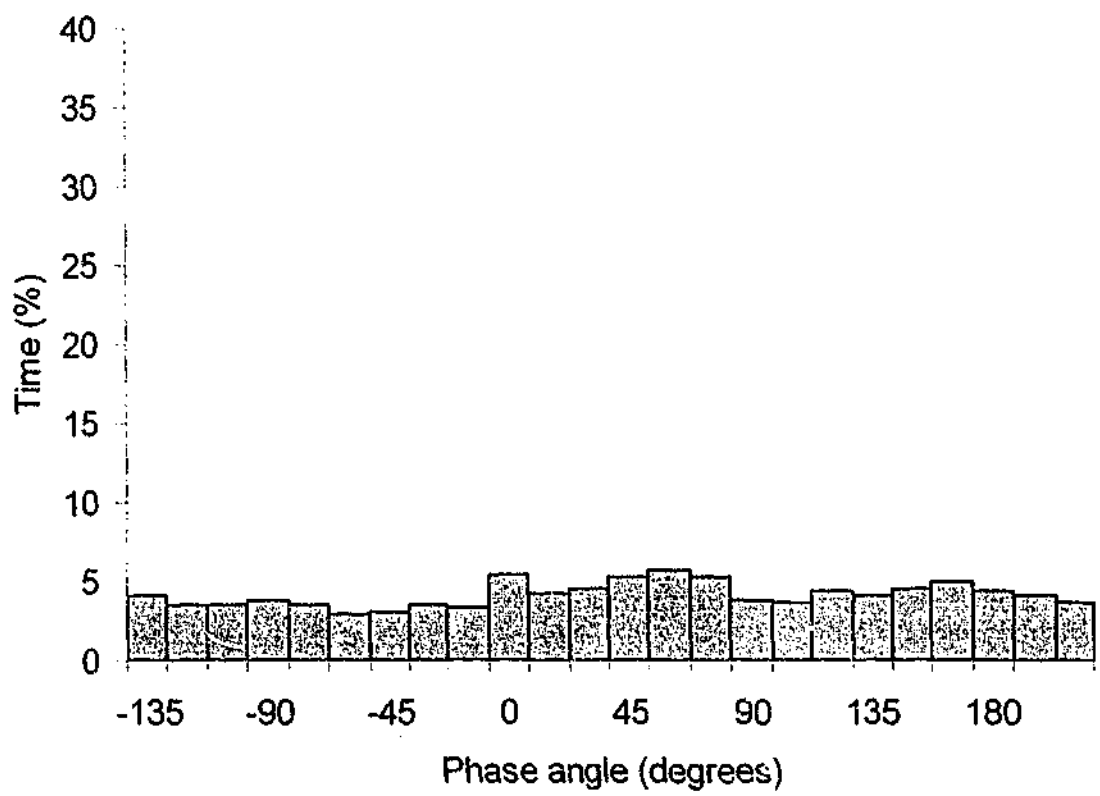


Figure 30: Out-of-phase histograms for a) control children and b) ADHD children, at the fast speed.

Accuracy of coordination pattern

ADHD children (99°) appeared to be less accurate than controls (65°), but this did not reach significance ($F(1, 22) = 3.51$, $p = .074$). There were no significant effects for this measure.

Variation in velocity

The controls were more stable in velocity (SD = ± .25 Hz) than the ADHD children (SD = ± .56 Hz; $F(1, 22) = 16.05$, $p = .001$). All participants were more stable in velocity with their right hand (SD = ± .38 Hz) than their left hand (SD = ± .43 Hz; $F(1,22) = 18.20$, $p < .001$), and showed a trend for more stable velocity at the slow (SD = ± 37) than the fast (SD = ± .43; $F(1, 22) = 3.76$, $p = .066$) speed.

Accuracy of velocity

ADHD children were able to perform the task at the same velocity as controls. Both groups performed the out-of-phase movements too fast, particularly at the fast speed (+.313 Hz) compared to the slow speed (+.043 Hz; $F(1,22) = 8.04$, $p = .010$). Movements were also faster than the target velocity with the left hand (+.208 Hz) compared to the right hand (+.147 Hz; $F(1,22) = 12.59$, $p = .002$).

Correlations with ADDES scores

Only one significant correlation was found between the ADDES scores and out-of-phase movements made by the ADHD children. Variation in coordination pattern at the slow speed correlated positively with overall percentile ranks as rated by parents ($r(11) = .650$, $p = .030$). Thus, somewhat unexpectedly, more severe parent-rated behaviour was associated with less variation in coordination pattern at a slow speed. For normal children, however, accuracy in coordination at the slow speed correlated negatively with scaled scores of inattentiveness on the school version of the ADDES ($r(8) = -.716$, $p = .046$). Variation in velocity at the fast speed (using the right hand) also correlated negatively with school scaled scores of inattention ($r(8) = -.714$, $p = .047$). Thus normal children who received better scores on school rated (in)attention also tended to perform out-of-phase movements more accurately at the slow speed, and performed more consistently with the right hand in terms of velocity at the fast speed.

6.2.3 *Discussion*

Results indicated that both ADHD children and the controls could perform the simple in-phase movement, and that both groups were more accurate and less variable at the slow than at the fast speed. The ADHD children were, however, significantly less accurate and less stable than control children in their maintenance of the in-phase relationship between the two hands. They were also more variable in velocity, even though they performed in-phase movements at the same mean velocity as controls. The lack of accuracy in coordination coupled with performance at the same mean velocity as controls suggests that ADHD children were not less accurate than controls simply because they were trading speed for accuracy.

Somewhat contrary to predictions was the finding that ADHD children did *not* perform less accurately than controls when making the complex out-of-phase movement. However, there was a trend in this direction ($p = .074$), which may become significant with a larger sample. This lack of significant difference between the groups may also to be due to the fact that *both ADHD children and controls* could not maintain the out-of-phase movement at either speed. It is possible that poor performance of the control children may have resulted in a floor effect.

All children were equally (in)accurate in performing out-of-phase movements at fast and slow speeds, although they showed greater variability for out-of-phase movements at the fast speed. ADHD children were able to perform the out-of-phase task at the same velocity as controls, and both groups performed the out-of-phase movements faster than the target velocity, especially at the fast speed, and when using the left rather than the right hand. Nevertheless, the ADHD children were more variable than controls in both velocity and maintaining the out-of-phase relationship between the two hands.

Results also indicated that children with ADHD showed greater variation in velocity with their left than their right hand when making in-phase movements at the fast speed. In the out-of-phase task *all* children showed more accurate and stable velocity with their right rather than left hand. Thus fast (but not slow) speed revealed a left hand deficit in the ADHD children in the simple in-phase task. In the more difficult out-of-

phase task, the hand asymmetry was apparent in all children. As most of the children were right-handed these results indicate that the preferred hand was generally better controlled than the non-preferred hand in making more difficult movements. This is consistent with a study by Rogers, Bradshaw, Cunnington and Phillips (1998), which showed that the non-preferred hand of both right and left-handed adults contributed more to error in bimanual coordination than did the preferred hand.

Only one significant correlation was found between the bimanual coordination measures and the ADDES scores for the ADHD children. This correlation suggested, somewhat unexpectedly, that more severe parent-rated ADHD behaviour was associated with less variability in these children's out-of-phase movements. A greater number of ADDES scores for normal children correlated significantly with measures of the bimanual coordination task. Better scores on school and home ratings of (in)attention and overall percentile ranks were correlated with greater accuracy in coordinating in-phase movements at fast and slow speeds, and with less variability in velocity for in-phase movements at the fast speed. Correlational analyses also revealed that normal children who received better scores on school-rated (in)attention tended to perform out-of-phase movements more accurately at the slow speed, and more consistently with the right hand at fast speed in terms of velocity. The finding that measures of (in)attention tend to correlate with bimanual coordination measures may reflect an attentional component of the task.

Table 13 lists the impairments found with this bimanual cranks task in various patient groups. Not only does this task clearly differentiate between ADHD children and controls, it also appears to tap different deficits in various clinical conditions. ADHD children most closely resemble Huntington's disease, and then Parkinson's disease and schizophrenia patients. They appear to least resemble Tourette's syndrome and obsessive-compulsive disorder patients.

Lesions to the supplementary motor area and the corpus callosum have been observed to result in deficits in bimanual coordination (Cunnington et al., 1996). Thus, the deficits in bimanual coordination observed in this study may reflect dysfunction in these brain areas of ADHD children. Neuroimaging studies have indeed reported

Table 13: The pattern of group effects on various measures of the bimanual cranks task in adults with Tourette's syndrome, obsessive-compulsive disorder, schizophrenia, Huntington's disease, and Parkinson's disease, compared to the current findings in children with ADHD.

	Tourette's syndrome adults	**Obsessive-compulsive disorder adults**	**Adults with chronic schizo-phrenia**	**Adults with Hunting-ton's disease**	**Adults with Parkin-son's disease**	**ADHD children in this study**
	Howells (2001)	Howells (2001)	Bellgrove et al. (2001)	Johnson et al. (2000)	Johnson et al. (1998)	
In-phase variation in coordina-tion pattern	TS = controls	OCD = controls	SCZ more variable than controls	HD more variable than controls	PD more variable than controls	ADHD more variable than controls
In-phase accuracy of coordina-tion pattern	TS = controls	OCD = controls	SCZ = controls (trend for SCZ to be less accurate than controls, p = .088)	HD less accurate than controls	PD less accurate than controls	ADHD less accurate than controls
In-phase variation in velocity	TS = controls	OCD = controls	SCZ more variable than controls	HD more variable than controls	PD more variable than controls	ADHD more variable than controls
In-phase accuracy of velocity	TS less accurate than controls	OCD = controls	SCZ = controls	HD = controls	PD = controls	ADHD = controls

	Tourette's syndrome adults	Obsessive-compulsive disorder adults	Adults with chronic schizo-phrenia	Adults with Hunting-ton's disease	Adults with Parkin-son's disease	ADHD children in this study
	Howells (2001)	Howells (2001)	Bellgrove et al. (2001)	Johnson et al. (2000)	Johnson et al. (1998)	
Out-of-phase variation in coordina-tion pattern	TS = controls	OCD = controls	SCZ = controls	HD more variable than controls	PD = controls	ADHD more variable than controls
Out-of-phase accuracy of coordina-tion pattern	TS = controls	TS = controls controls more accurate at fast speed	SCZ less accurate than controls	HD less accurate than controls	PD less accurate than controls	ADHD = controls Trend for ADHD to be less accurate than controls, p = .074
Out-of-phase variation in velocity	TS = controls	OCD = controls	SCZ = controls	HD more variable than controls	PD more variable than controls at slow speed only	ADHD more variable than controls
Out-of-phase accuracy of velocity	TS less accurate than controls	OCD = controls OCD more accurate at slow than fast speed	SCZ less accurate controls	HD = controls	PD = controls	ADHD = controls

reduced size of the corpus callosum in individuals with ADHD (Giedd et al., 1994; Baumgardner et al., 1996; cf. Castellanos et al., 1996); smaller cerebellum (Castellanos et al., 1996; Berquin et al., 1998); and smaller than normal structures of the basal ganglia (Castellanos et al., 1996).

Previous studies, using pegboard tasks (Oie & Rund, 1999; Reeve & Schandler, 2001; Mariani & Barkley, 1997) to study bimanual coordination in children with ADHD, have not consistently shown deficits in these children compared to controls. In comparison, the present study suggests that deficits in bimanual coordination may be evident even on a simple bimanual task. Whilst ADHD children could perform the in-phase movement on the cranks, they were more variable and less accurate in their coordination pattern in comparison to controls. Although ADHD children were significantly more variable, they were not significantly less accurate in their coordination pattern on a more complex bimanual out-of-phase movement task, compared to controls. However, they did show a *trend* for less accurate performance, which may become significant using a larger sample of children. Further, this finding of a lack of impairment in accuracy in performing complex out-of-phase movements may be due to a floor effect caused by normal children performing very poorly on this task. In fact, unlike normal adults who have been shown to be able to maintain the out-of-phase movement at least at the slow speed (Johnson et al., 1998), normal children could not maintain the out-of-phase movement at either speed, suggesting that coordination of complex asymmetrical movements of the hands develops later than 14 years of age. This may be consistent with immaturity of the corpus callosum. While myelination of the corpus callosum is thought to be complete at around 9-10 years of age (Thatcher, Walker, & Giudice, 1987; Jeeves, Silver, & Milne, 1988), it has been reported to continue developing (increasing in size) up to the mid-20s (Pujol, Vendrell, Junque, & Marti-Vilalta, 1994). It would therefore be of interest to administer this task to adults with ADHD in order to investigate whether bimanual coordination deficits on a complex task are evident in this disorder.

6.3 Experiment 13: Single subject design: Effects of stimulant medication on bimanual coordination: an off-on-on-off design.

The aim of this experiment was to conduct a preliminary investigation into the effects of stimulant medication on the bimanual coordination of a child with ADHD, combined type.

6.3.1 Participant

PO is a right-handed boy aged 7 years and 8 months at the time of testing, who has a diagnosis of ADHD combined type. He was first diagnosed with ADHD by a paediatrician when he was aged three years. Although he has not been diagnosed with a comorbid disorder, he did have difficulties learning to read when he started school. This improved upon completion of a specialist reading recovery program. PO is of average intelligence with a Full Scale IQ of 102 (as measured by the Kaufman Brief Intelligence Test; Kaufman & Kaufman, 1990), and takes 10 mg of methylphenidate in the morning and 5 mg at lunch-time. His home version ADDES rating scale indicated a scaled score of 4 for inattentiveness and a scaled score of 6 for hyperactivity-impulsivity, placing him at the 10th percentile overall. His school version ADDES rating scale indicated a scaled score of 8 for both inattentiveness and hyperactivity-impulsivity, placing him at the 27th percentile overall. PO was tested using the cranks task from Experiment 12 in the following sequence: off medication, on medication, on medication and off medication. When PO was tested off medication his last dose of methylphenidate was administered 8.5 and 10.5 hours prior to testing. When he was tested on medication he was tested 0.5 and 1.0 hour after having taken his normal 10 mg dose of methylphenidate.

6.3.2 Apparatus and Method

The task used was identical to the task used in Experiment 12. PO performed in-phase movements at both slow and fast speeds, but performed out-of-phase movements only at the slow speed, in order to reduce trial length. Three trials of each condition were administered, and the order of presentation of the three conditions was counterbalanced (see Appendix Q).

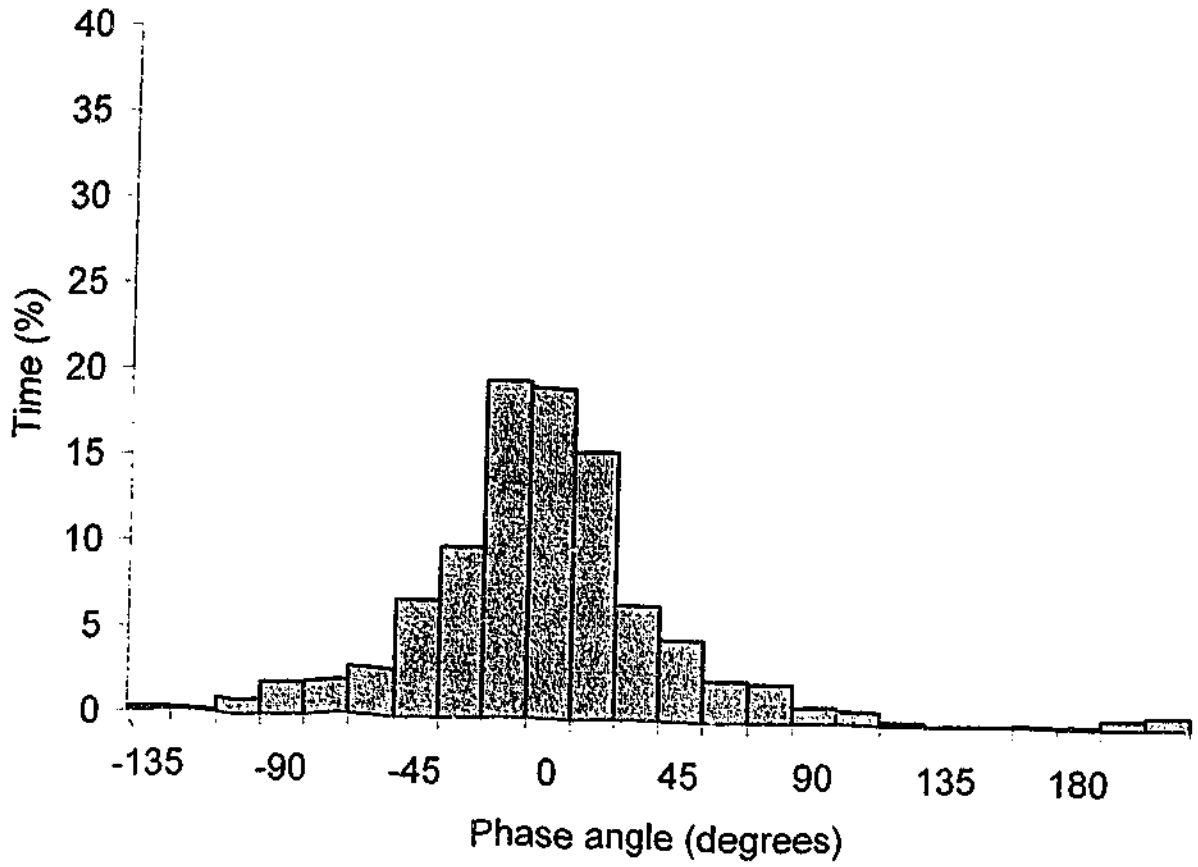
6.3.3 Results

6.3.3.1 Results for the in-phase task

Phase histograms

The phase histograms in Figures 31 and 32 indicate that PO performed the required in-phase movement most of the time, both off and on medication. When PO was off medication, however, he appeared to be more variable, spending a lower proportion of time in the correct in-phase-relationship (evident by the spread of data on the

a



b

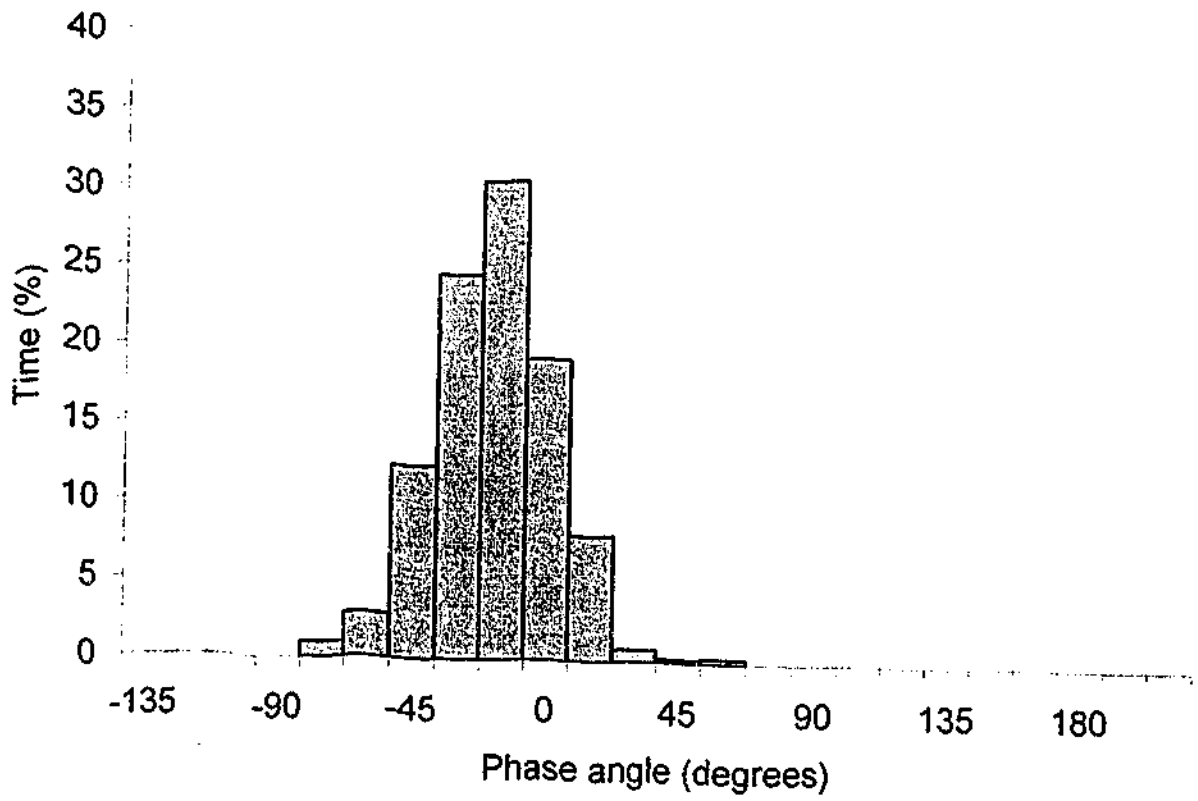
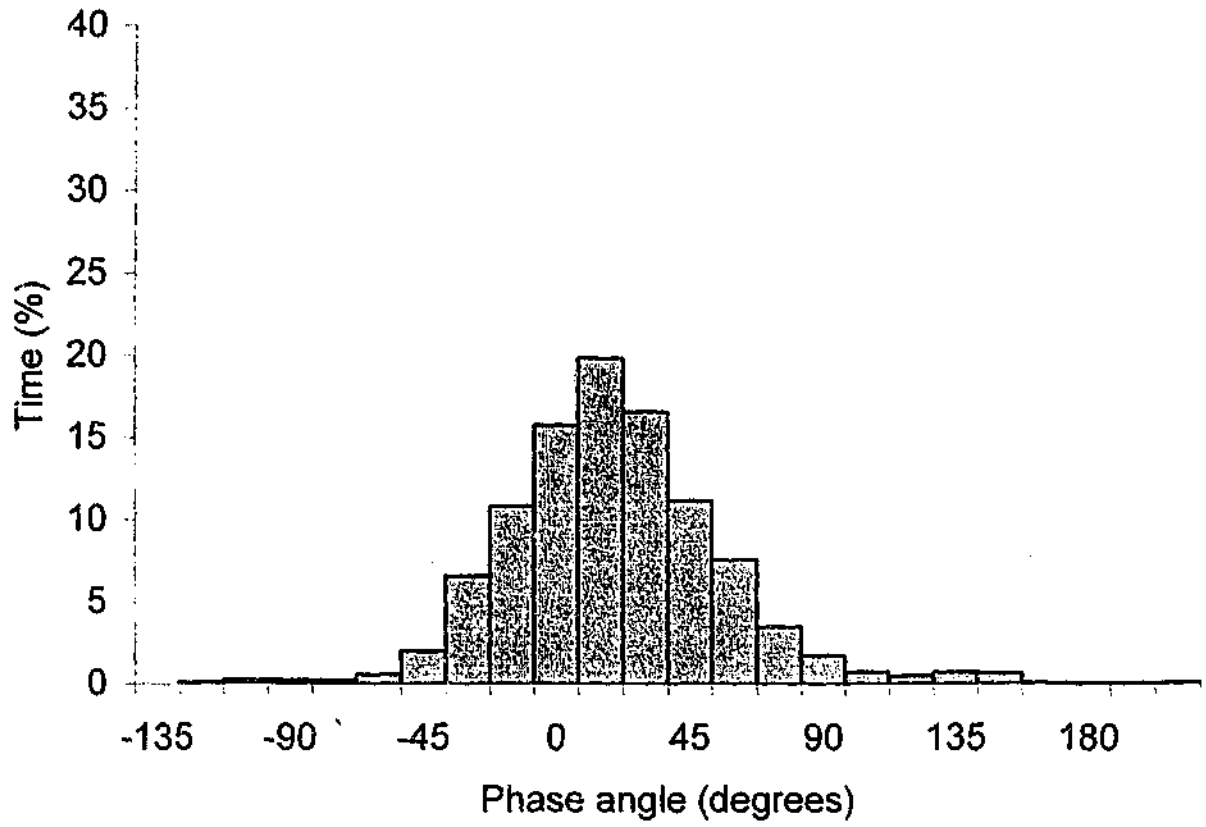


Figure 31: In-phase histograms for PO a) off medication and b) on medication, at the slow speed.

a



b

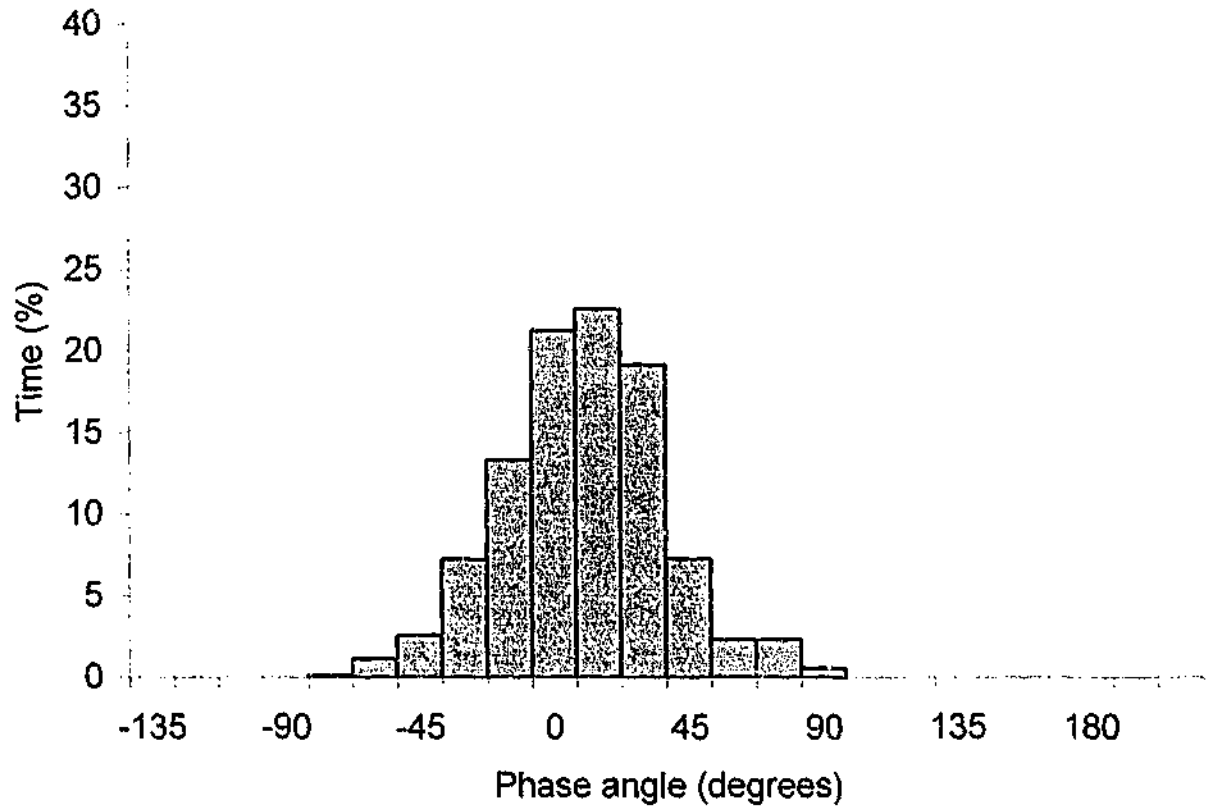


Figure 32: In-phase histograms for PO a) off medication and b) on medication, at the fast speed.

histograms), especially at the slow speed. He also appeared to be less accurate at the fast speed when off than on medication (evident by the reduced height of the histogram at zero).

Variation in coordination pattern

The variation in coordination pattern on and off medication at slow and fast speeds is depicted in Figure 33. It appears that PO shows less variable movements when on medication than when off medication, especially at the slow speed. Paired sample t-tests (see Appendix R) indicated that this difference in variation, when on and off medication, was only significant for the slow ($t(5) = -5.499$, $p = .003$) but not the fast ($t(5) = -1.697$, $p = .151$) speed. However, the non-significant finding is likely to be due to the small number of trials (6) conducted for each condition.

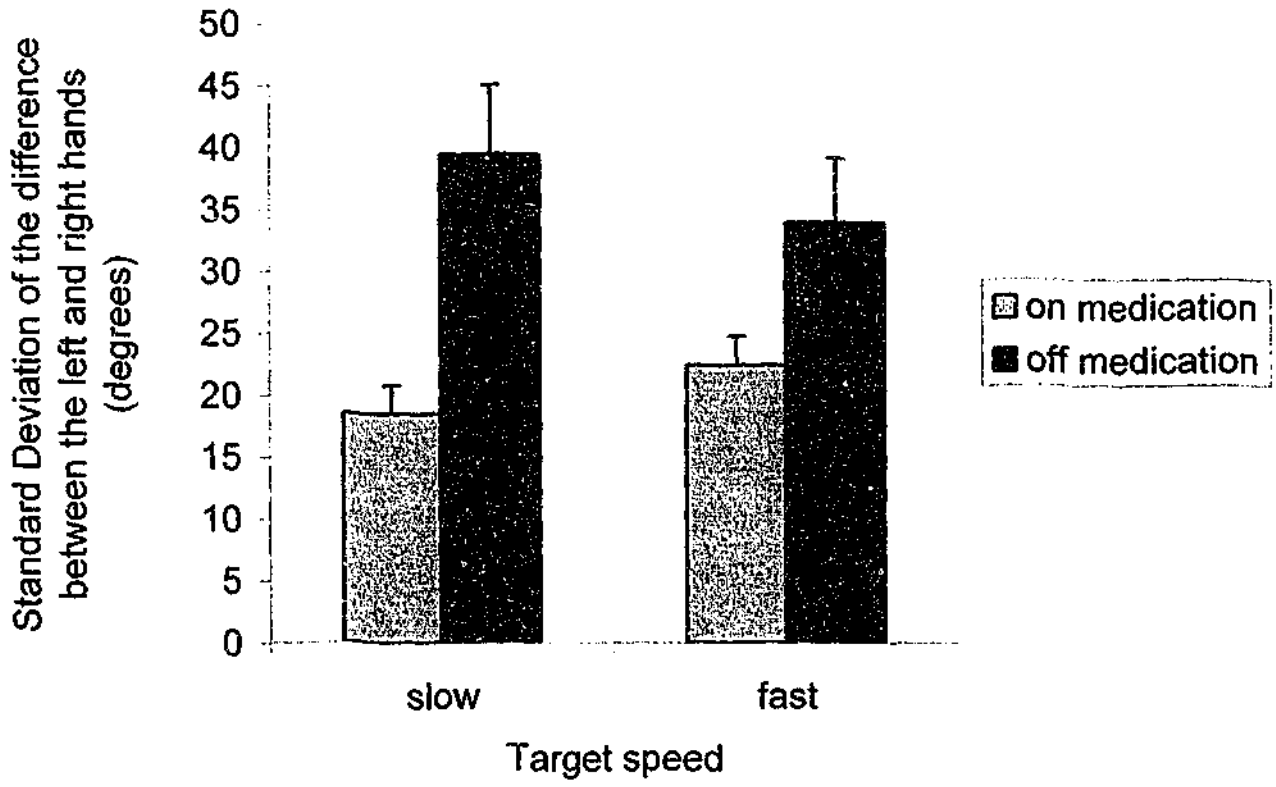


Figure 33: Variation in coordination pattern on and off medication at slow and fast speeds. Standard error bars are shown.

Accuracy of coordination pattern

PO performed the in-phase task with the same accuracy when on (11°) and when off (11°) medication, at the slow speed ($t(5) = -.201$, $p = .849$). At the fast speed PO appeared to perform the in-phase task with slightly more accuracy when on medication (20°) than when off medication (27°), but this difference was not statistically significant ($t(5) = -.811$, $p = .454$).

Variation in velocity

PO's variability in velocity for the in-phase task is depicted in Figure 34. The graph depicts that PO is more variable when off medication, regardless of hand or speed. Paired t-tests indicated that the greater variability when off-than-on medication was only significant at a fast speed with the left hand ($t(5) = -3.54$, $p = .017$), and failed to reach significance at a fast speed with the right hand ($t(5) = -2.25$, $p = .075$), and at a

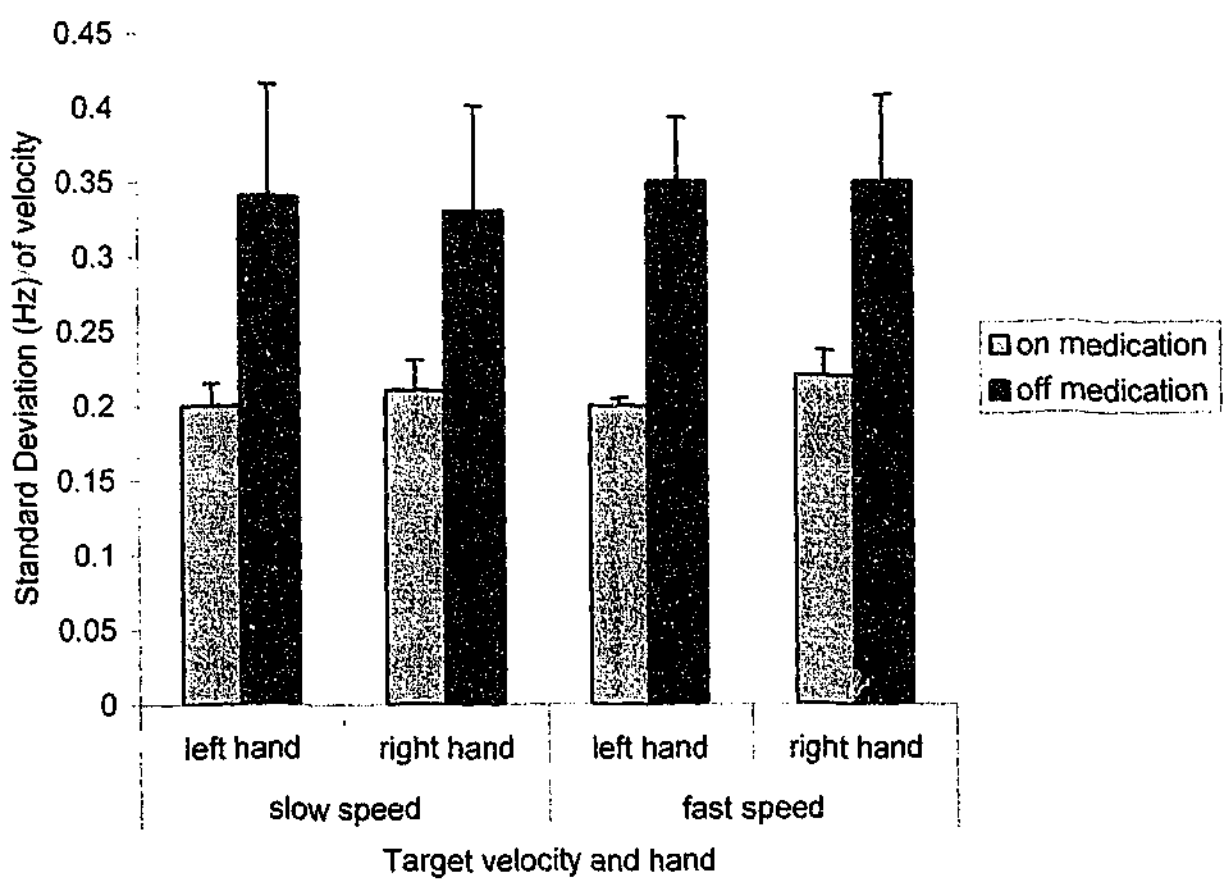


Figure 34: Variation in velocity when on and off medication at slow and fast speeds, with both left and right hands. Standard error bars are shown.

slow speed with both the left ($t(5) = -1.98$, $p = .105$) and right ($t(5) = -2.13$, $p = .086$) hands. However, this lack of significant differences appears to be due to the small number of trials and would probably attain significance had a larger number of trials been conducted.

Accuracy of velocity

Figure 35 depicts the actual and target velocity of the in-phase movements made by PO when on and off medication. Unexpectedly, the results suggest that PO performed substantially closer to the target velocity when off than when on medication. At the slow speed PO performed slightly faster than the target velocity with his left hand

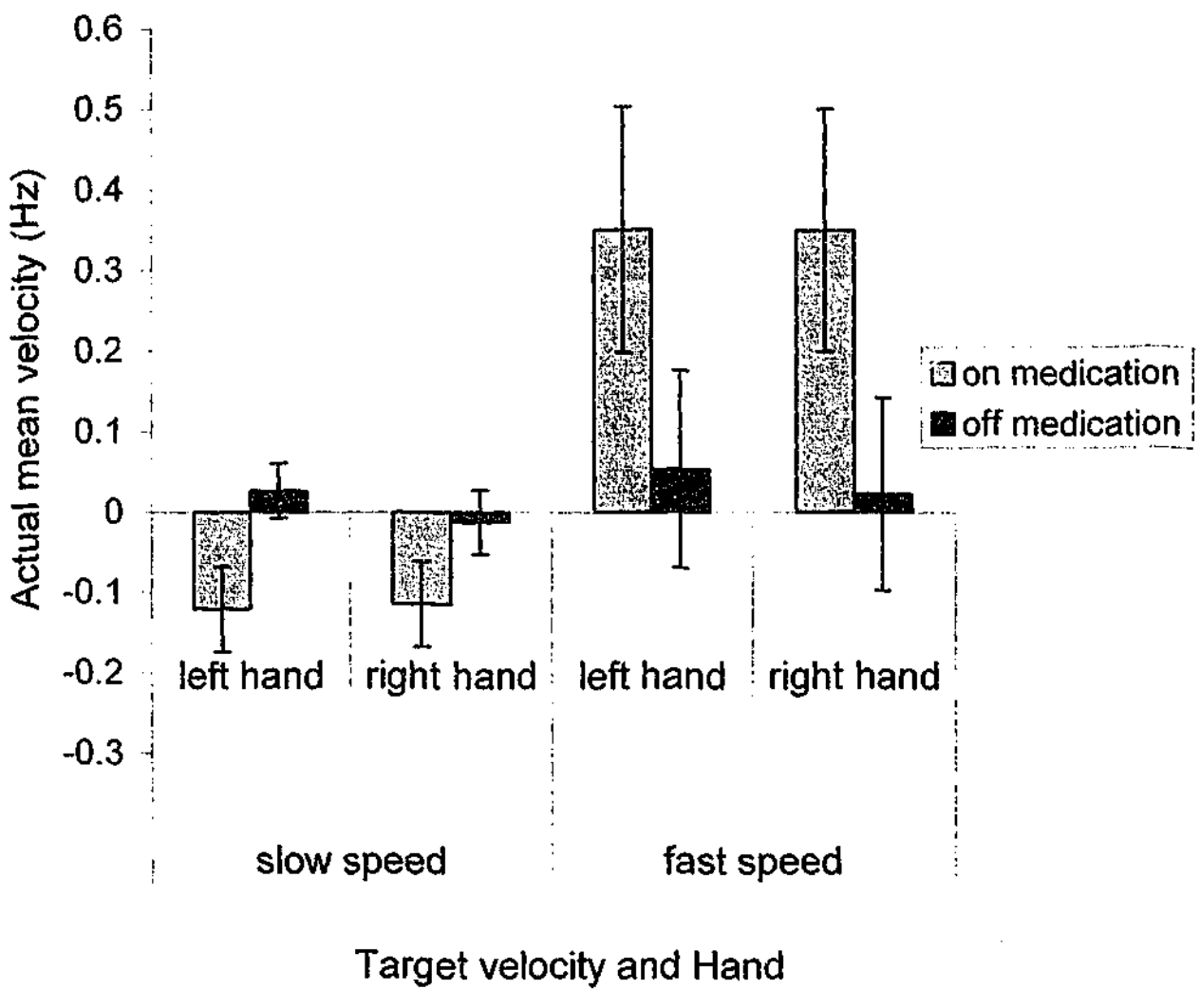


Figure 35: Accuracy of actual velocity compared to the slow and fast target velocity, for left and right hands when on and off medication. Standard error bars are shown.

when off medication, and much slower than the target velocity when on medication ($t(5) = -2.35$, $p = .066$). Similarly for the right hand at the slow speed, PO performed slightly slower than the target velocity when off medication, and much slower when on medication ($t(5) = -1.94$, $p = .110$). At the fast speed PO performed slightly faster than the target velocity with both hands when off medication, and substantially faster with the left ($t(5) = 2.18$, $p = .081$) and the right hand ($t(5) = 2.22$, $p = .077$) when on medication. Although none of these differences between medication and no-medication were significant, the magnitude of the p values suggests that these differences may become significant with a larger number of trials.

6.3.3.2 Results of the out-of-phase task

Phase histograms

The phase-histograms depicted in Figure 36 indicate that at the slow speed, PO had difficulties performing the out-of-phase movements both on and off medication. Medication appeared to result in a higher peak, although this was slightly displaced at a (negative) 135° phase angle, rather than 180°, with the left hand leading the right.

Variation in coordination pattern

PO displayed greater variation in coordinating the left and right hands at a slow speed when off medication (73°), than when on medication (62°), but this failed to reach significance ($t(5) = -2.107$, $p = .089$), presumably due to the small number of trials in each condition.

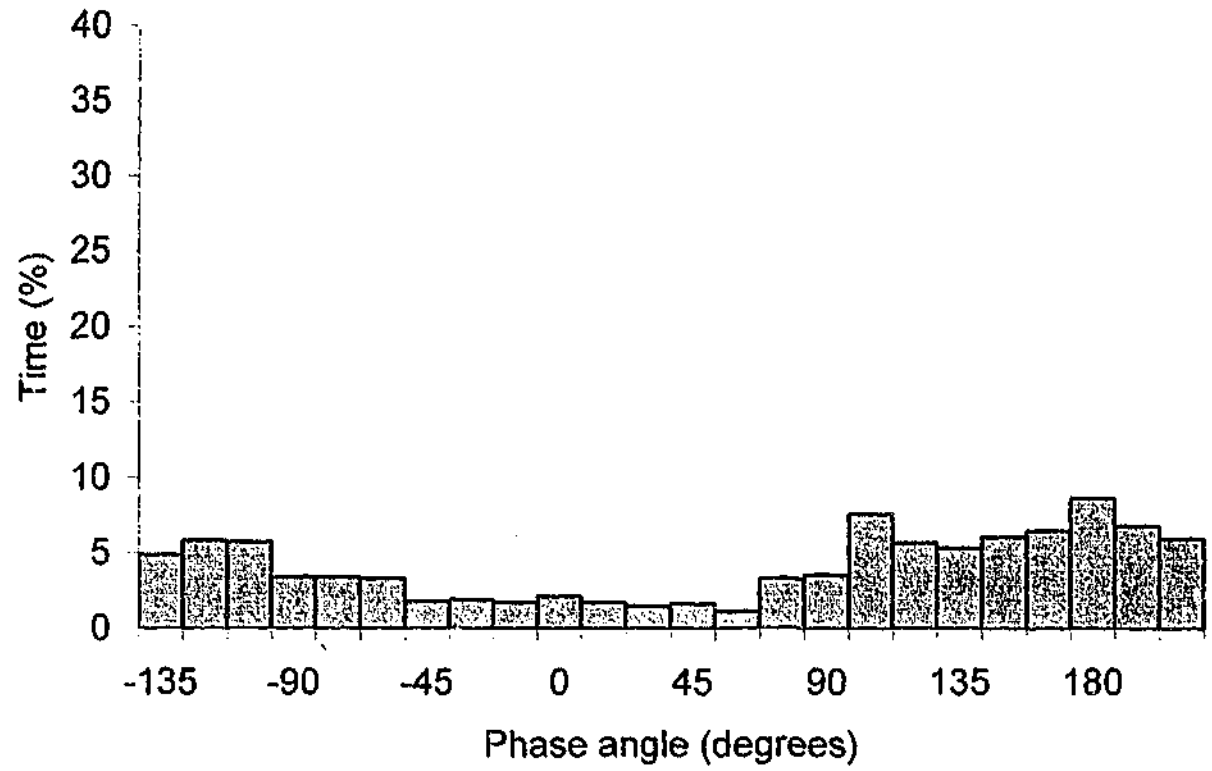
Accuracy in coordination pattern

PO appeared to perform the out-of-phase task with greater accuracy when off medication (49°) than when on medication (63°), but this failed to reach statistical significance ($t(5) = 0.837$, $p = .441$).

Variation in velocity

PO appeared to show slightly greater stability of movement velocity with his left hand when off medication (SD $\pm$ .25 Hz) than when on medication (SD $\pm$ .31 Hz), but this failed to reach significance ($t(5) = 1.538$, $p = .185$). There did not appear to be a difference between variation in velocity when PO was on (SD $\pm$ .25 Hz) and off (SD $\pm$

a



b

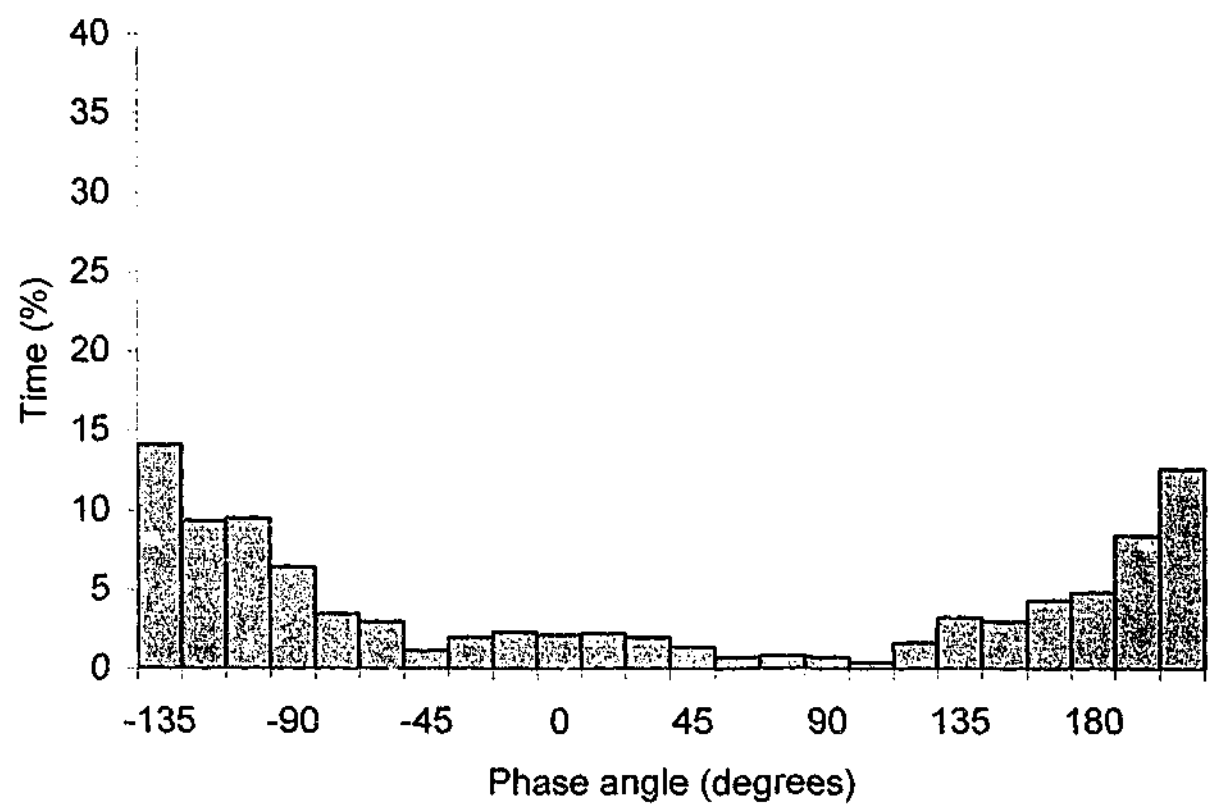


Figure 36: Out-of-phase histograms for PO a) off medication and b) on medication, at the slow speed.

.25 Hz) medication, for his right hand ($t(5) = -.013$, $p = .990$).

Variation in velocity

PO appeared to show slightly greater stability of movement velocity with his left hand when off medication (SD $\pm$ .25 Hz) than when on medication (SD $\pm$ .31 Hz), but this failed to reach significance ($t(5) = 1.538$, $p = .185$). There did not appear to be a difference between variation in velocity when PO was on (SD $\pm$ .25 Hz) and off (SD $\pm$ .25 Hz) medication, for his right hand ($t(5) = -.013$, $p = .990$).

Accuracy of velocity

PO performed the out-of-phase task faster than the target velocity with both hands. The difference between his performance on and off medication was not significantly different for his left (on medication = + .25 Hz, off medication = + .28 Hz; $t(5) = -0.92$, $p = .401$) or right (on medication = + .16 Hz, off medication = + .20 Hz; $t(5) = -0.92$, $p = .398$) hands.

6.3.4 Discussion

The results of this preliminary investigation suggest that differential effects of stimulant medication on bimanual coordination are evident, even with a small number of trials (6 trials per condition). Although the small number of trials limit the conclusions that can be drawn from this study, the results do indicate the need for further investigation into the effects of medication on motor coordination.

The results suggest that medication reduced variability in PO's ability to maintain a constant, stable relationship between his hands, when conducting both in-phase and out-of-phase movements. Similarly, medication also appeared to reduce PO's variability in movement velocity when performing in-phase movements. However, there did not appear to be any significant effects of medication on the accuracy of coordination between the two hands. In addition, medication tended to speed up in-phase movements at the fast target velocity and slow down in-phase movements at the slow target velocity, such that there was an even greater discrepancy between PO's actual and target velocity than when he was off medication.

In summary medication appeared to have an overall positive effect on the variability of PO's movements, but appeared to have a negative effect on PO's ability to keep movements in time with the target velocity. This suggests that although medication may improve some aspects of motor performance, perhaps those that reflect an attentional component, it may also have adverse effects. It is also possible that negative effects of stimulant medication are dose related. Proposals of an inverted u-shaped effect of methylphenidate on *cognitive* performance (with higher doses interfering with performance) have been made previously in the literature (Swanson, Cantwell, Lerner, McBurnett, & Hanna, 1991).

CHAPTER 7

GENERAL DISCUSSION

Neuroimaging studies (see Chapter 1) have implicated fronto-striatal regions in ADHD, and predict motor deficits and higher-order cognitive impairments, including aspects of attention and inhibition. The heterogeneity of ADHD and a variety of methodological issues, such as the greater use of batteries of clinical neuropsychological tests rather than more precise experimental techniques, may have confounded some of the neuropsychological findings of inhibitory, attentional and motor impairments in the ADHD literature. The primary aims of this research were to explore and offer a better understanding of the deficits underlying ADHD, by comparing and contrasting the performance of ADHD children and normal controls on experimental tasks designed to quantify various aspects of attention and motor functioning. It was hoped that the experimental data would provide important markers of ADHD that may in the future be helpful in diagnosing ADHD. Markers of a disorder may reflect both states and traits (Bradshaw, 2001). Bradshaw (2001) suggests that state markers should revert to normal on remission, and that these probably relate to symptomatology rather than aetiology of a disorder. Trait markers, on the other hand, should always be present, perhaps even in asymptomatic family members, and may reflect underlying genetic substrates.

Briefly, Experiments 1-5 (Chapter 3) of this thesis investigated the performance of unmedicated ADHD, medicated ADHD, normal, and (two) predominantly inattentive type children on a task that required participants to respond to targets and ignore distractors. This paradigm allowed quantification of problems of impulsivity, achieving and sustaining an alert state (vigilance), ability to inhibit responses to distracting stimuli, set-shifting, atypical spatial biases and motor performance. Studies 6-9 (Chapter 4) investigated behavioural aspects of ADHD that were reported by parents, teachers and ADHD children in the form of rating scales. Of particular interest was concordance between multiple informants and the ability of children to report their problems on a self-report visual analogue scale. Spatial biases or

perceptual asymmetries were further investigated in normal right-handed children and children with ADHD, through the use of various chimeric stimuli in free-viewing conditions in Experiments 10 and 11 (Chapter 5). Finally, motor performance in children with ADHD was explored further in Chapter 6, using a bimanual coordination task that required participants to produce simple symmetrical bimanual movements and complex asymmetrical bimanual movements at both slow and fast speeds. A summary of the overall results obtained from the various experimental tasks is listed in Table 14.

7.1 Behavioural aspects of ADHD

As the behaviours that comprise ADHD are not intrinsically abnormal, it makes the disorder more difficult to diagnose, than for example, schizophrenia, which is characterised by abnormal hallucinations and/ or delusions. Indeed, there is much debate about ADHD, ranging from the view that it may be underdiagnosed (Ratey, Middeldorp-Crispijn, & Leveroni, 1995), to the view that it is overdiagnosed and not legitimately a discrete condition (Goodman & Poillion, 1992). Adding to the difficulty for the clinician in diagnosing ADHD is the lack of concordance between multiple informants on a child's behaviour (Mandal et al., 1999).

This thesis examined behavioural aspects of ADHD that were reported by parents, teachers and children in the form of rating scales. Of particular interest was not only the concordance between multiple informants, but also the ability of children to report their problems. Results indicated discrepancies between parent and teacher ratings on the Attention Deficit Disorder Evaluation Scale (ADDES; McCarney, 1995) for both ADHD and normal children. Parents tended to report *more problematic behaviour* in ADHD and even in normal children than teachers. There was also a lack of correlation between parent and teacher ratings for ADHD, but not for the normal children. This suggests that ADHD children may show less stable, more inconsistent behaviour at home and school, than normal children. As the ADDES, like most rating scales, does not include a self-report form for children, children's ability to report their difficulties was investigated by using a self-report visual analogue scale (see Appendix K). Results indicated that children with ADHD, when compared with age-matched controls, were able to self-report greater ADHD-related symptoms (e.g., difficulties

with concentration, restlessness/ difficulty sitting still, following directions), lower self-esteem (e.g., greater negative self-perception and a more negative view of how they thought others perceived them), and fewer friendships (perhaps reflecting social problems). They also reported getting into more trouble at home and school, having messier handwriting and bedrooms, and having a greater dislike of reading and maths (perhaps due to difficulties in persisting in activities that require effort). Correlations between child and teacher and child and parent ratings were also low, especially for ADHD children. Poor agreement between multiple informants is consistent with reports of poor inter-rater reliability for a variety of assessment instruments in the ADHD literature (Mandal et al., 1999). The relationship between the self-report and the experimental variables (reaction time, movement time and errors) of Experiments 1, 2 and 3 was also investigated. Parent and teacher ADDES ratings showed poor correlation with experimental measures for both normal and ADHD children. There were slightly more significant correlations between the self-report of ADHD and normal children and the experimental variables.

These results suggest that children with ADHD can be reliable reporters of their behaviour, and highlight the importance of using multiple informants (including the children themselves) when trying to get an accurate overview of the child's behaviour and difficulties. In addition, the lack of concordance between informants makes it difficult to base an ADHD diagnosis solely on data derived from behavioural rating scales, and serves as a caution to research that bases ADHD diagnoses purely on rating scale data, rather than clinician-based diagnoses. Further, poor inter-rater reliability suggests the need for the identification of potential markers of ADHD that help with diagnosis and prognosis.

7.2 Attention

Aspects of attention were investigated in Experiments 1-5. In Experiment 3 it was found that normal children improved in their ability to maintain vigilance, reduce impulsive responding, and inhibit responses to distractors as they got older, but this improvement plateaued at age 9. The *magnitude* of response inhibition difficulty (that is, inhibiting responses to distractors presented in isolation), however, did not plateau and was observed to decrease with age. These results correspond with reports that

executive functions progress in a stage-like manner consistent with growth spurts within the central nervous system (Anderson, 1998). Childhood growth spurts in frontal regions are reported to occur in early infancy, and around 7-10 years of age (see Anderson, 1998 for a review).

Children with the combined type of ADHD, who had a mean age of 9.3 years, however, showed deficits in the areas of *maintaining vigilance* (they missed more targets), *impulsive responding* (they made more premature responses before stimulus presentation), and had difficulties with *inhibiting their responses to distractors*. They experienced difficulties ignoring distractors presented simultaneously with targets, that is, showed problems with selective/ focused attention, and experienced difficulties inhibiting their response to distractors presented in isolation, that is, showed problems with response inhibition. Although these ADHD children showed the *normal pattern* of greater difficulty with response inhibition (inhibiting their response to distractors presented in isolation) on this task, than with selective/ focused attention (inhibiting their response to distractors presented simultaneously with targets), they exhibited a *greater magnitude* of difficulty on the former than the latter compared to controls. Thus it appears that ADHD children, whilst showing a number of impairments, have their greatest difficulty in the ability to inhibit unwanted responses.

The systematic study of medication in Experiment 4 indicated that problems with vigilance, inhibition of responses to distractors, and impulsive responding when off medication all improved with administration of stimulant medication. The data for the medicated ADHD children in Experiment 2 indicated that *impulsive* responding remained a problem despite all of the other improvements, when compared to the performance of controls. In terms of Bradshaw's (2001) proposal of state and trait markers, the observed improvement with medication suggests that such deficits are state markers. The expression of these deficits appears to have a neurochemical basis that is corrected with medication. It is also tempting to think of markers that remain in spite of medication as reflecting more structural anomalies. This interpretation may, however, be too simplistic, and overlooks the possibility that medication may compensate for structural anomalies through a neurochemical basis.

Although unmedicated ADHD children made quantitatively *more errors* than controls, they appeared to make the *normal qualitative pattern of errors*: the greatest proportion of errors was in inhibition of responding to distractors, followed by maintaining vigilance, and lastly, impulsive responding. Young (7-8 year-old) normal children were the only group to differ in their pattern of errors; although they showed a similar pattern of errors overall, they made a lower proportion of errors in inhibiting responses to distractors and a greater proportion of vigilance errors than the older 9-12 year-old children. These results suggest that the pattern of errors made by unmedicated ADHD children is an exacerbation of the errors made by the controls, rather than a pathological or developmentally delayed error pattern. Interestingly, in Experiment 4, an 8 year-old child with the combined type of ADHD showed a similar error pattern to the normal 7-8 year-old children when tested *off* medication, and an error pattern more like the 9-12 year-old children when tested *on* stimulant medication. This suggests that medication may in some way compensate for general developmental immaturity.

The two children with the *inattentive* type of ADHD in Experiment 5 also showed a greater number of errors than their controls, *especially for errors in inhibiting responses to distractors*. In the reach task the majority of these errors comprised failed inhibitions of responses to distractors presented in isolation, rather than errors in focused attention, i.e., inhibition of responses to distractors presented simultaneously with targets. Their *pattern* of errors also revealed that just as with all other children (normal, combined type ADHD), their greatest proportion of errors was in inhibiting responses to distractors. It seems somewhat unexpected that problems in maintaining attention/ vigilance (in the form of missing targets) did not appear to play a major role in these children classified as having predominantly difficulties with inattention. The finding of greater deficits in response inhibition than in selective attention also appears to be inconsistent with Barkley's (1997b) claim that children with inattentive type ADHD have problems primarily in processing speed and selective attention. It appears that the underlying deficits in children with inattentive type ADHD are, instead, very similar to those deficits in children with the combined type of ADHD, whatever may be the apparent clinical manifestations.

7.3 Set-shifting

Difficulties with shifting-set were also explored in the first three experiments; they manifested in slower movement times in normal children. ADHD children did not show any greater impairment in movement time than controls when changing-set. Nevertheless, medication appeared to improve movement execution in the medicated ADHD children who, unlike their controls, did not show slower movement times when changing-set. Like the young 7-8 year-old normal children, unmedicated ADHD children had greater difficulty than controls in inhibiting their responses to distractors when required to change-set. Medication appeared to normalize this in the medicated ADHD children. While ADHD children appeared to perform like younger children in the set-changing task, the normal 7-8 year-olds exhibited other difficulties in the change-set task than the ADHD children, such as greater difficulty in maintaining vigilance. Thus it appears the prediction of set-shifting difficulties in ADHD children are partially supported by the findings. However, this does not reflect developmental delay per se; and these difficulties in set-shifting appear to normalize with stimulant medication.

7.4 Spatial biases

In order to determine whether right-handed ADHD children displayed any atypical performance asymmetries/ spatial biases compared to controls, as observed on line bisection (Sheppard et al., 1999) and target cancellation (Voeller & Heilman, 1988a) tasks, their performance (compared to that of controls) was investigated for targets located in the left and right visual fields, and/ or distractors located in the left or right visual fields in Experiments 1 and 2. However, no atypical performance asymmetries were found for either left-handed or right-handed unmedicated, or right-handed medicated ADHD children compared to controls. Spatial biases were further investigated in normal right-handed children and children with ADHD in Experiments 10 and 11 (Chapter 5), through the use of various chimeric stimuli in free-viewing conditions. Leftward biases were found for normal children with no effects of age. Contrary to expectations, normal leftward biases were also found for ADHD children in the face-matching and the chimeric faces tasks; however, a significant leftward bias was not observed in the grey scales task. When the ADHD children were separated according to medication status at the time of testing, the medicated ADHD children

appeared to have a larger non-significant leftward bias than unmedicated ADHD and normal children. However, this effect needs to be explored further using a larger sample of medicated and unmedicated ADHD children.

It is possible that the absence of anomalous perceptual biases in ADHD children on the chimeric tasks may have been confounded by the comorbid diagnoses of the sample of ADHD children. One study found that the right-visual field bias on a letter cancellation task was driven largely by a comorbid learning disorder in ADHD children (Malone et al., 1994). Differences in comorbid disorders between the samples may indeed explain the inconsistent findings across studies of line bisection and target cancellation in ADHD (Ben-Artsy et al., 1996; Sheppard et al., 1999; Voeller & Heilman, 1988a). In the present study using chimeric stimuli, the number of children with comorbid learning disorder was low (only four out of the fifteen children with comorbid disorders). The comorbid disorders diagnosed in different samples may also reflect the resources of the clinicians making those diagnoses. Different professionals are required for diagnosing different disorders: a psychologist is required for testing intellectual and academic functioning in order to diagnose a learning disorder, an occupational therapist's assessment is necessary to diagnose developmental coordination disorder, and a speech therapist's assessment is required to diagnose a language disorder. Thus diagnoses made by a single clinician may not have incorporated all these aspects of dysfunction, and these diagnoses may in turn vary from those made by a multi-discipline clinic. Another factor that may have confounded the results is medication: none of the samples in the literature and in the present study consisted of medication-naive children. It is possible that longer use of stimulant medication may be associated with normalization of asymmetries, as has been observed to be the case with neuroleptic medication for attentional asymmetries in schizophrenia (Maruff, Hay, Malone, & Currie, 1995).

On the other hand, absence of anomalous perceptual bias in ADHD children on these purely perceptual tasks may suggest that anomalous perceptual asymmetries in line bisection and cancellation tasks may have been influenced by the motor response, and/ or the explicit spatial components of those tasks. As there were no atypical spatial biases found in Experiments 1 and 2, which required a motor response (reaching

towards a target), it may be the explicit, active, non-motor, spatial-exploration component of a particular task that results in atypical spatial biases in children with ADHD. Future research may involve verbal multiple-choice answers for the "best" sample of line bisection in a set. This would remove the motor response component whilst leaving the spatial component of the task intact. If atypical performance was not found on this version of the line-bisection task, atypical line-bisection would probably reflect motor responding. Conversely, if atypical performance was found using this version, atypical line bisection would probably reflect aspects of active spatial exploration.

7.5 Motor deficits

Motor impairments in ADHD were explored both in Experiments 1-5 (Chapter 3) and Experiments 12 and 13 (Chapter 6). The former investigated the reaction and movement execution times of simple unimanual movements, whereas the latter investigated the ability to perform simple and complex bimanual movements.

Whilst normal children in Experiment 3 showed no significant improvement in motor execution (i.e., faster movement times) with age, they did show improved motor planning (i.e., faster reaction times) with age; but this improved little after age 9. The observed slower reaction times in younger children is consistent with the findings of Van der Meere et al. (1996) and Schachar and Logan (1990). Results indicated that, as predicted, children with ADHD showed problems with *movement preparation/ planning* (slower reaction times), but displayed normal *movement execution* (movement time). This finding is consistent with the view of Van der Meere (1996) who suggests that due to a primary state-regulation problem, individuals with ADHD have difficulties in the motor output stage of processing, reflecting cognitive processes just preceding the overt motor action. Results of the single-subject study (Experiment 4) indicated that motor *preparation*, but not motor *execution*, improved significantly when the ADHD child was tested on medication. In addition, the group of medicated ADHD children (Experiment 2) showed normal movement preparation and a trend for faster movement execution. The two children with the inattentive type of ADHD also appeared to exhibit a pattern of slower movement preparation compared to controls. However, in addition, they also appeared to show slower movement execution. This

could reflect the deficits in speed of information processing in children with the inattentive type of ADHD that Barkley (1997b) reports as a primary deficit in the inattentive type of ADHD.

The simple bimanual movements in Experiment 12 consisted of turning two wheels in a way that hand-movements were symmetrical, whilst complex bimanual movements consisted of asymmetrical hand-movements. Results indicated that ADHD children were less accurate and less stable in performing the simple bimanual movement than controls. They were also more variable in velocity, even though they performed simple bimanual movements at a similar velocity to controls. The combination of these findings suggests that ADHD children were not less accurate than controls simply because they were trading accuracy for speed.

The ADHD children showed only a trend for less accurate movements than controls on the *complex* bimanual task. They were, however, significantly more variable in their coordination pattern and velocity, despite being able to perform the complex movements at a similar velocity to controls. The lack of significant impairment in the accuracy of performing the complex bimanual movement may also be due to a floor effect caused by normal children performing very poorly on this task. It is possible that the poor performance of normal children on this task reflects immaturity of the corpus callosum (Pujol et al., 1994), which (along with the supplementary motor area) is postulated to be involved in bimanual coordination (Cunnington et al., 1996).

Previous studies using this bimanual coordination task have also found *less accurate* simple bimanual movements in adults with Huntington's disease (Johnson et al., 2000) and Parkinson's disease (Johnson et al., 1998), but not in adults with Tourette's syndrome (Howells, 2001), obsessive-compulsive disorder (Howells, 2001) or schizophrenia (Bellgrove et al., 2001). *Greater variability* in simple bimanual movements were, however, observed in individuals with Huntington's disease, Parkinson's disease and schizophrenia (but not Tourette's syndrome or obsessive compulsive disorder). Complex bimanual movements in children with ADHD cannot be as easily compared to those in other disorders, as both normal and ADHD children had difficulties performing accurate bimanual movements. Future research should be

conducted with ADHD adults to see how they perform on the complex coordination task. The present research suggests that the bimanual cranks task is sensitive to patients with a variety of frontostriatal disorders, and can discriminate different impairments in the various patient groups. It would be of great interest to determine whether children with the inattentive type of ADHD have similar deficits in bimanual coordination as those with the combined type.

As it was also of interest to determine whether deficits in bimanual motor coordination are a trait or a state marker, a preliminary investigation was conducted into the effects of stimulant medication in Experiment 13. One ADHD child's performance on the bimanual task was examined when he was both on and off medication. The small number of trials per condition resulted in few statistically significant effects, but still gave some indication of the differential effects of medication on bimanual coordination. The results suggested that medication may have both negative and positive effects on bimanual coordination. The pattern of results indicated that although medication may reduce the variability of movements, it may have a negative effect on the ability to keep movements in time with the target velocity. The effects of stimulant medication on motor coordination remains an interesting area for future research.

7.6 Summary

A variety of tasks showed no support for an anomalous right-visual-field spatial bias that has previously been interpreted in terms of greater right hemisphere impairment in ADHD. The results of the present research indicate that the performance of ADHD children is characterised by both slow and inaccurate responding. Inaccurate responding appears to reflect problems with response inhibition, selective attention, impulsive premature responding, and difficulties in achieving and maintaining an alert state. These deficits seem to be state rather than trait markers, because they are normalized with administration of stimulant medication. Impulsive premature responding was the only deficit that did not appear to return completely to normal, and remained a problem for medicated ADHD children when compared to controls.

While problems with set-shifting manifested as slow movement execution in unmedicated ADHD children *and* their controls, these were not evident in the medicated ADHD children. The only set-shifting difficulties of the (unmedicated) ADHD children manifested as a greater amount of distractibility errors. This appeared to normalize with medication.

Slow responding in ADHD reflects problems with the cognitive processes associated with *preparation* for a simple movement, rather than with problems in the *execution* of a simple unimanual movement. However, ADHD children were found to have difficulties accurately executing stable simple *bimanual* movements, although they could produce these as accurately as controls at the designated (slow or fast) speeds. A preliminary investigation of the effects of stimulant medication on bimanual coordination suggested that medication may reduce the variability of movements, but may also have a negative effect on the ability to produce movements at the target velocity. Further research is necessary to ascertain which aspects of bimanual-coordination are affected by stimulant medication, and whether these deficits persist into adulthood.

Table 14: Summary of overall results from tasks of attention, changing-set, spatial biases, and movement/ motor functioning in ADHD and normal children

	Unmedicated ADHD children	Medicated ADHD children	Normal children
MOTOR FUNCTIONING	*Experiment 1* * Problems with *movement preparation.* * Normal *motor execution.* *Experiment 5* * *Movement preparation* appears to be impaired in predominantly inattentive type ADHD. * *Motor execution* appears to be impaired in predominantly inattentive type ADHD. *Experiment 12* * Problems in making accurate and stable *simple symmetrical bimanual* movements. * Trend for less accuracy (and significantly greater variability) in making *complex asymmetrical bimanual* movements. * More variable in velocity when making both *simple symmetrical* and *complex asymmetrical bimanual* movements.	*Experiment 2* * Normal *movement preparation.* * Normal (trend for faster) *motor execution.* *Experiment 4* * *Movement preparation* improved on medication. * *Motor execution* the same on and off medication *Experiment 13* * Variability in making *bimanual movements* appears to improve on medication * *Timing movements* to the target velocity appears to be impaired on medication	*Experiment 3* * *Movement preparation* improves with age; it plateaus after age 9 years * *Motor execution* is well established by age 7 and does not improve with age

	Unmedicated ADHD children	Medicated ADHD children	Normal children
	Experiment 1 * Problems in maintaining *vigilance.* * Problems with *impulsive* responding. * Problems *inhibiting responses to distractors.* * Normal pattern: *response inhibition* is a greater difficulty than focused/ selective attention. * Greater *magnitude* of difficulty for *response inhibition* than focused/ selective attention. * Normal error pattern (highest to lowest proportion of errors = inhibiting responses to distractors, vigilance, impulsive responding, respectively). * ADHD children exacerbate errors made by controls, and do not show a developmentally delayed error pattern. *Experiment 5* * *problems inhibiting responses to distractors* appear to be greater than vigilance problems in inattentive type of ADHD.	*Experiment 2* * *Normal* vigilance. * Problems with *impulsive* responding. * Normal *inhibition of responses to distractors.* * Normal pattern: *response inhibition* is a greater difficulty than focused/ selective attention. * Normal error pattern (highest to lowest proportion of errors = inhibiting responses to distractors, vigilance, impulsive responding, respectively). *Experiment 4* * better *vigilance on* medication. * greater *inhibition of responses* to distractors *on* medication. * less *impulsive* responding *on* medication. * *Off* medication = error pattern of normal 7-8 year old children. *On* medication = error pattern of 9-12 year-old normal children.	*Experiment 3* * *Vigilance, impulsive* responding, and *inhibition of responses to distractors* improve with age; this plateaus at age 9 years. * *Response inhibition* is a greater difficulty than focused/ selective attention. * Magnitude of *response inhibition* difficulty decreases with age. * Error pattern: (highest to lowest proportion of errors = inhibiting responses to distractors, vigilance, impulsive responding, respectively). * Young (7-8 year-old) children make a *lower proportion* of errors inhibiting responses to distractors and a *greater proportion* of vigilance errors than older (9-12 year-old) children.
A T T E N T I O N			

	Unmedicated ADHD children	Medicated ADHD children	Normal children
CHANGING SET	*Experiment 1* * Normal *slowed movement time* when changing-set. * More problems *inhibiting responses* to distractors when changing-set.	*Experiment 2* * Unlike their controls, ADHDs did not show *slowed movement times* when changing-set. * Normal *inhibition of responses* to distractors when changing-set.	*Experiment 3* * *Slower movement times* when changing-set. * Young (7-8 year-old) children had difficulty in *maintaining vigilance* when changing-set. * Young (7-8 year old) children had difficulty *inhibiting responses* to distractors when changing-set. * *Change in error pattern*: Higher proportion of errors in maintaining vigilance when changing-set; and lower proportion of impulsive responding when changing-set.

	Unmedicated ADHD children	Medicated ADHD children	Normal children
SPATIAL BIASES	*Experiment 1* * *No atypical performance asymmetries/* spatial biases for targets located in the left and right visual fields, and/ or distractors located in the left and right visual fields. *Experiment 11* * Combined with unmedicated ADHD children, medicated ADHDs showed significant *leftward bias* when making judgements of affect in chimeric faces task; and when making judgments of resemblance in face-matching task; but *no significant biases* when making brightness judgements on grey scales task.	*Experiment 2* * *No atypical performance asymmetries/* spatial biases for targets located in the left and right visual fields, and/ or distractors located in the left and right visual fields. *Experiment 11* * Combined with medicated ADHD children, unmedicated ADHDs showed significant *leftward bias* when making judgements of affect in chimeric faces task; and when making judgments of resemblance in face-matching task; but *no significant biases* when making brightness judgements on grey scales task. * Despite non-significant results, medicated ADHD children *appeared to have larger leftward bias* than unmedicated ADHD children and normal children.	*Experiment 10* * *leftward bias* when making judgements of affect in chimeric faces task; and when making judgments of resemblance in face-matching task. * *no significant bias* when making brightness judgements on the grey scales task. * *No effect of age* on magnitude of perceptual bias.

APPENDICES

APPENDIX A: DIAGNOSTIC CRITERIA FOR ADHD

A.1 DSM-IV Diagnostic Criteria for ADHD

(taken from American Psychiatric Association (1994), pp 83-85)

A. Either 1) or 2)

1) six (or more) of the following symptoms of inattention have persisted for

at least 6 months to a degree that is maladaptive and inconsistent with developmental level:

Inattention

(a) often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities

(b) often has difficulty sustaining attention in tasks or play activities

(c) often does not seem to listen when spoken to directly

(d) often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behaviour or failure to understand instructions)

(e) often has difficulty organizing tasks and activities

(f) often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)

(g) often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books, or tools)

(h) is often easily distracted by extraneous stimuli

(i) is often forgetful in daily activities

2) six (or more) of the following symptoms of hyperactivity-impulsivity have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:

Hyperactivity

(a) often fidgets with hands or feet or squirms in seat

(b) often leaves seat in classroom or in other situations in which

remaining seated is expected

(c) often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)

(d) often has difficulty playing or engaging in leisure activities quietly

(e) is often "on the go" or often acts as if "driven by a motor"

(f) often talks excessively

Impulsivity

(g) often blurts out answers before questions have been completed

(h) often has difficulty awaiting turn

(i) often interrupts or intrudes on others (e.g., butts into conversations or games)

B. Some hyperactive-impulsive or inattentive symptoms that caused impairment were present before age 7 years

C. Some impairment from the symptoms is present in two or more settings (e.g., at school [or work] and at home)

D. There must be clear evidence of clinically significant impairment in social, academic, or occupational functioning.

E. The symptoms do not occur exclusively during the course of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder and are not better accounted for by another mental disorder (e.g., Mood Disorder, Anxiety Disorder, Dissociative Disorder, or a Personality Disorder)

Type

314.01 Attention-Deficit/Hyperactivity Disorder, Combined Type: if both Criteria A1 and A2 are met for the past 6 months

314.00 Attention-Deficit/Hyperactivity Disorder, Predominantly Inattentive Type: if Criterion A1 is met but Criterion A2 is not met for the past 6 months

314.01 Attention-Deficit/Hyperactivity Disorder, Predominantly Hyperactive-Impulsive Type: if Criterion A2 is met but Criterion A1 is not met for the past 6 months

A.2 ICD-10 Diagnostic Criteria for Hyperkinetic Disorder

(taken from World Health Organization (1993), pp 155-157)

F90 Hyperkinetic disorders

The research diagnosis of hyperkinetic disorder requires the definite presence of abnormal levels of inattention, hyperactivity, and restlessness that are pervasive across situations and persistent over time and that are not caused by other disorders such as autism or affective disorders.

G1. *Inattention.*

At least six of the following symptoms of inattention have persisted for at least 6 months, to a degree that is maladaptive and inconsistent with the developmental level of the child:

(1) often fails to give close attention to details, or makes careless errors in schoolwork, work, or other activities
(2) often fails to sustain attention in tasks or play activities
(3) often appears not to listen to what is being said to him or her
(4) often fails to follow through on instructions or to finish schoolwork, chores, or duties in the workplace (not because of oppositional behaviour or failure to understand instructions)
(5) is often impaired in organizing tasks and activities
(6) often avoids or strongly dislikes tasks, such as homework, that require sustained mental effort

(7) often loses things necessary for certain tasks or activities, such as school assignments, pencils, books, toys, or tools

(8) is often easily distracted by external stimuli

(9) is often forgetful in the course of daily activities

G2. *Hyperactivity*

At least three of the following symptoms of hyperactivity have persisted for at least 6 months, to a degree that is maladaptive and inconsistent with the developmental level of the child:

(1) often fidgets with hands or feet or squirms on seat

(2) leaves seat in classroom or in other situations in which remaining seated is expected

(3) often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, only feelings of restlessness may be present)

(4) is often unduly noisy in playing or has difficulty in engaging quietly in leisure activities

(5) exhibits a persistent pattern of excessive motor activity that is not substantially modified by social context or demands

G3. *Impulsivity*

At least one of the following symptoms of impulsivity has persisted for at least 6 months, to a degree that is maladaptive and inconsistent with the developmental level of the child:

(1) often blurts out answers before questions have been completed

(2) often fails to wait in lines or await turns in games or group situations

(3) often interrupts or intrudes on others (e.g. butts into others' conversations or games)

(4) often talks excessively without appropriate response to social constraints

G4. Onset of the disorder is no later than the age of 7 years

G5. *Pervasiveness*

The criteria should be met for more than a single situation, e.g. the combination of inattention and hyperactivity should be present both at home and at school, or at both school and another setting where children are observed, such as a clinic.

G6. The symptoms in G1-G3 cause clinically significant distress or impairment in social, academic, or occupational functioning

G7. The disorder does not meet the criteria for pervasive developmental disorders (F84), manic episode (F30), depressive episode (F32), or anxiety disorders (F41)

F90.0 Disturbance of activity and attention

The general criteria for hyperkinetic disorder (F90) must be met, but not those for conduct disorders (F91)

F90.1 Hyperkinetic conduct disorder

The general criteria for both hyperkinetic disorder (F90) and conduct disorders (F91) must be met

F90.8 Other hyperkinetic disorders

F90.9 Hyperkinetic disorder, unspecified

This residual category is not recommended and should be used only when there is a lack of differentiation between F90.0 and F90.1 but the overall criteria for F90 are fulfilled

APPENDIX B: HANDEDNESS QUESTIONNAIRE

Name:.....

Date:.....

Sex:.....

1. **Which hand do you draw with?**

   Left Right Both

2. **Which hand do you write with?**

   Left Right Both

3. **Which hand do you throw a tennis ball with?**

   Left Right Both

4. **Which hand do you hold your toothbrush in?**

   Left Right Both

5. **Which hand do you hold scissors in?**

   Left Right Both

APPENDIX C: COUNTERBALANCING OF EXPERIMENTAL CONDITIONS FOR ADHD AND NORMAL CHILDREN IN EXPERIMENTS 1, 2, AND 3

Table C.1: Counterbalancing of reach (R) and no-reach (NR) conditions; and left (a), centre (b) and right (c) hand-start positions, in the maintain and change set tasks for children with ADHD

Participants	Task 1 : Maintain-set task		Task 2 : Change-set task	
1	NR abc	R cab	R abc	NR cba
2	R abc	NR cba	NR abc	R cab
3	NR cba	R acb	R cba	NR abc
4	R cba	NR abc	NR cba	R acb
5	NR bac	R abc	R bac	NR cab
6	R bac	NR cab	NR bac	R abc
7	NR bca	R cba	R bca	NR acb
8	R bca	NR acb	NR bca	R cba
9	NR acb	R bca	R acb	NR bac
10	R acb	NR bca	NR acb	R bac
11	NR cab	R bac	R cab	NR bac
12	R cab	NR bac	NR cab	R bac
13	NR acb	R cba	NR cba	R bca
14	R bca	NR cba	NR bca	R cba
15	NR bac	R abc	R bac	NR cab
16	R cab	NR cab	NR cab	R bac
17	NR cba	R acb	R bca	NR acb
18	R abc	NR bac	NR abc	R cab
19	NR abc	R cab	R abc	NR cba
20	R cba	NR acb	NR cba	R abc
21	NR cab	R bac	R cab	NR bac
22	R bac	NR abc	NR bac	R abc
23	NR bca	R cba	R acb	NR bca

24	R acb	NR bca	NR acb	R bca
25	NR cba	R acb	R bca	NR acb
26	R acb	NR bca	NR acb	R bac
27	NR cab	R bac	R cab	NR bac

Table C.2: Counterbalancing of reach (R) and no-reach (NR) conditions; and left (a), centre (b) and right (c) hand-start positions, in the maintain and change set tasks for normal children

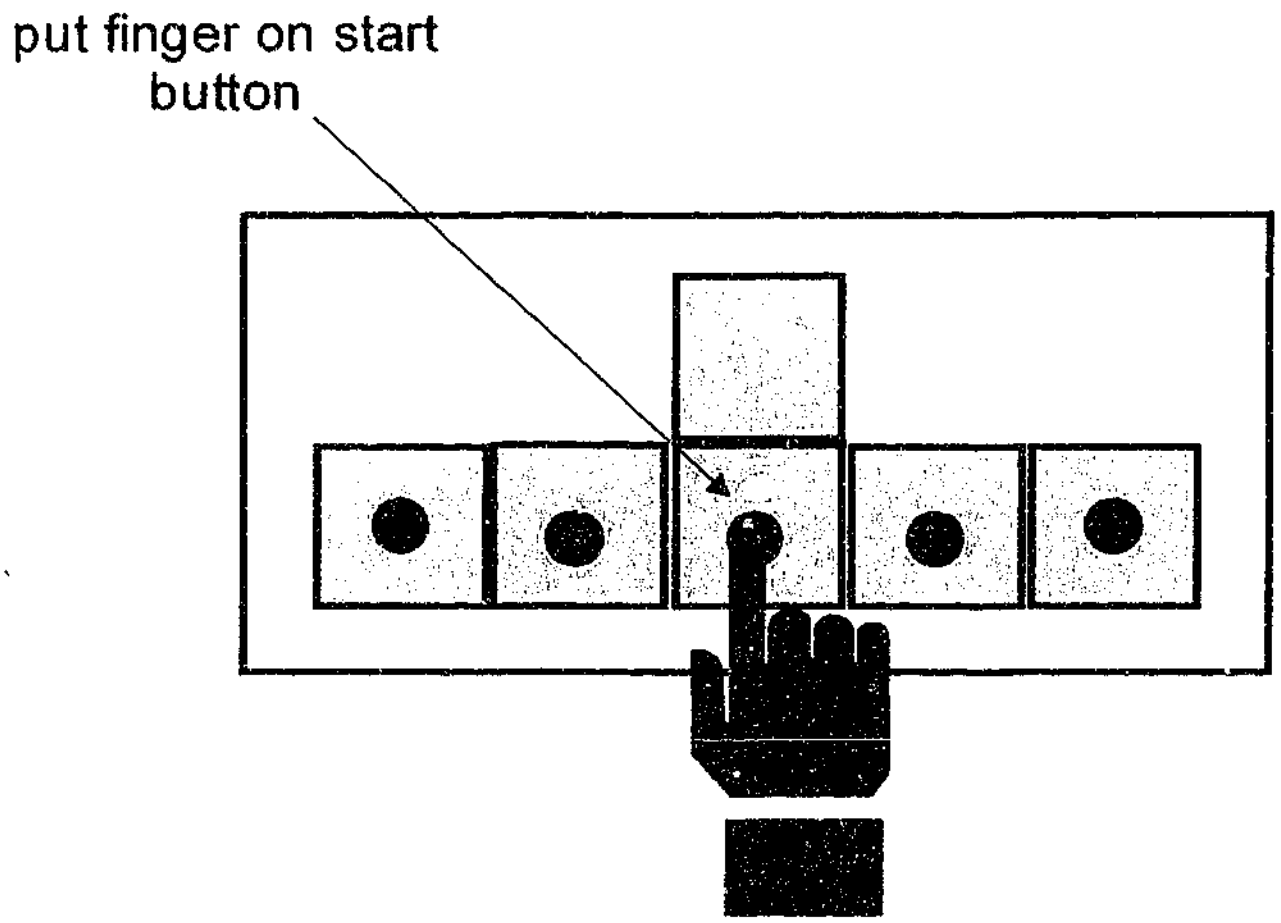
Participants	Task 1 : Maintain-set task		Task 2 : Change-set task	
1	R abc	NR cba	NR abc	R cab
2	NR abc	R cab	R abc	NR cba
3	R cba	NR abc	NR cba	R acb
4	NR cba	R acb	R cba	NR abc
5	R bac	NR cab	NR bac	R abc
6	NR bac	R abc	R bac	NR cab
7	R bca	NR acb	NR bca	R cba
8	NR bca	R cba	R bca	NR acb
9	R acb	NR bca	NR acb	R bac
10	NR acb	R bca	R acb	NR bac
11	R cab	NR bac	NR cab	R bac
12	NR cab	R bac	R cab	NR bac
13	R abc	NR cba	NR abc	R cab
14	NR abc	R cab	R abc	NR cba
15	R cba	NR abc	NR cba	R acb
16	NR cba	R acb	R cba	NR abc
17	R bac	NR cab	NR bac	R abc
18	NR bac	R abc	R bac	NR cab
19	R bca	NR acb	NR bca	R cba
20	NR bca	R cba	R bca	NR acb

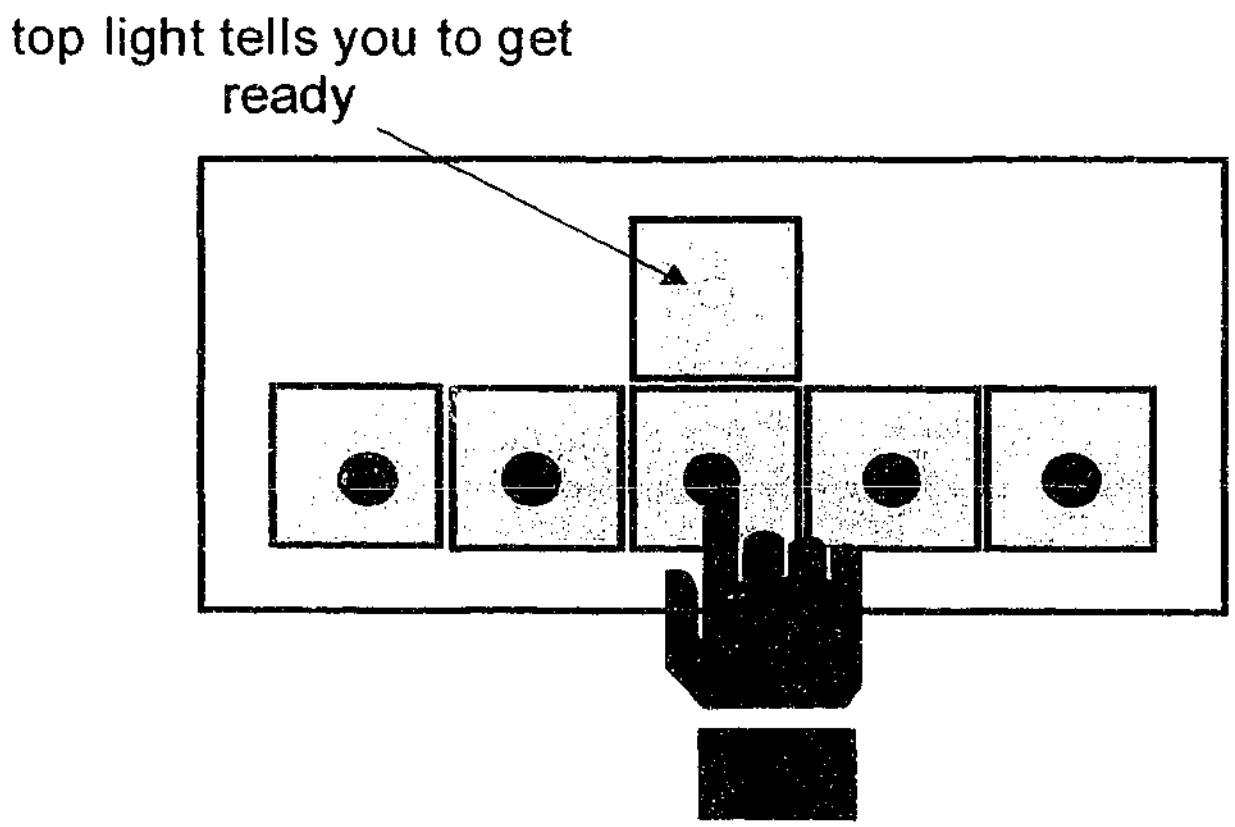
21	R acb	NR bca	NR acb	R bac
22	NR acb	R bca	R acb	NR bac
23	R cab	NR bac	NR cab	R bac
24	NR cab	R bac	R cab	NR bac
25	R abc	NR cba	NR abc	R cab
26	NR abc	R cab	R abc	NR cba
27	R cba	NR abc	NR cba	R acb
28	NR cba	R acb	R cba	NR abc
29	R bac	NR cab	NR bac	R abc
30	NR bac	R abc	R bac	NR cab
31	R abc	NR cba	NR abc	R cab
32	NR abc	R cab	R abc	NR cba
33	R cba	NR abc	NR cba	R acb
34	NR cba	R acb	R cba	NR abc
35	R bac	NR cab	NR bac	R abc
36	NR bac	R abc	R bac	NR cab
37	R bca	NR acb	NR bca	R cba
38	NR bca	R cba	R bca	NR acb
39	R acb	NR bca	NR acb	R bac
40	NR acb	R bca	R acb	NR bac
41	R cab	NR bac	NR cab	R bac
42	NR cab	R bac	R cab	NR bac
43	R abc	NR cba	NR abc	R cab
44	NR abc	R cab	R abc	NR cba
45	R cba	NR abc	NR cba	R acb
46	NR cba	R acb	R cba	NR abc
47	R bac	NR cab	NR bac	R abc
48	NR bac	R abc	R bac	NR cab
49	R bca	NR acb	NR bca	R cba
50	NR bca	R cba	R bca	NR acb
51	R acb	NR bca	NR acb	R bac
52	NR acb	R bca	R acb	NR bac
53	R cab	NR bac	NR cab	R bac

54	NR cab	R bac	R cab	NR bac
55	R abc	NR cba	NR abc	R cab
56	NR abc	R cab	R abc	NR cba
57	R cba	NR abc	NR cba	R acb
58	NR cba	R acb	R cba	NR abc
59	R bac	NR cab	NR bac	R abc
60	NR bac	R abc	R bac	NR cab
61	R bca	NR acb	NR bca	R cba
62	NR bca	R cba	R bca	NR acb
63	R acb	NR bca	NR acb	R bac
64	NR acb	R bca	R acb	NR bac
65	R cab	NR bac	NR cab	R bac
66	NR cab	R bac	R cab	NR bac

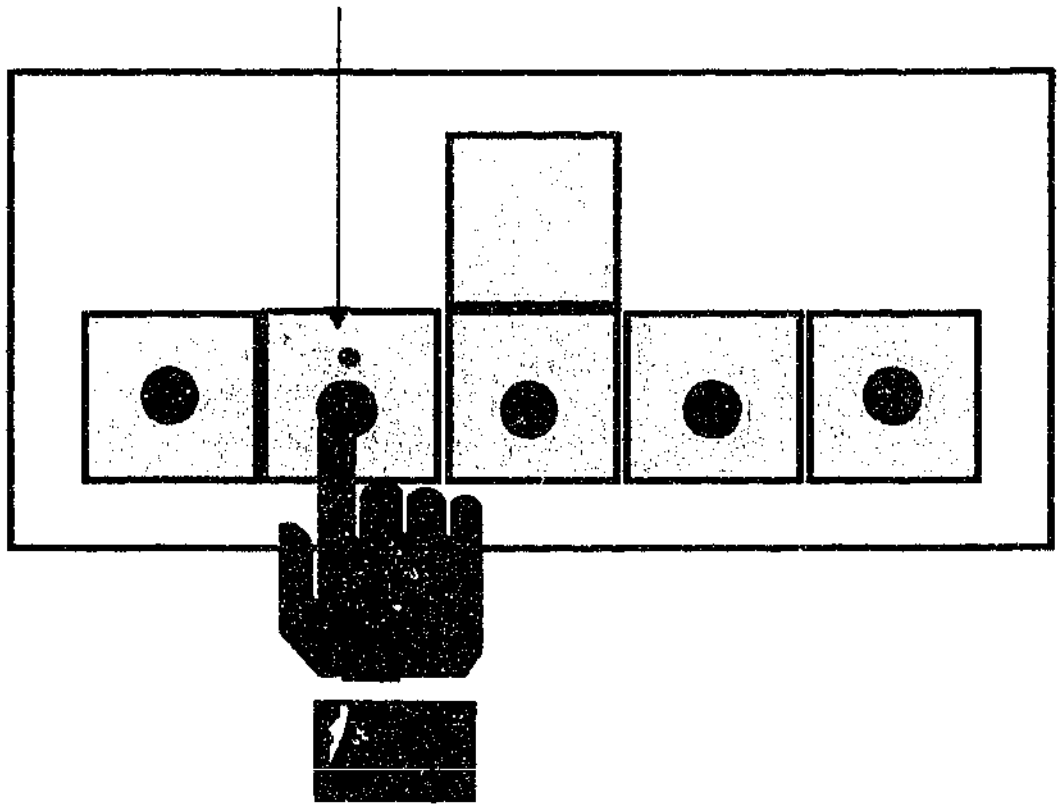
APPENDIX D: INSTRUCTIONS TO PARTICIPANTS IN EXPERIMENTS 1-5

D.1 Instructions to participants in the reach condition of the maintain-set task:

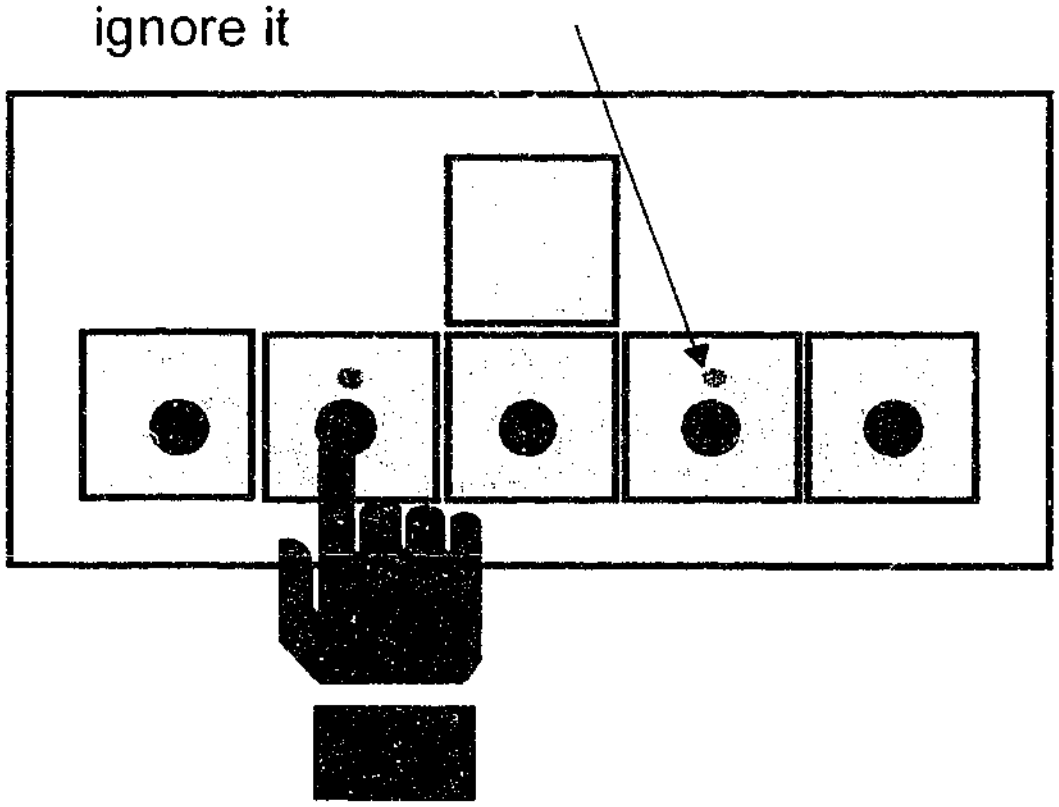


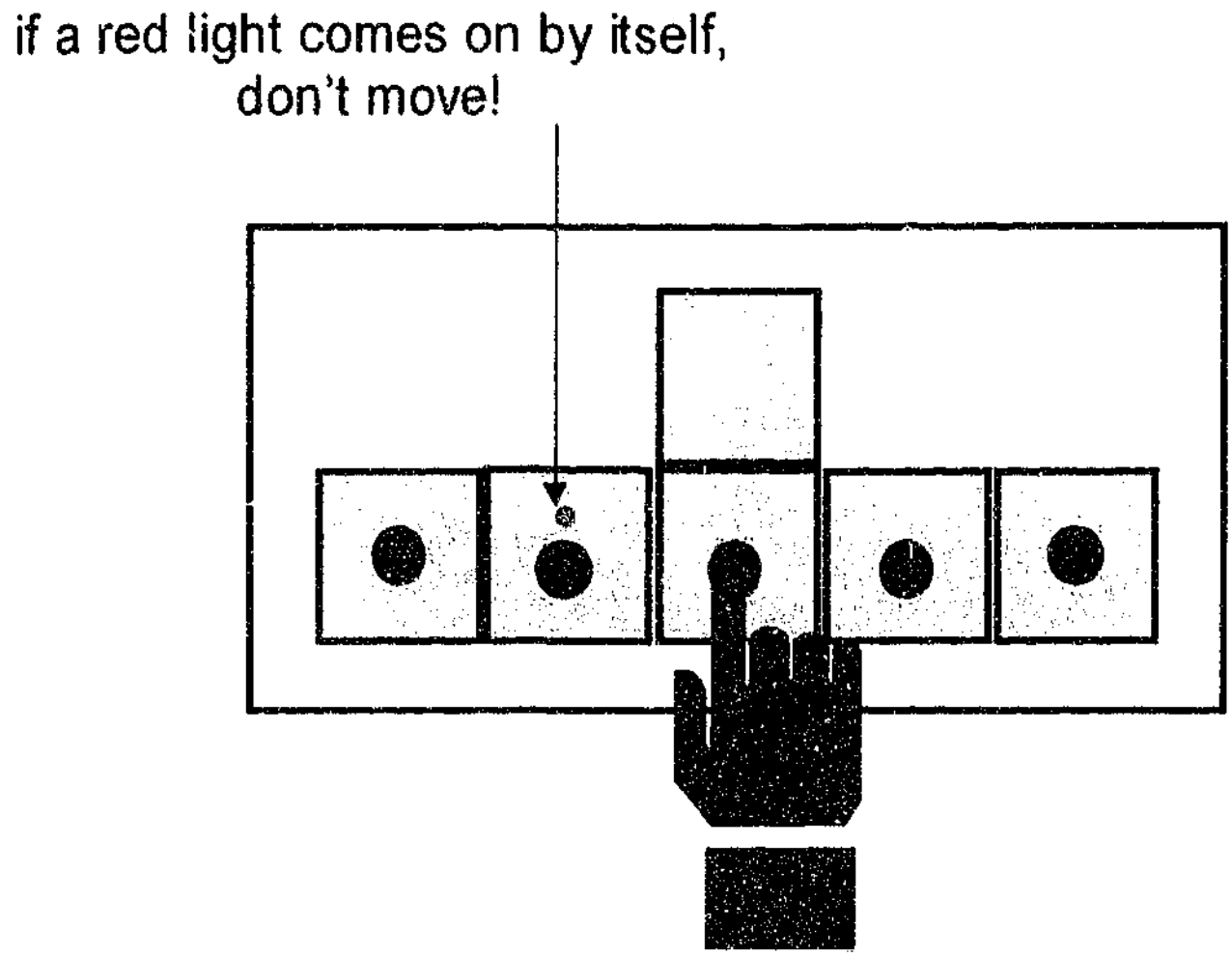


look for the green light and push its button as quickly as you can



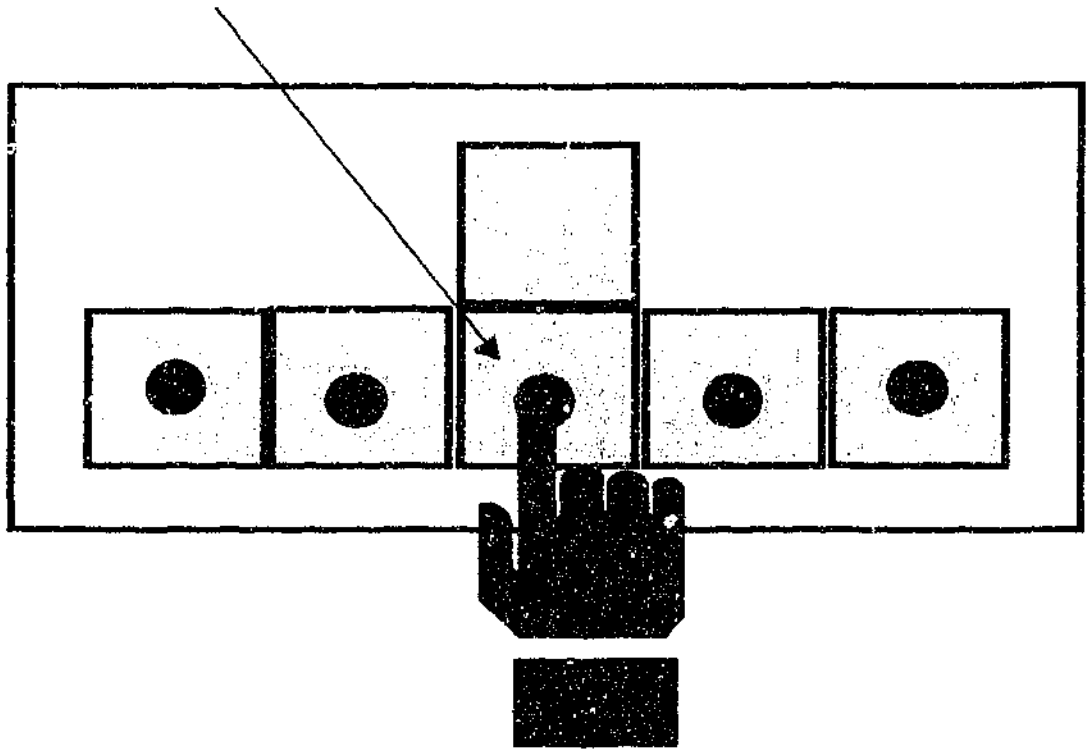
If a red light comes on too, just ignore it



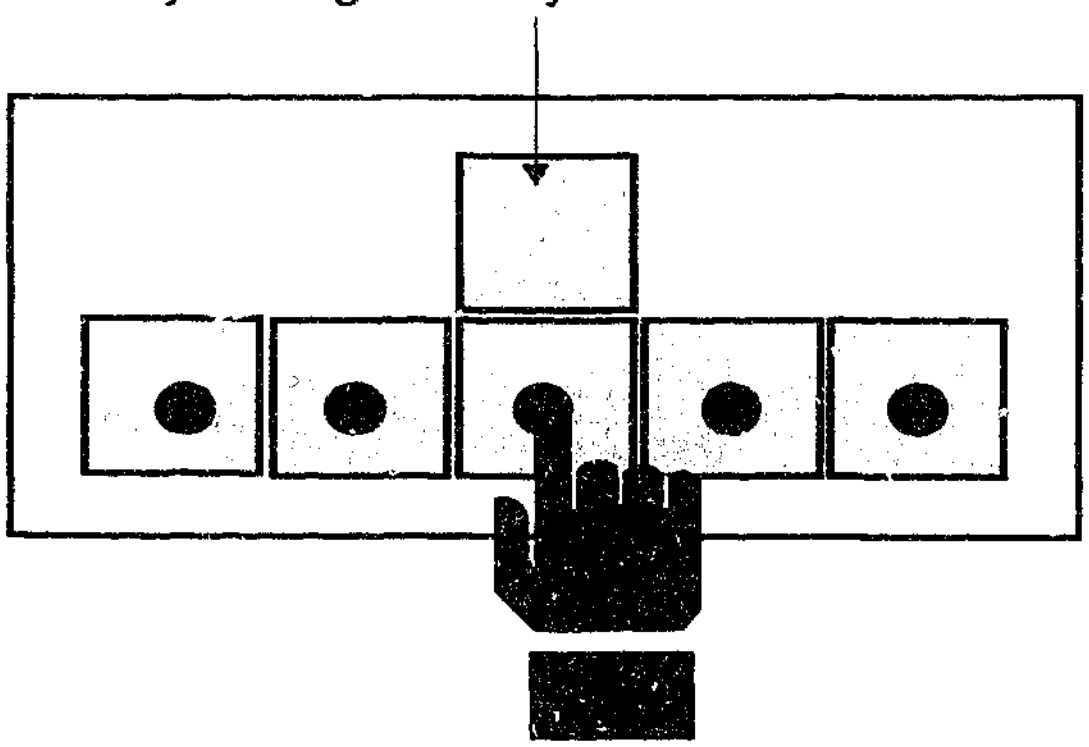

if a red light comes on by itself,
don't move!

D.2 Instructions to participants in the no-reach condition of the maintain-set task:

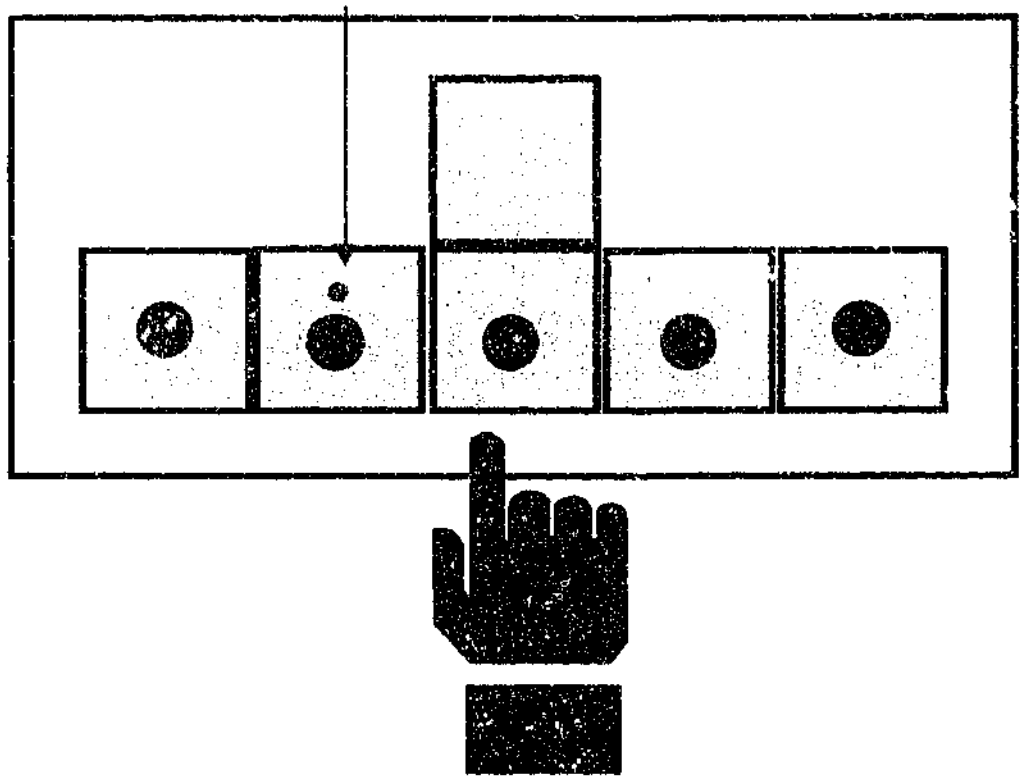
put finger on start button



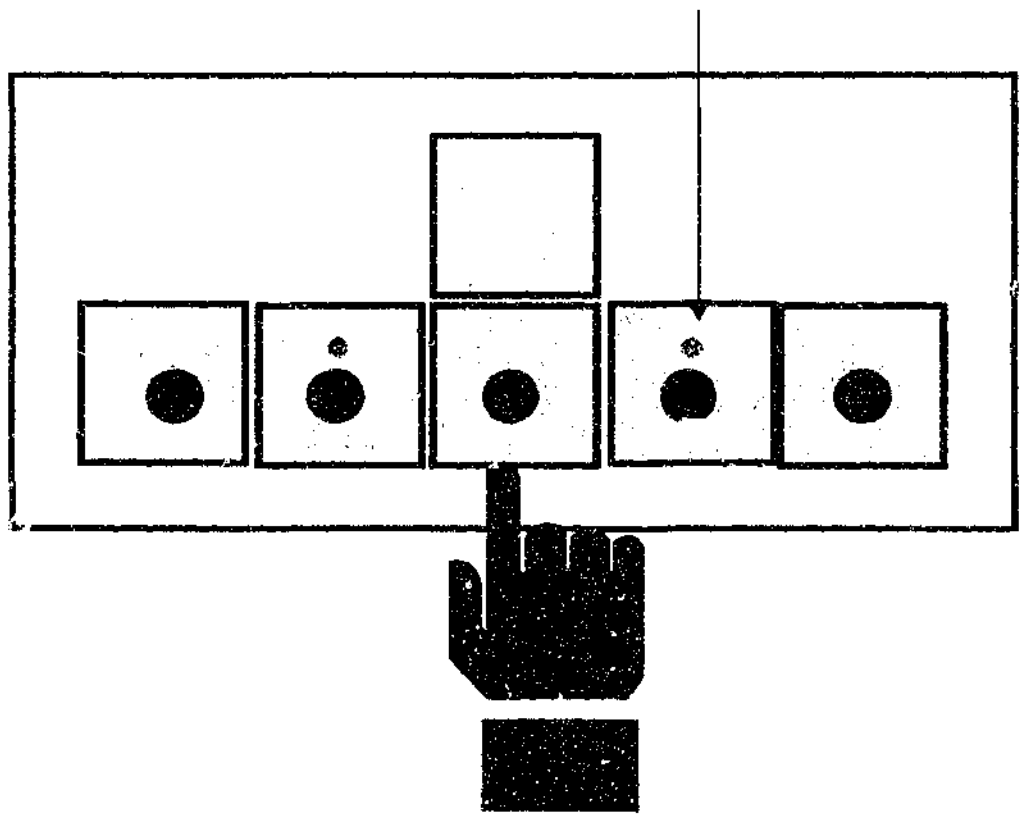
top light tells you to get ready



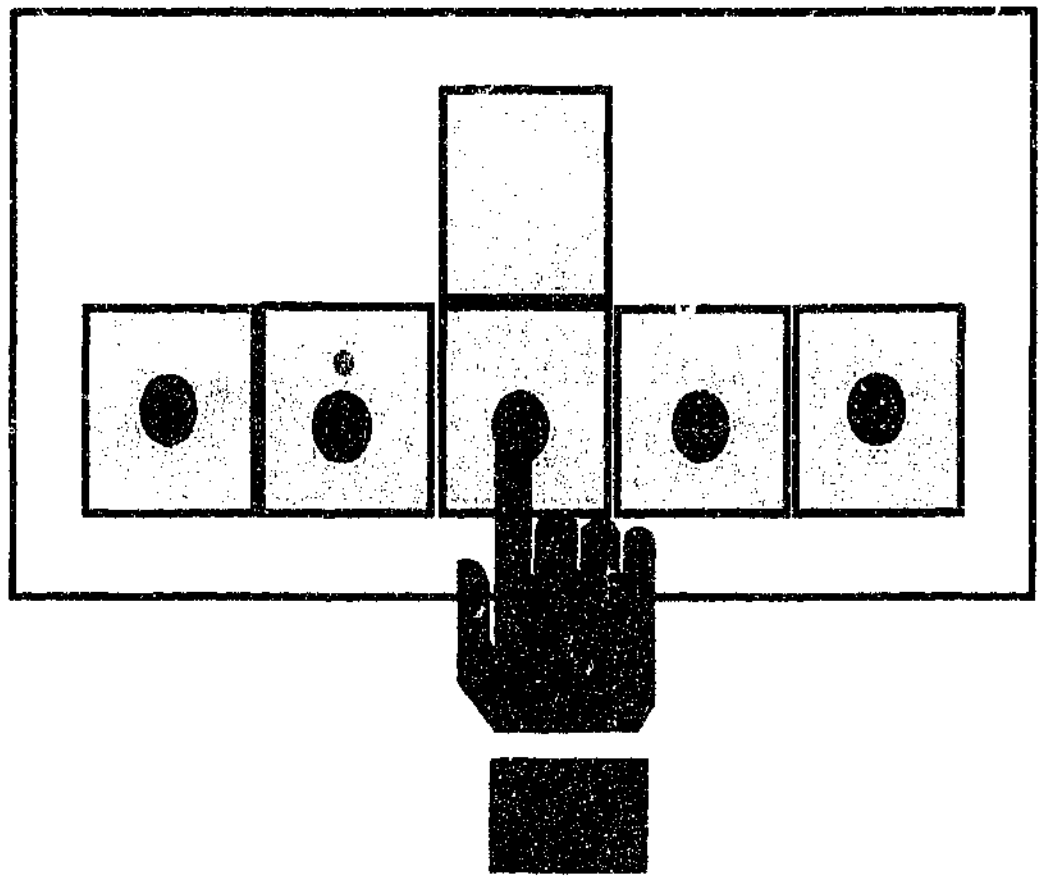
look out for the green light and lift your finger off the start button, as quickly as you can



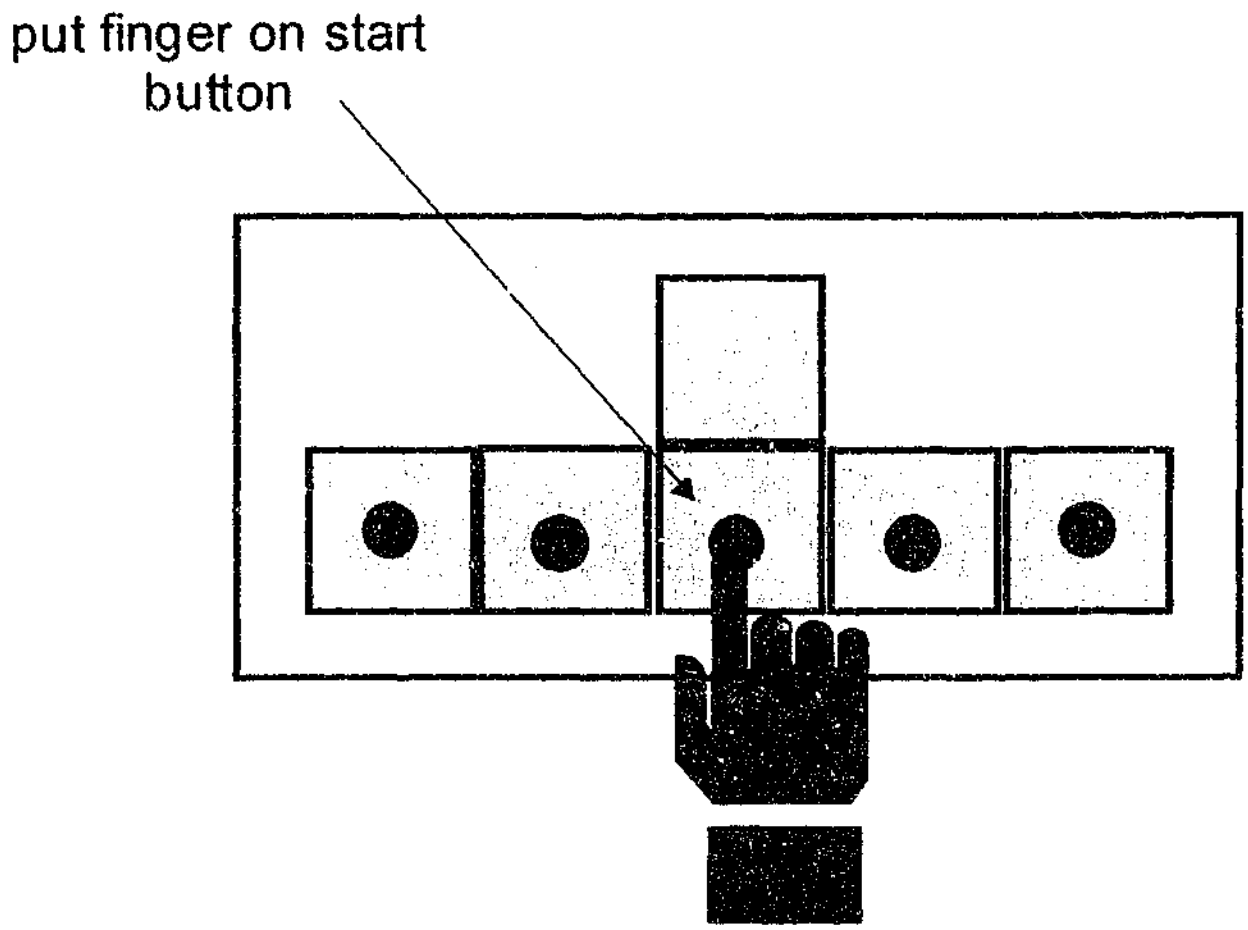
If a red light comes on too, just ignore it



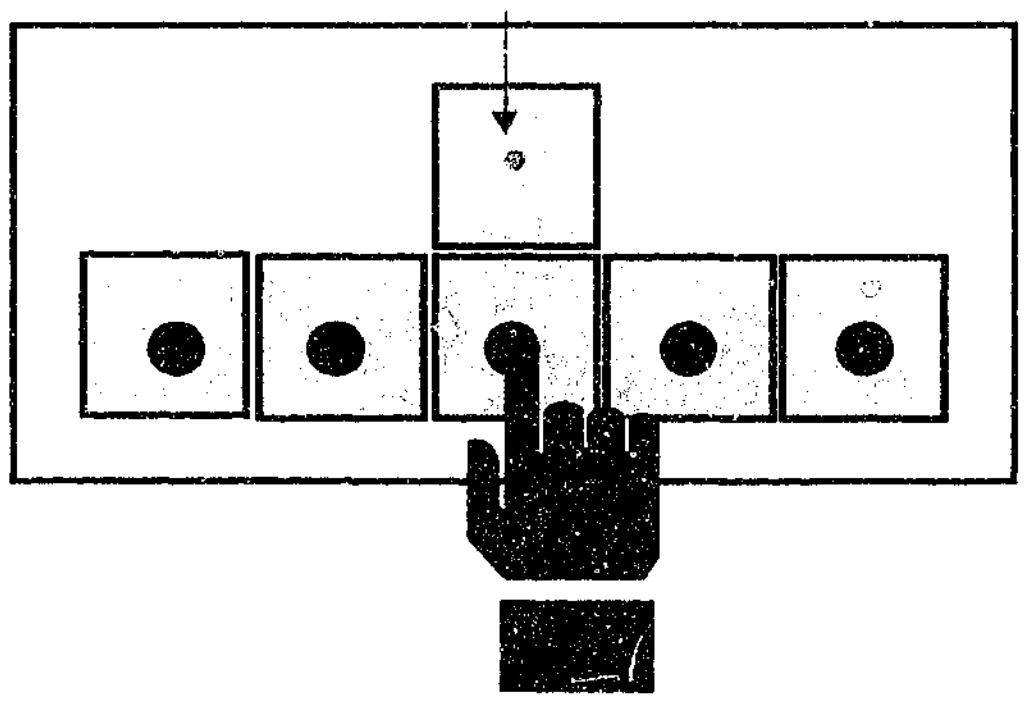
If a red light comes on by itself, don't move!



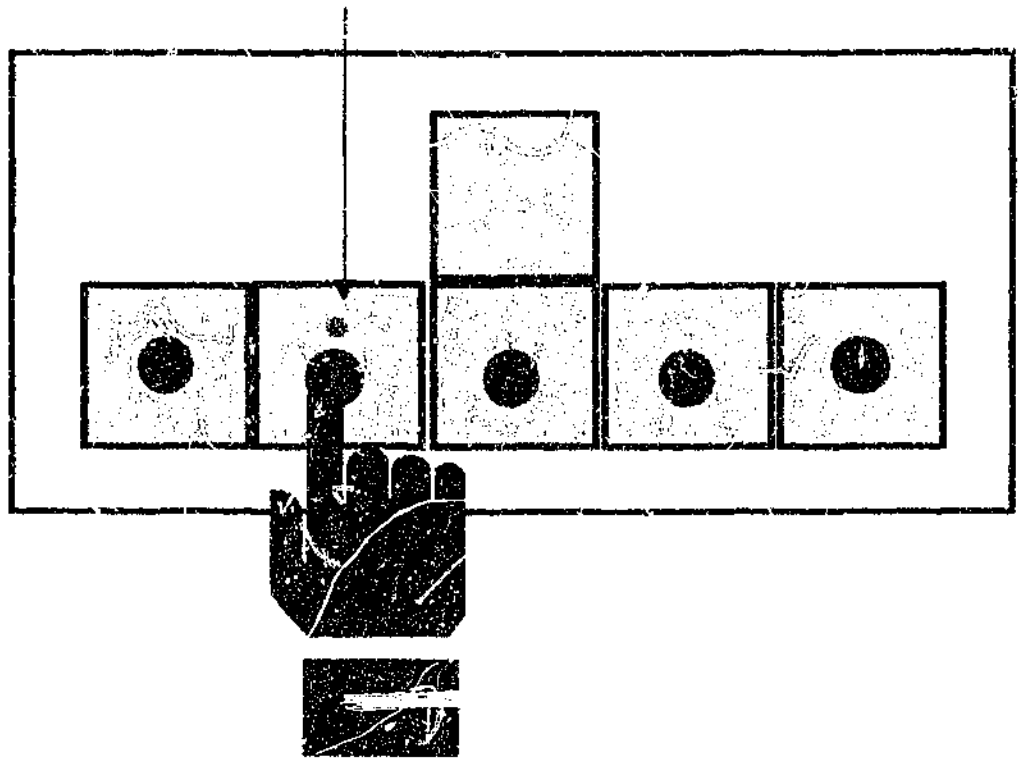
D.3 Instructions to participants in the reach condition of the change-set task:



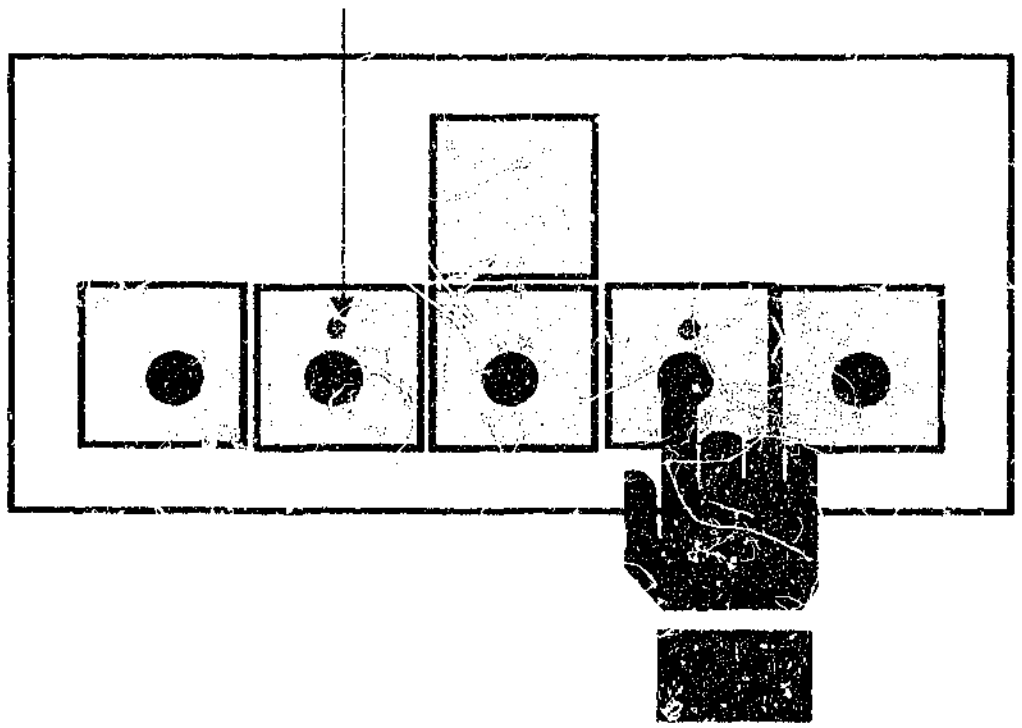
The red top light tells you to look out for red lights, and ignore green lights



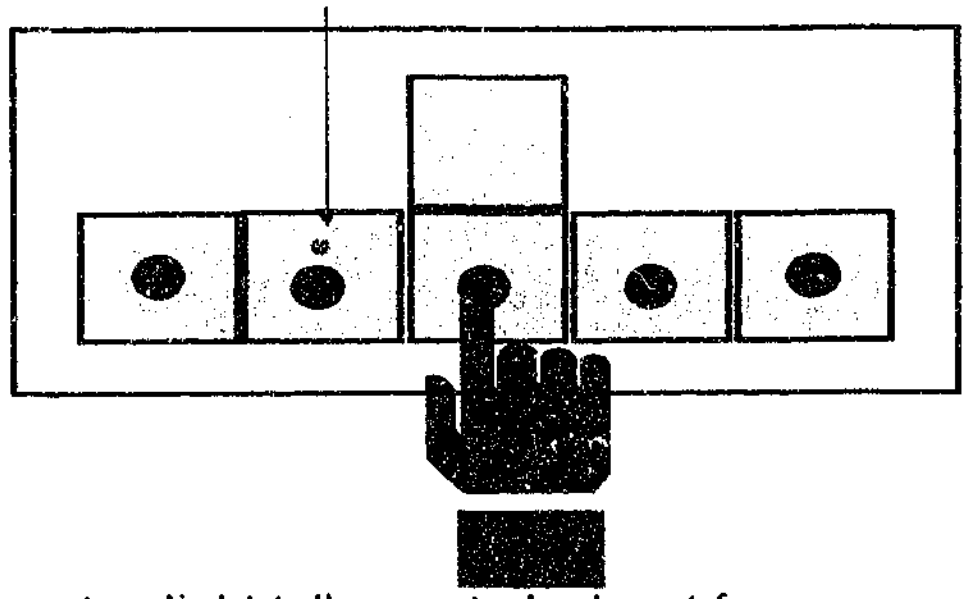
look for the red light and push its button as quickly as you can



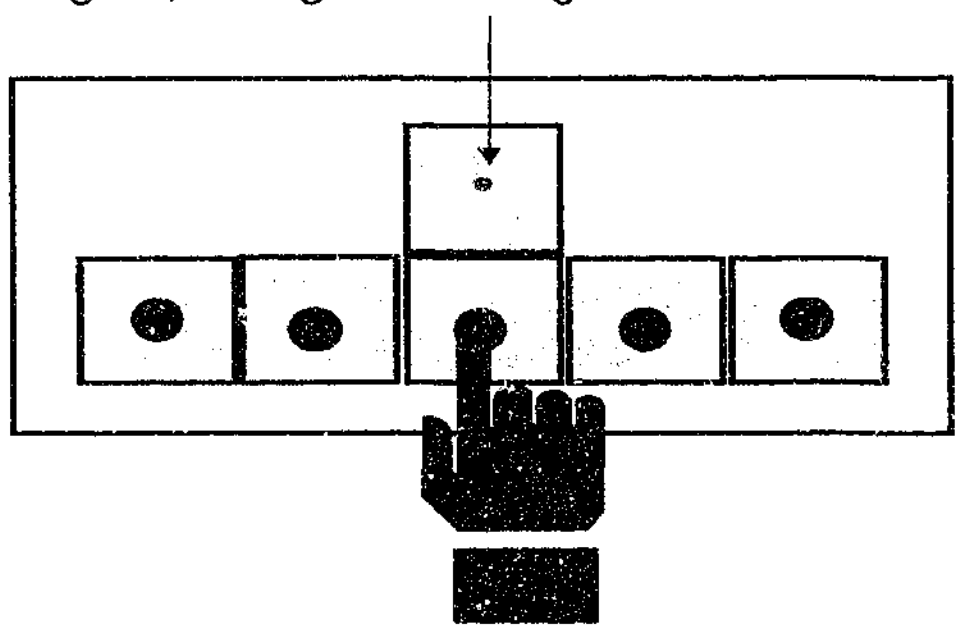
if a green light comes on too, just ignore it



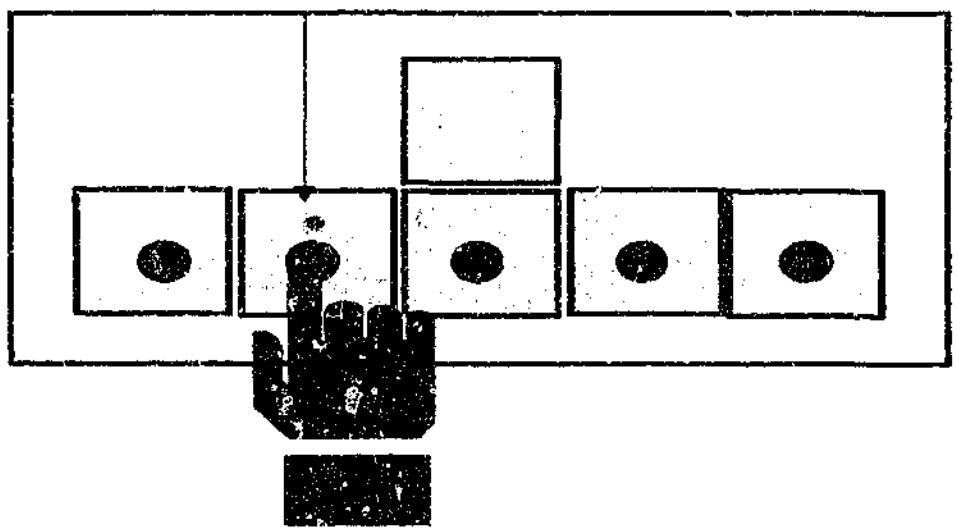
If a green light comes on by itself, don't move!



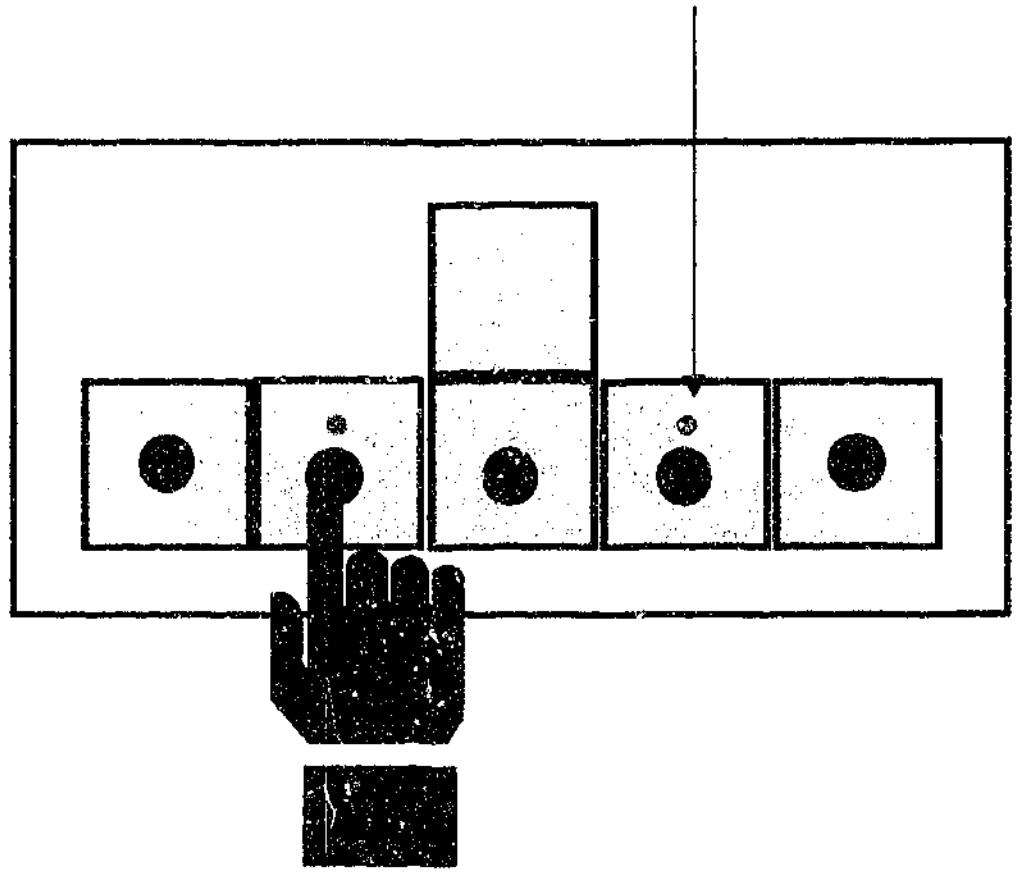
The green top light tells you to look out for green lights, and ignore red lights



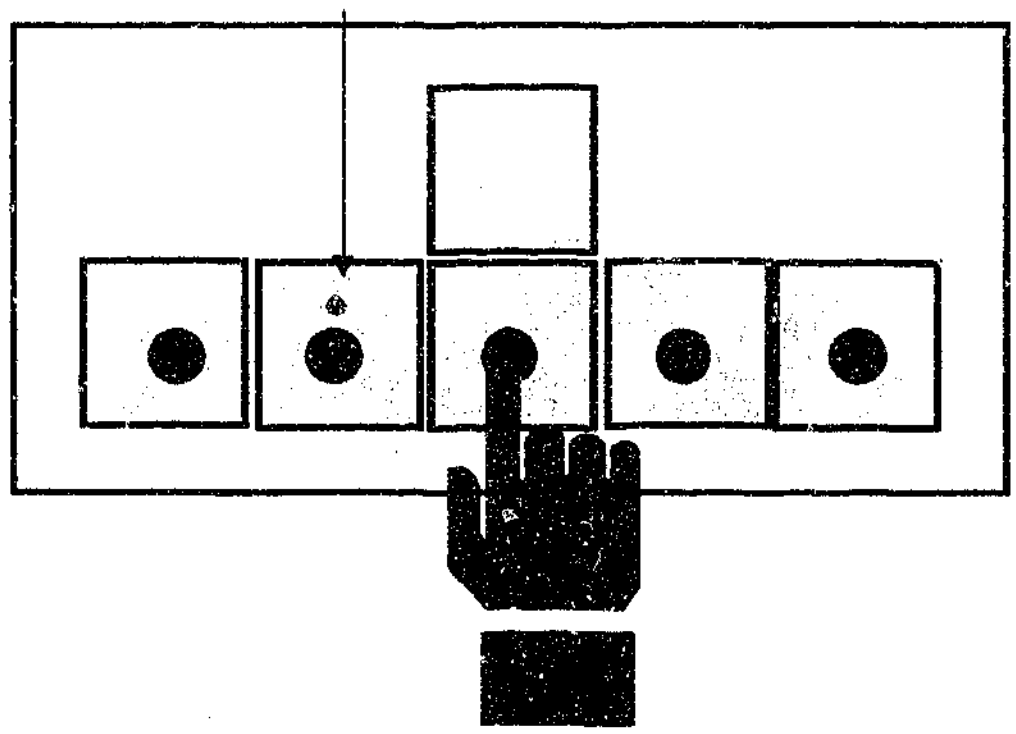
look for the green light and push its button as quickly as you can



If a red light comes on too, just ignore it

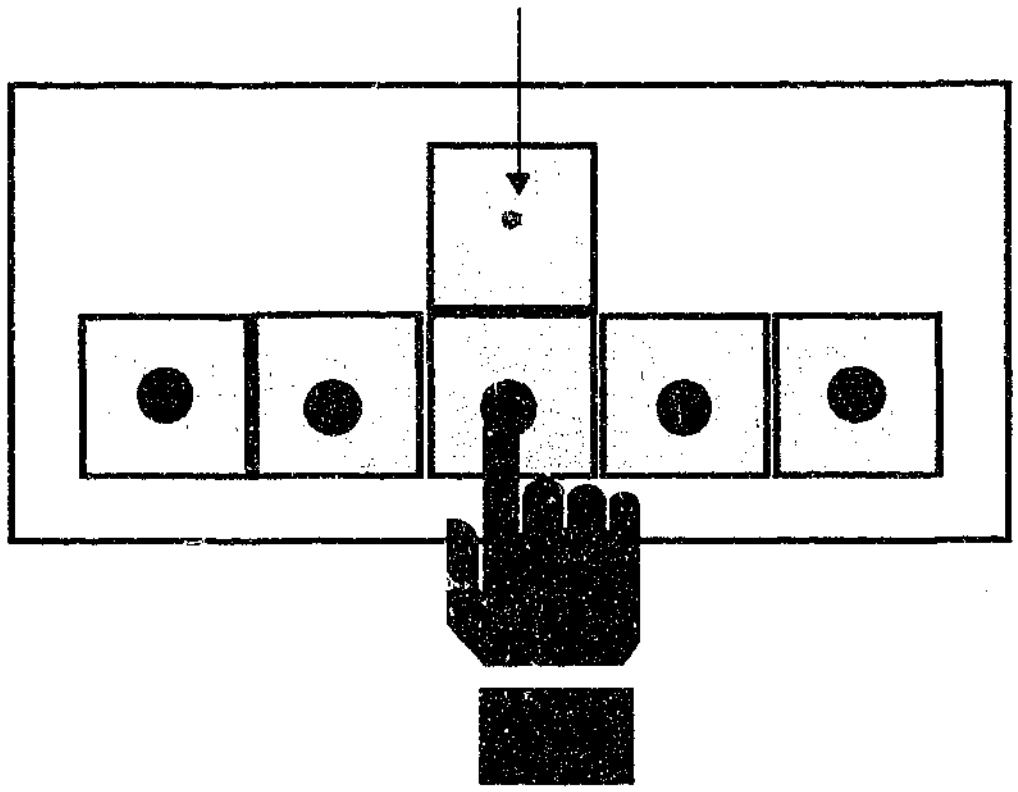


If a red light comes on by itself,
don't move!

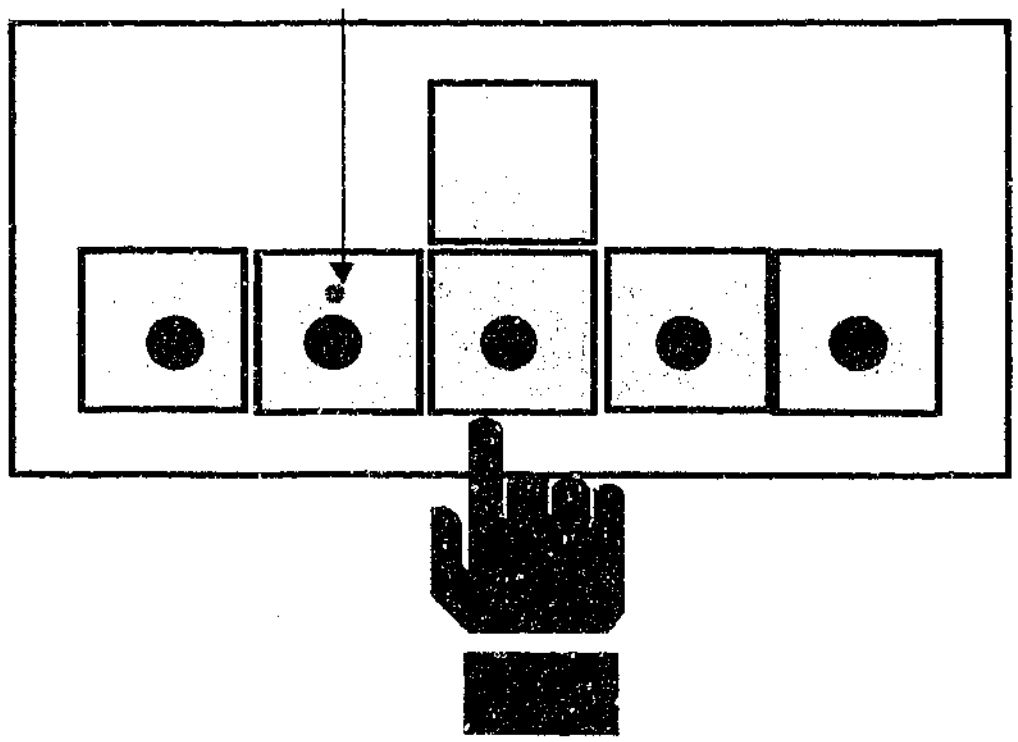


D.4 Instructions to participants in the no-reach condition of the change-set task:

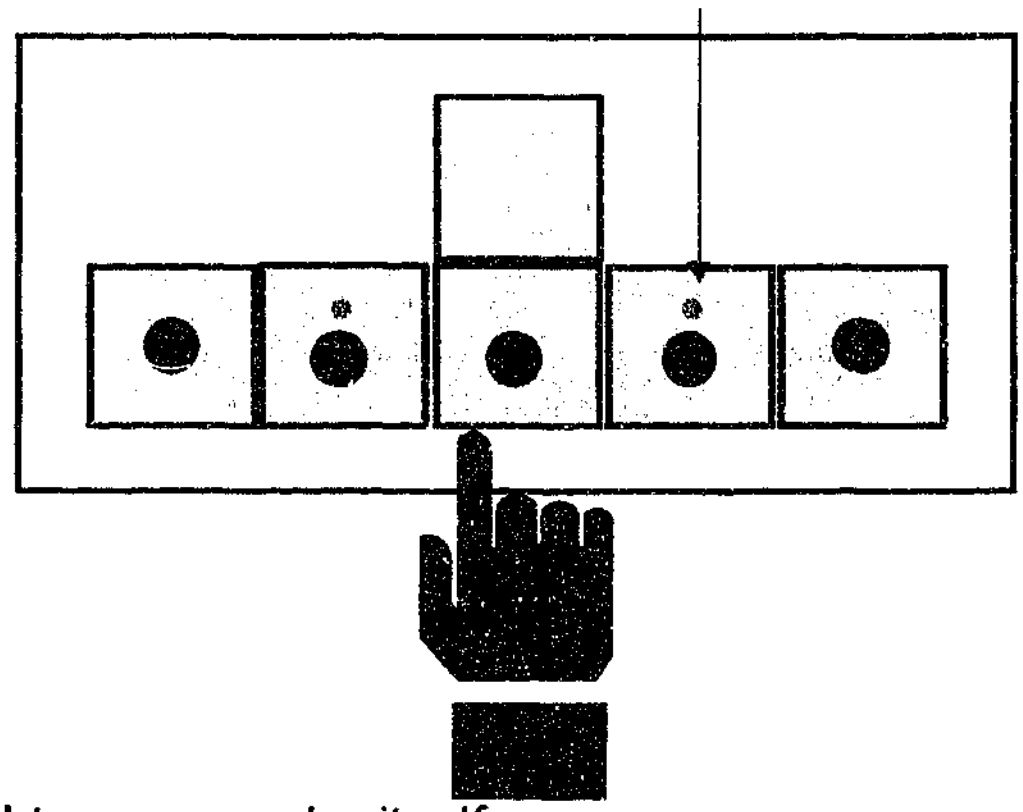
The green top light tells you to look out for green lights and ignore red lights



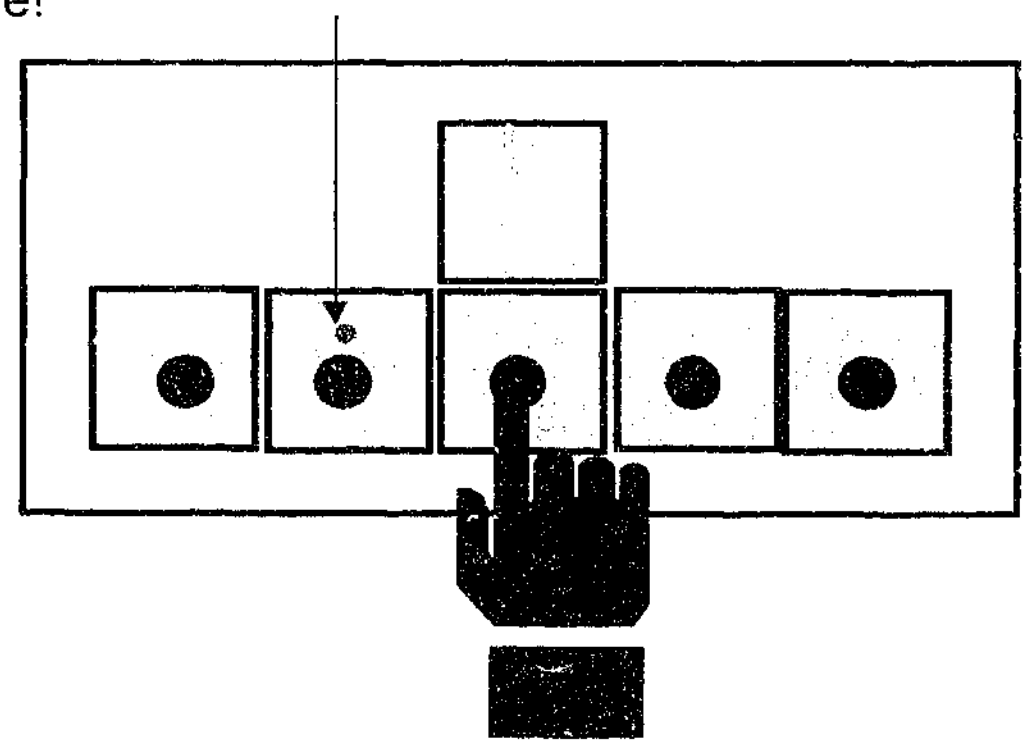
look for the green light and take your finger off the start button as quickly as you can



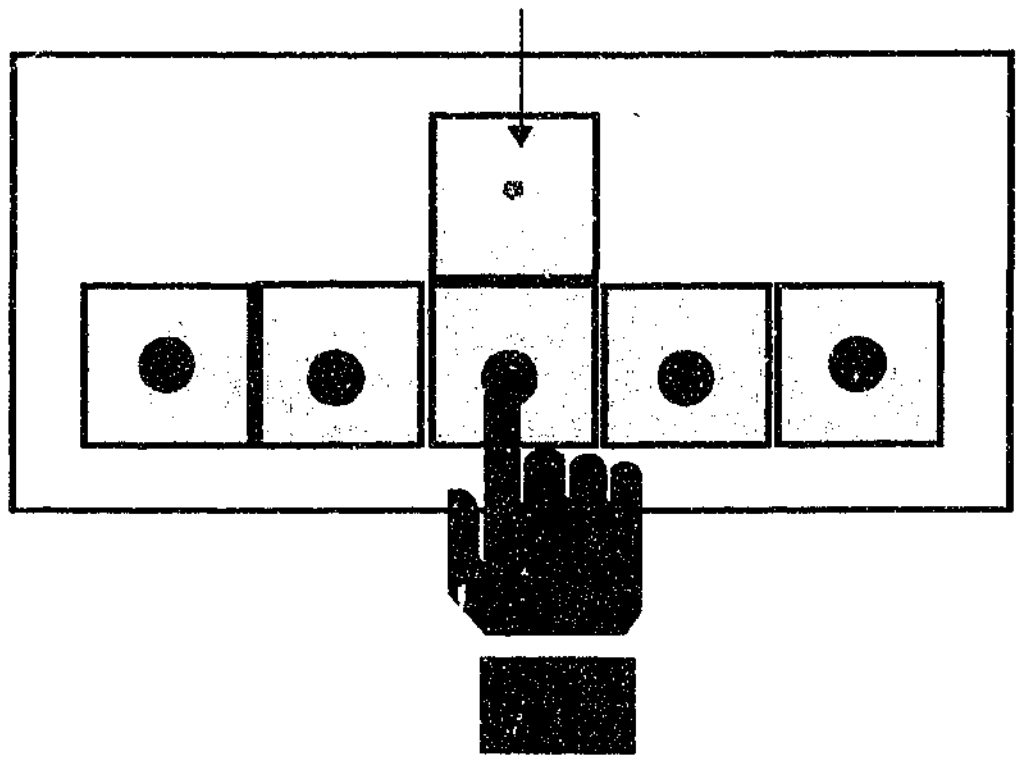
If a red light comes on too, just ignore it



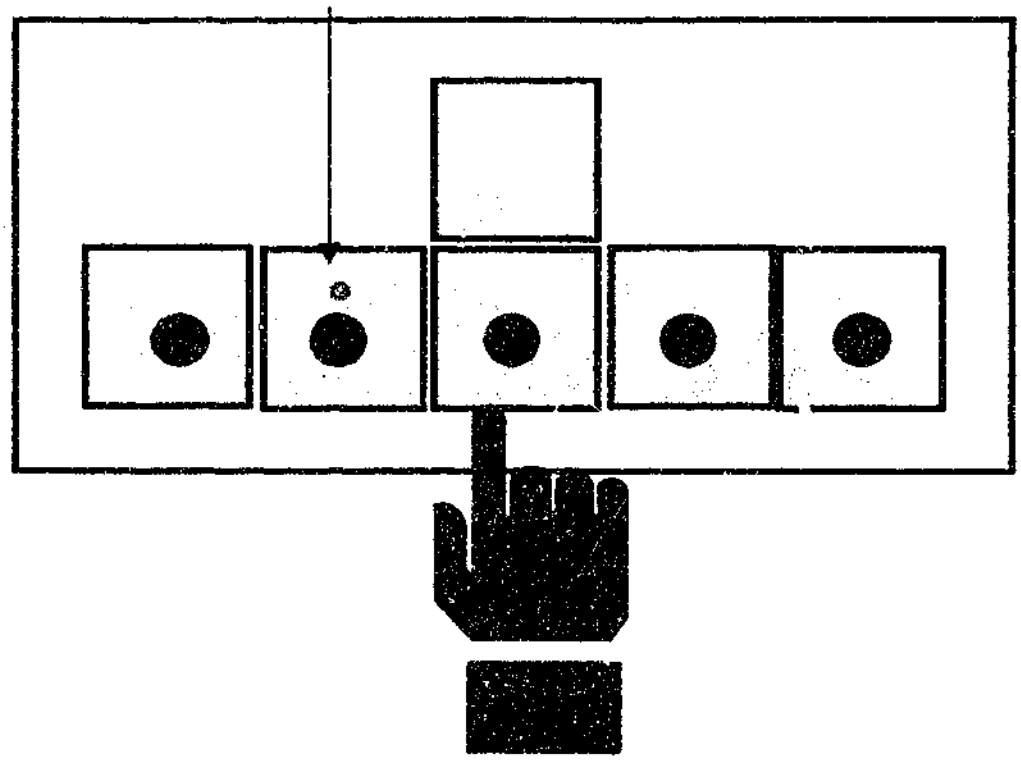
If a red light comes on by itself,
don't move!



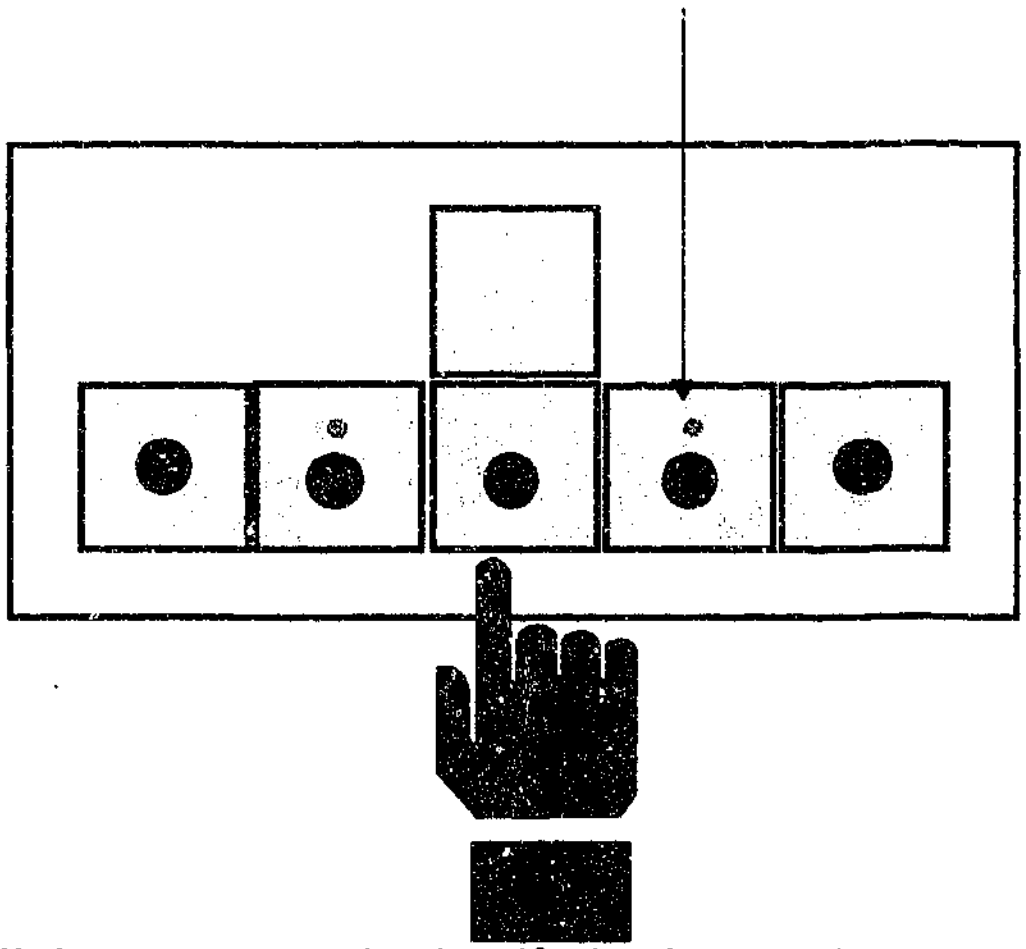
The red top light tells you to look out for red lights and ignore green lights



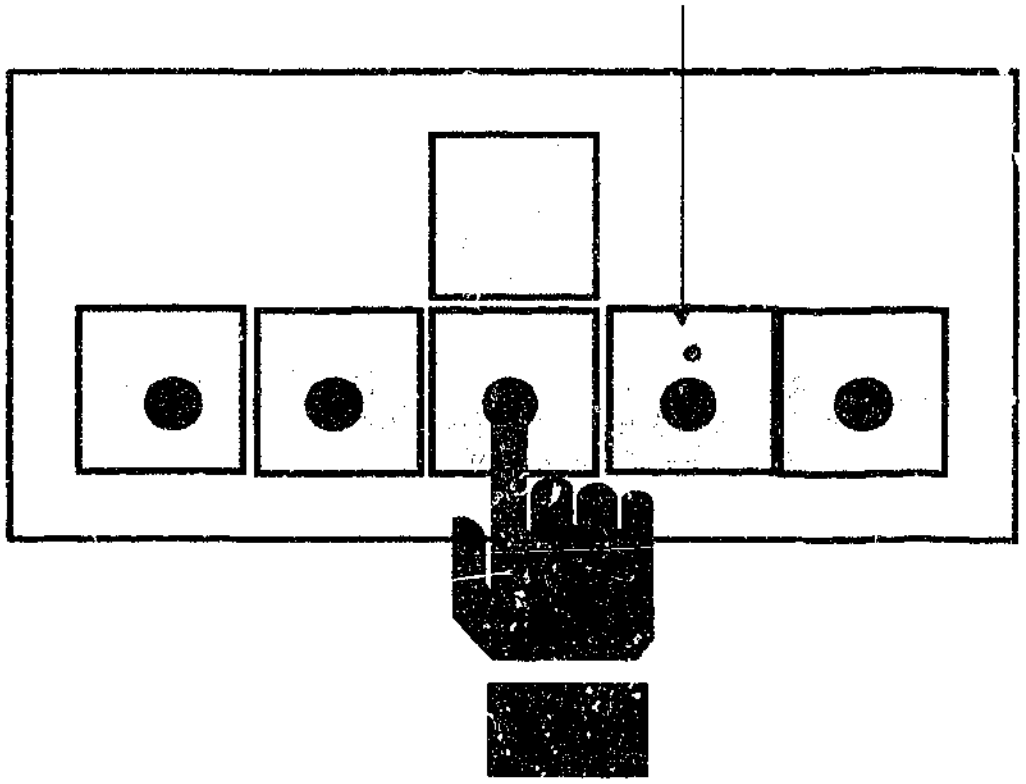
look for the red light and lift your finger off the start button as quickly as you can



If a green light comes on too, just ignore it



If a green light comes on by itself, don't move!



APPENDIX E: ONE-WAY ANOVA CONDUCTED ON AGE DATA FROM THE UNMEDICATED VERSUS MEDICATED ADHD GROUPS, FOR EXPERIMENTS 1 AND 2

Descriptive Statistics

AGE				
Group	N	Mean Age	Std. Deviation	Std. Error
unmedicated	15	9.261078	1.587983	.410015
medicated	7	11.178543	2.164773	.818207
Total	22	9.871180	1.963583	.418637

ANOVA table

ANOVA AGE					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	17.548	1	17.548	5.534	.029
Within Groups	63.421	20	3.171		
Total	80.969	21			

APPENDIX F: ANALYSES FOR EXPERIMENT 1

Analyses of demographic data

F.1 Demographic details of the unmedicated ADHD and control children.

		N	Mean	Std. Deviation	Std. Error
AGE	clinical	15	9.261078	1.587983	.410015
	control	15	9.311082	1.506754	.389042
GRADE	clinical	15	3.4667	1.8848	.4866
	control	15	3.6000	1.5492	.4000
FSIQ	clinical	15	100.9333	11.6953	3.0197
	control	15	105.4667	9.6796	2.4993
Rating Scale Home Percentile rank	clinical	15	5.5333	7.8728	2.0327
	control	15	68.1333	25.8038	6.6625
Rating Scale School Percentile rank	clinical	15	27.5333	14.4463	3.7300
	control	14	85.0714	17.1844	4.5927
rating scale home hyperactivity-impulsivity	clinical	15	3.2000	2.3964	.6188
	control	15	11.8000	1.8205	.4701
rating scale home inattentiveness	clinical	15	2.5333	2.1996	.5679
	control	15	11.0667	2.1202	.5474

	clinical	15	7.8667	2.0999	.5422
rating scale school hyperactivity-impulsivity	control	14	12.5000	1.0190	.2724
	clinical	15	7.6667	1.7182	.4437
rating scale school inattentiveness	control	14	12.5714	1.5549	.4156

F.2 One-way ANOVAs for age, grade, full scale IQ, and ADDES rating scale data, for unmedicated ADHD versus control children.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
AGE	Between Groups	1.875E-02	1	1.875E-02	.008	.930
	Within Groups	67.088	28	2.396		
	Total	67.107	29			
GRADE	Between Groups	.133	1	.133	.045	.834
	Within Groups	83.333	28	2.976		
	Total	83.467	29			
FSIQ	Between Groups	154.133	1	154.133	1.338	.257
	Within Groups	3226.667	28	115.238		

	Total	3380.800	29			
Rating Scale Home Percentile Rank	Between Groups	29390.700	1	29390.700	80.764	.000
	Within Groups	10189.467	28	363.910		
	Total	39580.167	29			
Rating Scale School Percentile Rank	Between Groups	23973.545	1	23973.545	95.743	.000
	Within Groups	6760.662	27	250.395		
	Total	30734.207	28			
rating scale home hyperactivity-impulsivity	Between Groups	554.700	1	554.700	122.489	.000
	Within Groups	126.800	28	4.529		
	Total	681.500	29			
rating scale home inattentiveness	Between Groups	546.133	1	546.133	117.029	.000
	Within Groups	130.667	28	4.667		
	Total	676.800	29			
rating scale school hyperactivity-impulsivity	Between Groups	155.456	1	155.456	55.791	.000

	Within Groups	75.233	27	2.786		
	Total	230.690	28			
rating scale school inattentiveness	Between Groups	174.204	1	174.204	64.642	.000
	Within Groups	72.762	27	2.695		
	Total	246.966	28			

Analyses of reaction time data in the reach task

F.3 Three-way ANOVA: Group (unmedicated ADHD, controls) x set (change, maintain) x distractor (absent, present) for reaction time data (collapsed across start position and target location) in the reach task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach rt maintain-set distractor absent	unmedicated	655.129	100.003	15
	controls	524.719	125.359	15
reach rt maintain-set distractor present	unmedicated	675.556	89.244	15
	controls	559.968	148.708	15
reach rt change-set distractor absent	unmedicated	655.339	87.106	15
	controls	539.966	95.032	15
reach rt change-set distractor present	unmedicated	678.137	96.991	15
	controls	544.576	100.818	15

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	13.117	1	13.117	0.003	0.957
SET x GROUP	Huynh-Feldt	16.163	1	16.163	0.004	0.953
Error(SET)	Huynh-Feldt	126062.202	28	4502.221		
DIST	Huynh-Feldt	12943.019	1	12943.019	15.763	0.000
DIST x GROUP	Huynh-Feldt	21.246	1	21.246	0.026	0.873
Error(DIST)	Huynh-Feldt	22990.402	28	821.086		
SET x DIST	Huynh-Feldt	1498.317	1	1498.317	2.136	0.155
SET x DIST x GROUP	Huynh-Feldt	2043.034	1	2043.034	2.912	0.099
Error(SET x DIST)	Huynh-Feldt	19643.128	28	701.540		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	43803081.166	1	43803081.166	1095.979	0.000
GROUP	459297.212	1	459297.212	11.492	0.002
Error	1119078.404	28	39967.086		

Analyses of movement time data for the reach task

F.4 Three-way ANOVA: Group (unmedicated ADHD, controls) x set (change, maintain) x distractor (absent, present), for movement time data (collapsed across start position and target location) in the reach task.

Descriptive statistics

	GROUP	Mean	Std. Deviation	N
reach mt maintain-set distractor absent	unmedicated	299.773	52.100	15
	controls	300.086	68.737	15
reach mt maintain-set distractor present	unmedicated	306.075	55.468	15
	controls	308.710	77.475	15
reach mt change-set distractor absent	unmedicated	312.320	78.322	15
	controls	340.947	91.365	15
reach mt change-set distractor present	unmedicated	336.941	84.552	15
	controls	349.821	96.060	15

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	29477.651	1	29477.651	7.940	0.009
SET x GROUP	Huynh-Feldt	2787.799	1	2787.799	0.751	0.394
Error(SET)	Huynh-Feldt	103954.916	28	3712.676		
DIST	Huynh-Feldt	4396.222	1	4396.222	8.201	0.008
DIST x GROUP	Huynh-Feldt	337.874	1	337.874	0.630	0.434
Error(DIST)	Huynh-Feldt	15009.843	28	536.066		
SET x DIST	Huynh-Feldt	646.550	1	646.550	1.439	0.240
SET x DIST x GROUP	Huynh-Feldt	612.201	1	612.201	1.362	0.253
Error(SETxDIST)	Huynh-Feldt	12583.093	28	449.396		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	12236911.269	1	12236911.269	644.380	0.000
GROUP	3705.288	1	3705.288	0.195	0.662
Error	531725.803	28	18990.207		

Analyses of reaction time data for the no-reach task

F.5 Three-way ANOVA: Group (unmedicated ADHD, controls) x set (change, maintain) x distractor (absent, present), for reaction time data (collapsed across start position and target location) in the no-reach task.

Descriptive statistics

	GROUP	Mean	Std. Deviation	N
no-reach rt maintain-set distractor absent	unmedicated	736.974	139.019	15
	controls	632.062	182.982	15
no-reach rt maintain-set distractor present	unmedicated	720.697	144.386	15
	controls	619.843	175.477	15
no reach rt change-set distractor absent	unmedicated	786.618	136.772	15
	controls	637.476	168.005	15
no reach rt change-set distractor present	unmedicated	710.490	92.906	15
	controls	590.078	111.618	15

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	426.597	1	426.597	0.018	0.893
SET x GROUP	Huynh-Feldt	7629.242	1	7629.242	0.328	0.571
Error(SET)	Huynh-Feldt	651253.202	28	23259.043		
DIST						

	Huynh-Feldt	43332.387	1	43332.387	15.510	0.000
DIST x GROUP	Huynh-Feldt	2015.773	1	2015.773	0.722	0.403
Error(DIST)	Huynh-Feldt	78226.274	28	2793.796		
SET x DIST	Huynh-Feldt	16932.695	1	16932.695	14.075	0.001
SET x DIST x GROUP	Huynh-Feldt	1141.382	1	1141.382	0.949	0.338
Error(SETxDIST)	Huynh-Feldt	33684.787	28	1203.028		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	55370507.729	1	55370507.729	938.813	0.000
GROUP	423616.601	1	423616.601	7.182	0.012
Error	1651420.386	28	58979.300		

Subanalyses of distractor x set interaction

F.6 One-way repeated measures ANOVA for distractor (absent, present) in the maintain-set condition.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
DIST	Huynh-Feldt	3045.014	1.000	3045.014	2.851	.102
Error(DIST)	Huynh-Feldt	30974.583	29.000	1068.089		

F.7 One-way repeated measures ANOVA for distractor (absent, present) in the change-set condition.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
DIST	Huynh-Feldt	57220.068	1.000	57220.068	19.733	.000
Error(DIST)	Huynh-Feldt	84093.634	29.000	2899.780		

Analyses of performance asymmetries/ spatial biases for right-handed unmedicated ADHD children compared to matched controls

F.8 Three-way ANOVA: Group (right-handed unmedicated ADHD, right-handed controls) x target (left, right) x distractor (absent, present), for centre-start reaction-time data, in the reach condition, maintain-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left target only rt	unmedicated	633.290	121.548	10
	controls	562.340	148.765	10
reach centre start left target right distractor rt	unmedicated	689.260	122.587	10
	controls	613.580	160.893	10
reach centre start right target only rt	unmedicated	664.830	147.906	10
	controls	596.030	134.676	10
reach centre start right target left distractor rt	unmedicated	669.290	195.032	10
	controls	648.870	178.352	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET	Huynh-Feldt	8110.359	1	8110.359	1.544	0.230
TARGET x MED	Huynh-Feldt	4119.900	1	4119.900	0.784	0.387
Error(TARGET)	Huynh-Feldt	94534.373	18	5251.910		
DIST	Huynh-Feldt	33829.459	1	33829.459	9.878	0.006
DIST x MED	Huynh-Feldt	2381.641	1	2381.641	0.695	0.415
Error(DIST)	Huynh-Feldt	61642.373	18	3424.576		
TARGET x DIST						

	Huynh-Feldt	3113.749	1	3113.749	0.610	0.445
TARGET x DIST x MED	Huynh-Feldt	3525.827	1	3525.827	0.691	0.417
Error(TARGETxDIST)	Huynh-Feldt	91860.310	18	5103.351		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	32226129.344	1	32226129.344	402.524	0.000
GROUP	69531.477	1	69531.477	0.868	0.364
Error	1441081.000	18	80060.056		

F.9 Three-way ANOVA: Group (right-handed unmedicated ADHD, right-handed controls) x target (left, right) x distractor (absent, present), for centre-start reaction-time data, in the no-reach condition, maintain-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left target only rt	unmedicated	728.600	154.243	10
	controls	669.660	169.294	10
no reach centre start left target right distractor rt	unmedicated	718.670	197.128	10
	controls	622.640	143.476	10
no reach centre start right target only rt	unmedicated	758.542	162.977	10
	controls	640.040	177.984	10
no reach centre start right target left distractor rt	unmedicated	739.680	170.825	10
	controls	611.950	129.498	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET	Huynh-Feldt	141.571	1	141.571	0.014	0.906
TARGET x GROUP	Huynh-Feldt	10410.990	1	10410.990	1.057	0.317
Error(TARGET)	Huynh-Feldt	177233.406	18	9846.300		
DIST	Huynh-Feldt	13494.590	1	13494.590	2.463	0.134
DIST x GROUP	Huynh-Feldt	2681.671	1	2681.671	0.489	0.493
Error(DIST)	Huynh-Feldt	98628.267	18	5479.348		
TARGET x DIST	Huynh-Feldt	124.945	1	124.945	0.047	0.831
TARGET x DIST x GROUP	Huynh-Feldt	970.379	1	970.379	0.364	0.554
Error(TARGET*DIST)	Huynh-Feldt	48034.760	18	2668.598		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	37672135.989	1	37672135.989	418.350	0.000
GROUP	201204.019	1	201204.019	2.234	0.152
Error	1620886.242	18	90049.236		

F.10 Three-way ANOVA: Group (right-handed unmedicated ADHD, right-handed controls) x target (left, right) x distractor (absent, present), for centre-start movement-time data, in the reach condition, maintain-set task.

Descriptive statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left target only mt	unmedicated	255.670	68.570	10
	controls	303.110	89.388	10

reach centre start left target right distractor mt	unmedicated	262.310	93.575	10
	controls	282.930	74.829	10
reach centre start right target only mt	unmedicated	272.240	67.591	10
	controls	301.580	71.234	10
reach centre start right target left distractor mt	unmedicated	272.280	87.149	10
	controls	309.080	130.381	10

Test of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET	Huynh-Feldt	3271.683	1	3271.683	1.636	0.217
TARGET x GROUP	Huynh-Feldt	4.608	1	4.608	0.002	0.962
Error(TARGET)	Huynh-Feldt	35992.907	18	1999.606		
DIST	Huynh-Feldt	45.000	1	45.000	0.017	0.898
DIST x BROUP	Huynh-Feldt	468.512	1	468.512	0.177	0.679
Error(DIST)	Huynh-Feldt	47742.261	18	2652.348		
TARGET x DIST	Huynh-Feldt	555.459	1	555.459	0.258	0.617
TARGET x DIST x GROUP	Huynh-Feldt	1468.899	1	1468.899	0.683	0.419
Error(TARGETxDIST)	Huynh-Feldt	38694.693	18	2149.705		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	6379980.757	1	6379980.757	267.608	0.000
GROUP	22512.047	1	22512.047	0.944	0.344
Error	429133.194	18	23840.733		

F.11 Three-way ANOVA: Group (right-handed unmedicated ADHD, right-handed controls) x target (left, right) x distractor (absent, present), for centre-start reaction-time data, in the reach condition, change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left target only reaction time change set	unmedicated	665.660	143.590	10
	controls	562.950	110.963	10
reach centre start left target right distractor reaction time change set	unmedicated	703.330	117.865	10
	controls	549.940	93.497	10
reach centre start right target only reaction time change set	unmedicated	655.050	117.003	10
	controls	550.910	113.693	10
reach centre start right target left distractor reaction time change set	unmedicated	677.680	138.408	10
	controls	577.920	109.702	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET	Huynh-Feldt	516.128	1	516.128	0.206	0.655
TARGET x GROUP	Huynh-Feldt	3406.050	1	3406.050	1.361	0.259
Error(TARGET)	Huynh-Feldt	45058.630	18	2503.257		
DIST	Huynh-Feldt	6900.608	1	6900.608	1.891	0.186
DIST x GROUP	Huynh-Feldt	2679.609	1	2679.609	0.734	0.403
Error(DIST)	Huynh-Feldt	65689.736	18	3649.430		
TARGET x DIST	Huynh-Feldt	779.999	1	779.999	0.331	0.572
TARGET x DIST x GROUP	Huynh-Feldt	3789.505	1	3789.505	1.608	0.221
Error(TARGETxDIST)	Huynh-Feldt	42422.293	18	2356.794		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F
Intercept	30546998.627	1	30546998.627	634.063
GROUP	264499.989	1	264499.989	5.490
Error	867179.067	18	48176.615	

F.12 Three-way ANOVA: Group (right-handed unmedicated ADHD, right-handed controls) x target (left, right) x distractor (absent, present), for centre-start reaction-time data, in the no-reach condition, change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left target only reaction time change set	unmedicated	816.360	130.012	10
	controls	681.870	176.850	10
no reach centre start left target right distractor reaction time change set	unmedicated	759.730	120.442	10
	controls	630.820	112.039	10
no reach centre start right target only reaction time change set	unmedicated	766.500	163.179	10
	controls	688.230	165.783	10
no reach centre start right target left distractor reaction time change set	unmedicated	705.030	165.406	10
	controls	639.430	121.178	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET	Huynh-Feldt	10032.956	1	10032.956	1.389	0.254
TARGET x GROUP	Huynh-Feldt	17859.281	1	17859.281	2.472	0.133
Error(TARGET)	Huynh-Feldt	130017.804	18	7223.211		
DIST	Huynh-Feldt	59377.756	1	59377.756	6.475	0.020

DIST x GROUP	Huynh-Feldt	416.328	1	416.328	0.045	0.834
Error(DIST)	Huynh-Feldt	165053.869	18	9169.659		
TARGET x DIST	Huynh-Feldt	8.385	1	8.385	0.002	0.963
TARGET x DIST x GROUP	Huynh-Feldt	62.835	1	62.835	0.017	0.898
Error(TARGETxDIST)	Huynh-Feldt	66881.627	18	3715.646		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	40441253.431	1	40441253.431	616.597	0.000
GROUP	207336.050	1	207336.050	3.161	0.092
Error	1180580.445	18	65587.803		

F.13 Three-way ANOVA: Group (right-handed unmedicated ADHD, right-handed controls) x target (left, right) x distractor (absent, present), for centre-start movement-time data, in the reach condition, change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left target only movement time change set	unmedicated	276.590	95.917	10
	controls	316.610	74.958	10
reach centre start left target right distractor movement time change set	unmedicated	307.810	72.134	10
	controls	331.940	93.644	10
reach centre start right target only movement time change set	unmedicated	282.650	88.892	10
	controls	308.230	103.386	10
reach centre start right target left distractor movement time change set	unmedicated	292.080	55.159	10
	controls	321.360	107.321	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET	Huynh-Feldt	1024.597	1	1024.597	0.235	0.634
TARGET x GROUP	Huynh-Feldt	107.880	1	107.880	0.025	0.877
Error(TARGET)	Huynh-Feldt	78485.703	18	4360.317		
DIST	Huynh-Feldt	5970.242	1	5970.242	4.020	0.060
DIST x GROUP	Huynh-Feldt	185.745	1	185.745	0.125	0.728
Error(DIST)	Huynh-Feldt	26733.076	18	1485.171		
TARGET x DIST	Huynh-Feldt	719.401	1	719.401	0.287	0.599
TARGET x DIST x GROUP	Huynh-Feldt	479.710	1	479.710	0.191	0.667
Error(TARGETxDIST)	Huynh-Feldt	45159.295	18	2508.850		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	7425356.258	1	7425356.258	328.313	0.000
GROUP	17704.224	1	17704.224	0.783	0.388
Erro	407100.967	18	22616.720		

Analyses of error data

Analyses of inattentive error data

F.14. Three-way ANOVA: Group (unmedicated ADHD, controls) x set (maintain, change) x distractor (absent, present) for inattentive error data (collapsed across start and target conditions) in the reach task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no-change reach distractor absent	clinical	0.911	0.982	15
	control	0.133	0.229	15
no-change reach dist present	clinical	0.678	0.689	15
	control	0.144	0.226	15
change-set reach distractor absent	clinical	1.156	0.995	15
	control	0.278	0.453	15
change-set reach dist present	clinical	1.178	1.138	15
	control	0.222	0.331	15

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	1.752	1	1.752	7.29	0.012
SET x GROUP	Huynh-Feldt	0.511	1	0.511	2.128	0.156
Error(SET)	Huynh-Feldt	6.73	28	0.24		
DIST	Huynh-Feldt	0.122	1	0.122	1.593	0.217
DIST x GROUP	Huynh-Feldt	5.21E-02	1	5.21E-02	0.678	0.417
Error(DIST)	Huynh-Feldt	2.152	28	7.69E-02		
SET x DIST	Huynh-Feldt	6.69E-02	1	6.69E-02	0.354	0.556

SET x DIST x GROUP						
	Huynh-Feldt	0.195	1	0.195	1.031	0.319
Error(SETxDIST)						
	Huynh-Feldt	5.287	28	0.189		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	41.419	1	41.419	26.47	0
GROUP	18.539	1	18.539	11.848	0.002
Error	43.813	28	1.565		

F.15 Three-way ANOVA: Group (unmedicated ADHD, controls) x set (maintain, change) x distractor (absent, present) for inattentive error data (collapsed across start and target conditions) in the no-reach task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no-change no-reach dist absent	clinical	1.033	1.095	15
	control	0.111	0.265	15
no-change no-reach dist present	clinical	1.022	1.342	15
	control	8.89E-02	0.139	15
change-set no-reach distractor absent	clinical	2.456	2.016	15
	control	0.489	0.803	15
change-set no-reach distractor present	clinical	1.067	1.516	15
	control	0.111	0.174	15

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	6.533	1	6.533	5.256	0.03
SET x GROUP						

	Huynh-Feldt	2.133	1	2.133	1.716	0.201
Error(SET)						
	Huynh-Feldt	34.806	28	1.243		
DIST						
	Huynh-Feldt	6.075	1	6.075	19.089	0.00
DIST x GROUP						
	Huynh-Feldt	1.875	1	1.875	5.892	0.022
Error(DIST)						
	Huynh-Feldt	8.911	28	0.318		
SET x DIST						
	Huynh-Feldt	5.633	1	5.633	9.581	0.004
SET x DIST x GROUP						
	Huynh-Feldt	1.959	1	1.959	3.332	0.079
Error(SETxDIST)						
	Huynh-Feldt	16.463	28	0.588		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	76.268	1	76.268	26.171	0
GROUP	42.801	1	42.801	14.687	0.001
Error	81.598	28	2.914		

Subanalyses of group x distractor interaction

F.16 One-way repeated measures ANOVA for distractor (absent, present) for the unmedicated ADHD children.

Descriptive statistics:

	GROUP	Mean	Std. Deviation	N
no reach distractor absent	clinical	1.744	1.371	15
no-reach distractor present	clinical	1.044	1.060	15

ANOVA table

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	3.675	1	3.675	14.735	0.002
DIST x GROUP						.
	Huynh-Feldt	0	0	.	.	.
Error(DIST)						
	Huynh-Feldt	3.492	14	0.249		

F.17 One-way repeated measures ANOVA for distractor (absent, present) for the control children.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach distractor absent	control	0.3	0.462	15
no-reach distractor present	control	0.1	0.127	15

ANOVA Table

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	0.3	1	0.3	4.357	0.056
DIST x GROUP						
	Huynh-Feldt	0	0	.	.	.
Error(DIST)						
	Huynh-Feldt	0.964	14	6.89E-02		

Analyses of spatial biases/ performance asymmetries for inattentive error data

F.18 Three-way ANOVA: Target (left, right) x distractor (absent, present) x group (right-handed unmedicated ADHD, right-handed controls) for centre-start inattentive error data in the reach condition, for the maintain-set task.

Descriptive statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left target only inatt errors	clinical	1.1	1.912	10
	control	0.2	0.422	10
Reach center start left target right dist inatt errors	clinical	0.7	1.160	10
	control	0.2	0.632	10
reach centre start right target only inatt errors	clinical	1.8	2.486	10
	control	0.2	0.422	10
reach centre start right target left distractor inatt errors	clinical	1.1	1.595	10
	control	0.3	0.483	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET						
	Huynh-Feldt	1.8	1	1.8	4.075	0.059
TARGET x GROUP						
	Huynh-Feldt	1.25	1	1.25	2.83	0.11
Error(TARGET)						
	Huynh-Feldt	7.95	18	0.442		
DIST						
	Huynh-Feldt	1.25	1	1.25	1.187	0.29
DIST x GROUP						
	Huynh-Feldt	1.8	1	1.8	1.71	0.207
Error(DIST)						
	Huynh-Feldt	18.95	18	1.053		
TARGET x DIST						
	Huynh-Feldt	5.00E-02	1	5.00E-02	0.157	0.697
TARGET x DIST x GROUP						
	Huynh-Feldt	0.2	1	0.2	0.626	0.439
Error(TARGETxDIST)						
	Huynh-Feldt	5.75	18	0.319		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	39.2	1	39.2	7.074	0.016
GROUP	18.05	1	18.05	3.257	0.088
Error	99.75	18	5.542		

F.19 Three-way ANOVA: Target (left, right) x distractor (absent, present) x group (right-handed unmedicated ADHD, right-handed controls) for centre-start inattentive error data in the no-reach condition, for the maintain-set task.

Descriptive statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left target only inatt error	clinical	1.1	1.197	10
	control	0.1	0.316	10
no reach centre start left target right dist inatt error	clinical	1.2	1.687	10
	control	0	0.000	10
no reach centre start right target only inatt error	clinical	0.7	0.823	10
	control	0.4	0.843	10
no reach centre start right target left dist inatt error	clinical	1.4	1.776	10
	control	0.4	0.699	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET						
	Huynh-Feldt	0.312	1	0.312	0.282	0.602
TARGET x GROUP						
	Huynh-Feldt	1.013	1	1.013	0.915	0.352
Error(TARGET)						
	Huynh-Feldt	19.925	18	1.107		

DIST						
	Huynh-Feldt	0.612	1	0.612	0.592	0.452
DIST x GROUP						
	Huynh-Feldt	1.012	1	1.012	0.979	0.336
Error(DIST)						
	Huynh-Feldt	18.625	18	1.035		
TARGET x DIST						
	Huynh-Feldt	0.612	1	0.612	1.068	0.315
TARGET x DIST x GROUP						
	Huynh-Feldt	0.313	1	0.313	0.545	0.47
Error(TARGETxDIST)						
	Huynh-Feldt	10.325	18	0.574		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	35.112	1	35.112	17.642	0.001
GROUP	15.312	1	15.312	7.694	0.013
Error	35.825	18	1.99		

F.20 Three-way ANOVA: Target (left, right) x distractor (absent, present) x group (right-handed unmedicated ADHD, right-handed controls) for centre-start inattentive error data in the reach condition for the change-set task.

Descriptive statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left target only inatt errors change set	clinical	1	1.944	10
	control	0.2	0.632	10
reach centre start left target right distractor inatt errors change set	clinical	1.9	2.558	10

	control	0.2	0.422	10
reach centre start right target onlt inatt errors change set	clinical	2	2.539	10
	control	0.5	0.707	10
reach centre start right target left distractor inatt errors change set	clinical	1.4	1.713	10
	control	0.5	0.850	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET						
	Huynh-Feldt	1.512	1	1.512	0.901	0.355
TARGET x GROUP						
	Huynh-Feldt	1.25E-02	1	1.25E-02	0.007	0.932
Error(TARGET)						
	Huynh-Feldt	30.225	18	1.679		
DIST						
	Huynh-Feldt	0.112	1	0.112	0.192	0.666
DIST x GROUP						
	Huynh-Feldt	0.112	1	0.112	0.192	0.666
Error(DIST)						
	Huynh-Feldt	10.525	18	0.585		
TARGET x DIST						
	Huynh-Feldt	2.812	1	2.812	3.584	0.075
TARGET x DIST x GROUP						
	Huynh-Feldt	2.813	1	2.813	3.584	0.075
Error(TARGETxDIST)						
	Huynh-Feldt	14.125	18	0.785		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	74.112	1	74.112	9.623	0.006
GROUP	30.012	1	30.012	3.897	0.064
Error	138.625	18	7.701		

F.21 Three-way ANOVA: Target (left, right) x distractor (absent, present) x group (right-handed unmedicated ADHD, right-handed controls) for centre-start inattentive error data in the no-reach condition for the change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left target only inatt error change set	clinical	3.3	3.302	10
	control	0.8	1.229	10
no reach centre start left target right distractor inatt error changesct	clinical	2.4	3.373	10
	control	0.1	0.316	10
no reach centre start right target only inatt error change set	clinical	2.9	3.035	10
	control	1.2	1.135	10
no reach centre start right target left distractor inatt error change set	clinical	1.9	3.315	10
	control	0.1	0.316	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET						
	Huynh-Feldt	0.313	1	0.313	0.476	0.499
TARGET x GROUP						
	Huynh-Feldt	2.112	1	2.112	3.216	0.09
Error(TARGET)						
	Huynh-Feldt	11.825	18	0.657		
DIST						
	Huynh-Feldt	17.113	1	17.113	5.392	0.032
DIST x GROUP						
	Huynh-Feldt	1.25E-02	1	1.25E-02	0.004	0.951
Error(DIST)						
	Huynh-Feldt	57.125	18	3.174		

TARGET x DIST						
	Huynh-Feldt	0.312	1	0.312	0.246	0.626
TARGET x DIST x GROUP						
	Huynh-Feldt	0.112	1	0.112	0.089	0.769
Error(TARGETxDIST)						
	Huynh-Feldt	22.825	18	1.268		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	201.612	1	201.612	11.429	0.003
GROUP	86.112	1	86.112	4.882	0.04
Error	317.525	18	17.64		

Analyses of impulsive errors

F.22 Three-way ANOVA: Group (unmedicated ADHD, controls) x reach (reach, no-reach) x set (maintain, change) for impulsive error data collapsed across start, target and distractor conditions.

Descriptive Statistics

Descriptive Statistics				
	GROUP	Mean	Std. Deviation	N
off key errors - reach maintain-set	clinical	7.4667	11.2939	15
	control	.9333	1.2228	15
off key errors - no reach maintain-set	clinical	6.1333	7.1201	15
	control	1.6667	1.3973	15
offkey errors - reach change-set	clinical	8.0667	10.5996	15
	control	.6667	1.0465	15
offkey errors - no reach change-set	clinical	7.0000	11.7656	15
	control	1.0000	1.2536	15

Tests of within-subjects effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	.533	1.000	.533	.047	.831
SET * GROUP	Huynh-Feldt	10.800	1.000	10.800	.945	.339
Error(SET)	Huynh-Feldt	320.167	28.000	11.435		
REACH	Huynh-Feldt	3.333	1.000	3.333	.214	.647
REACH * GROUP	Huynh-Feldt	22.533	1.000	22.533	1.445	.239
Error(REACH)	Huynh-Feldt	436.633	28.000	15.594		
SET * REACH	Huynh-Feldt	3.333E-02	1.000	3.333E-02	.003	.959
SET * REACH * GROUP	Huynh-Feldt	.833	1.000	.833	.068	.796
Error(SET*REACH)	Huynh-Feldt	342.633	28.000	12.237		

a Computed using alpha = .05

Tests of between-subjects effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	2033.633	1	2033.633	11.405	.002
GROUP	1116.300	1	1116.300	6.261	.018
Error	4992.567	28	178.306		

a Computed using alpha = .05

Analyses of distractibility errors

F.23 Three-way ANOVA: Group (unmedicated ADHD, controls) x set (maintain, change) x target (absent, present) for distractibility error data (collapsed across start position and distractor location) in the reach task.

Descriptive statistics

	GROUP	Mean	Std. Deviation	N
no-change target absent reach	clinical	2.611	1.623	15
	control	0.789	0.680	15
no-change reach target present	clinical	0.744	1.166	15
	control	0.133	0.157	15
change-set reach target absent	clinical	3.733	2.619	15
	control	1.067	1.008	15
change-set reach target present	clinical	2.022	1.793	15
	control	0.367	0.554	15

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	15.89	1	15.89	9.44	0.005
SET x GROUP						
	Huynh-Feldt	6.69	1	6.69	3.975	0.056
Error(SET)						
	Huynh-Feldt	47.129	28	1.683		
TARGET						
	Huynh-Feldt	45.633	1	45.633	44.686	0.000
TARGET x GROUP						
	Huynh-Feldt	9.259	1	9.259	9.067	0.005
Error(TARGET)						
	Huynh-Feldt	28.594	28	1.021		
SET x TARGET						
	Huynh-Feldt	2.32E-02	1	2.32E-02	0.052	0.821
SET x TARGET x GROUP						
	Huynh-Feldt	7.50E-02	1	7.50E-02	0.17	0.684
Error(SETxTARGET)						
	Huynh-Feldt	12.388	28	0.442		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	246.533	1	246.533	51.474	.000
GROUP	85.57	1	85.57	17.866	.000
Error	134.105	28	4.789		

Subanalyses for the target x group interaction

F.24 One-way ANOVA for unmedicated ADHD and control children in the target absent condition (otherwise known as the distractor only condition).

Descriptive Statistics

	N	Mean	Std. Deviation	Std. Error
clinical	15	3.17	1.80	0.47
control	15	0.93	0.72	0.19

ANOVA table

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	37.781	1	37.781	20.037	.000
Within Groups	52.796	28	1.886		
Total	90.578	29			

F.25 One-way ANOVA for unmedicated ADHD and control children in the target present condition (otherwise known as the target + distractor condition).

Descriptive Statistics

Descriptives reach target present				
	N	Mean	Std. Deviation	Std. Error
clinical	15	1.3833	1.3912	.3592
control	15	.2500	.3227	8.333E-02

ANOVA table

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9.633	1	9.633	9.447	.005
Within Groups	28.553	28	1.020		
Total	38.186	29			

F.26 Two-way ANOVA: Group (unmedicated ADHD, controls) x set (maintain, change) for distractibility error data (collapsed across start position and distractor location) in the no-reach task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no-change no-reach	clinical	3.356	2.305	15
	control	2.089	1.833	15
change-set no reach	clinical	5.578	3.556	15
	control	2.167	2.878	15

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	19.838	1	19.838	7.283	0.012
SET x GROUP						

	Huynh-Feldt	17.245	1	17.245	6.331	0.018
Error(SET)						
	Huynh-Feldt	76.265	28	2.724		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	652.3	1	652.3	54.012	0
GROUP	82.056	1	82.056	6.794	0.014
Error	338.157	28	12.077		

Subanalyses for the set x group interaction

F.27 One-way ANOVA for set (change, maintain) in the unmedicated ADHD children.

Descriptive Statistics

Descriptive Statistics(a)			
	Mean	Std. Deviation	N
no-change no-reach	3.3556	2.3050	15
change-set no reach	5.5778	3.5562	15
a GROUP = clinical			

ANOVA table

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	37.037	1.000	37.037	13.048	.003
Error(SET)	Huynh-Feldt	39.741	14.000	2.839		

a Computed using alpha = .05

GROUP = clinical

F.28 One-way ANOVA for set (change, maintain) in the control children.

Descriptive Statistics

Descriptive Statistics

	Mean	Std. Deviation	N
no-change no-reach	2.0889	1.8332	15
change-set no reach	2.1667	2.8778	15

GROUP = control

ANOVA table

Tests of Within-Subjects Effects(b)

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	4.537E-02	1.000	4.537E-02	.017	.897
Error(SET)	Huynh-Feldt	36.524	14.000	2.609		

a Computed using alpha = .05

b GROUP = control

Analyses of spatial biases/ performance asymmetries for distractibility error data

F.29 Three-way ANOVA: Group (right-handed unmedicated ADHD, right-handed controls) x distractor (left, right) x target (absent, present) for centre-start distractibility errors in the reach condition of the maintain-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left distractor distractibility errors	clinical	3.5	3.028	10
	control	1	1.333	10
reach centre start right target left distractor distractibility	clinical	1.9	3.381	10

errors				
	control	0.1	0.316	10
reach centre start right distractor distractibility errors	clinical	2.7	2.791	10
	control	0.6	0.699	10
reach centre start left target right distractor distractibility errors	clinical	0.9	1.912	10
	control	0.3	0.483	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	5	1	5	2.703	0.118
DIST x GROUP						
	Huynh-Feldt	3.2	1	3.2	1.73	0.205
Error(DIST)						
	Huynh-Feldt	33.3	18	1.85		
TARG						
	Huynh-Feldt	26.45	1	26.45	20.7	0.000
TARG x GROUP						
	Huynh-Feldt	6.05	1	6.05	4.735	0.043
Error(TARG)						
	Huynh-Feldt	23	18	1.278		
DIST x TARG						
	Huynh-Feldt	0.2	1	0.2	0.136	0.717
DIST x TARG x GROUP						
	Huynh-Feldt	0.8	1	0.8	0.543	0.471
Error(DISTxTARG)						
	Huynh-Feldt	26.5	18	1.472		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	151.25	1	151.25	11.889	0.003
GROUP	61.25	1	61.25	4.814	0.042
Error	229	18	12.722		

F.30 Two-way ANOVA: Group (right-handed unmedicated ADHD, right-handed controls) x distractor (left, right) for centre-start distractibility errors in the no- reach condition of the maintain-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left distractor distractibility error	clinical	4.7	3.653	10
	control	1.3	1.829	10
no reach centre start right distractor distractibility error	clinical	3.3	2.406	10
	control	1.3	2.541	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	4.9	1	4.9	1.869	0.188
DIST x GROUP						
	Huynh-Feldt	4.9	1	4.9	1.869	0.188
Error(DIST)						
	Huynh-Feldt	47.2	18	2.622		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	280.9	1	280.9	23.716	0
GROUP	72.9	1	72.9	6.155	0.023
Error	213.2	18	11.844		

F.31 Three-way ANOVA: Group (right-handed unmedicated ADHD, right-handed controls) x distractor (left, right) x target (absent, present) for centre-start distractibility errors in the reach condition of the change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left distractor distractibility errors change set	clinical	4.4	3.921	10
	control	1	1.826	10
reach centre start right target left distractor distractibility errors change set	clinical	2.3	3.164	10
	control	0.3	0.483	10
reach centre start right distractor distractibiltiy errors	clinical	2.7	2.791	10
	control	0.6	0.699	10
reach centre start left target right distractor distractibility errors change set	clinical	1.9	2.514	10
	control	0.2	0.632	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	8.45	1	8.45	1.893	0.186
DIST x GROUP						
	Huynh-Feldt	3.2	1	3.2	0.717	0.408
Error(DIST)						
	Huynh-Feldt	80.35	18	4.464		
TARG						
	Huynh-Feldt	20	1	20	15.031	0.001
TARG x GROUP						
	Huynh-Feldt	4.05	1	4.05	3.044	0.098
Error(TARG)						
	Huynh-Feldt	23.95	18	1.331		
DIST x TARG						
	Huynh-Feldt	3.2	1	3.2	1.211	0.286
DIST x TARG x GROUP						
	Huynh-Feldt	1.25	1	1.25	0.473	0.5
Error(DISTxTARG)						
	Huynh-Feldt	47.55	18	2.642		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	224.45	1	224.45	16.575	0.001
GROUP	105.8	1	105.8	7.813	0.012
Error	243.75	18	13.542		

F.32 Two-way ANOVA: Group (right-handed unmedicated ADHD, right-handed controls) x distractor (left, right) for centre-start distractibility errors in the no-reach condition of the change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left distractor distractibility error change set	clinical	5.7	6.237	10
	control	1.6	2.221	10
no reach centre start right distractor distractibility error change set	clinical	6.4	4.274	10
	control	2.5	4.197	10

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	6.4	1	6.4	0.803	0.382
DIST x GROUP						
	Huynh-Feldt	0.1	1	0.1	0.013	0.912
Error(DIST)						
	Huynh-Feldt	143.5	18	7.972		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	656.1	1	656.1	20.578	0
GROUP	160	1	160	5.018	0.038
Error	573.9	18	31.883		

Analyses of proportional errors

F.33 Four-way ANOVA: Group (unmedicated ADHD, controls) x set (maintain, change) x reach (reach, no-reach) x error type (inattentive, impulsive, distractibility) for error data converted to proportions of total errors made.

Descriptive Statistics

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no-change reach dist proportion errors	clinical	.6222	.2474	15
	controls	.6297	.3178	15
no-change reach inatt proportion errors	clinical	.2328	.1639	15
	controls	.1859	.2610	15
no-change reach impulsive proportion errors	clinical	.1126	.1104	15
	controls	8.445E-02	.1223	15
no-change no-reach dist prop errors	clinical	.5935	.2293	15
	controls	.8035	.1948	15
no-change no-reach inatt prop errors	clinical	.2761	.2119	15
	controls	7.853E-02	.1339	15
no-change no-reach impulsive prop errors	clinical	.1304	7.506E-02	15
	controls	.1179	.1033	15
change-set reach dist prop errors	clinical	.6149	.1797	15
	controls	.7176	.2080	15

	clinical	.2310	.1464	15
change-set reach inatt prop errors	controls	.2117	.1853	15
	clinical	.1096	7.459E-02	15
change-set reach impulsive prop errors	controls	3.664E-02	5.281E-02	15
	clinical	.6076	.1593	15
change-set no-reach dist prop errors	controls	.7130	.2573	15
	clinical	.3003	.1149	15
change-set no-reach inatt prop errors	controls	.2188	.2837	15
	clinical	9.205E-02	8.731E-02	15
change-set no-reach impulsive prop errors	controls	6.820E-02	9.193E-02	15

Tests of within-subjects effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	1.805E-03	1.000	1.805E-03	.577	.454
SET * GROUP	Huynh-Feldt	3.803E-03	1.000	3.803E-03	1.216	.280
Error(SET)	Huynh-Feldt	8.757E-02	28.000	3.128E-03		
REACH	Huynh-Feldt	2.782E-02	1.000	2.782E-02	10.279	.003
REACH * GROUP	Huynh-	2.032E-03	1.000	2.032E-03	.751	.394

	Feldt					
Error(REACH)	Huynh-Feldt	7.579E-02	28.000	2.707E-03		
ERROR	Huynh-Feldt	21.497	1.332	16.136	105.832	.000
ERROR * GROUP	Huynh-Feldt	.597	1.332	.448	2.937	.084
Error(ERROR)	Huynh-Feldt	5.687	37.301	.152		
SET * REACH	Huynh-Feldt	1.805E-03	1.000	1.805E-03	.577	.454
SET * REACH * GROUP	Huynh-Feldt	3.803E-03	1.000	3.803E-03	1.216	.280
Error(SET*REACH)	Huynh-Feldt	8.757E-02	28.000	3.128E-03		
SET * ERROR	Huynh-Feldt	.101	1.259	8.022E-02	1.874	.179
SET * ERROR * GROUP	Huynh-Feldt	4.093E-02	1.259	3.252E-02	.760	.418
Error(SET*ERROR)	Huynh-Feldt	1.509	35.241	4.281E-02		
REACH * ERROR	Huynh-Feldt	1.379E-02	1.391	9.915E-03	.215	.726
REACH * ERROR * GROUP	Huynh-Feldt	.170	1.391	.122	2.642	.101
Error(REACH*ERROR)	Huynh-Feldt	1.798	38.944	4.617E-02		
SET * REACH * ERROR	Huynh-Feldt	8.404E-02	1.625	5.172E-02	1.302	.277
SET * REACH * ERROR * GROUP	Huynh-Feldt	8.798E-02	1.625	5.415E-02	1.363	.263
Error(SET*REACH*ERROR)	Huynh-Feldt	1.808	45.495	3.973E-02		

a Computed using alpha = .05

Tests of between-subjects effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	37.918	1	37.918	14007.847	.000
GROUP	2.032E-03	1	2.032E-03	.751	.394
Error	7.579E-02	28	2.707E-03		

a Computed using alpha = .05

Post hoc tests with Bonferroni correction

F.34 Pairwise comparisons of distractibility, inattentive and impulsive error type.

Descriptive Statistics

ERROR	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1. distractibility	.663	.029	.603	.723
2. inattentive	.217	.027	.162	.272
3. impulsive	9.397E-02	.012	6.977E-02	.118

Pairwise Comparisons

Pairwise Comparisons

(I) ERROR	(J) ERROR	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
1	2	.446(*)	.054	.000	.307	.585
	3	.569(*)	.036	.000	.477	.660
2	1	-.446(*)	.054	.000	-.585	-.307
	3	.123(*)	.029	.001	5.015E-02	.196
3	1	-.569(*)	.036	.000	-.660	-.477
	2	-.123(*)	.029	.001	-.196	-5.015E-02

Based on estimated marginal means

* The mean difference is significant at the .05 level.

a Adjustment for multiple comparisons: Bonferroni.

F.35 Correlations between experimental variables (reaction times, movement time) and demographic variables for unmedicated ADHD children

		reach rt	reach mt	no reach rt	AGE	FSIQ	GRADE	RSHPERC	RSSPERC	RSHIMP	RSSIMP	rating scale hh	rating scale hi	rating scale sh	rating scale si
reach rt	Pearson	1	-0.414	.741(**)	-.587(*)	-0.25	-.580(*)	0.2	-0.173	0.048	-0.201	0.175	0.023	0.183	-0.494
	Sig. (2-tailed)	.	0.125	0.002	0.021	0.368	0.023	0.474	0.538	0.865	0.473	0.534	0.935	0.514	0.061
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
reach mt	Pearson Correlation	-0.414	1	-0.258	.538(*)	-0.038	0.509	-0.15	0.193	-0.3	-0.01	-0.079	-0.059	-0.114	0.367
	Sig. (2-tailed)	0.125	.	0.354	0.039	0.893	0.053	0.593	0.491	0.277	0.973	0.779	0.834	0.685	0.178
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
no reach rt	Pearson Correlation	.741(**)	-0.258	1	-.644(**)	-0.141	-.579(*)	0.187	-0.266	-0.025	0.058	0.154	0.12	-0.049	-0.381
	Sig. (2-tailed)	0.002	0.354	.	0.01	0.615	0.024	0.505	0.338	0.931	0.839	0.583	0.67	0.862	0.162
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
AGE	Pearson Correlation	-.587(*)	.538(*)	-.644(**)	1	0.016	.979(**)	-0.426	.520(*)	0.031	-0.402	-0.406	-0.332	0.381	0.416
	Sig. (2-tailed)	0.021	0.039	0.01	.	0.954	0	0.114	0.047	0.912	0.138	0.133	0.226	0.162	0.123
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
FSIQ	Pearson Correlation	-0.[illegible]	-0.038	-0.141	0.016	1	0.05	0.416	-0.098	-0.34	0.403	0.37	.607(*)	-0.245	0.116
	Sig. (2-tailed)	0.368	0.893	0.615	0.954	.	0.859	0.123	0.727	0.215	0.136	0.175	0.016	0.379	0.68

	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
GRADE	Pearson Correlation	-.580(*)	0.509	-.579(*)	.979(**)	0.05	1	-0.456	.541(*)	0.131	-0.459	-0.449	-0.374	0.432	0.404
	Sig. (2-tailed)	0.023	0.053	0.024	0	0.859	.	0.088	0.037	0.641	0.085	0.093	0.169	0.108	0.135
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
RSHPERC	Pearson Correlation	0.2	-0.15	0.187	-0.426	0.416	-0.456	1	-0.202	-0.471	0.369	.891(**)	.853(**)	-0.207	-0.039
	Sig. (2-tailed)	0.474	0.593	0.505	0.114	0.123	0.088	.	0.469	0.077	0.176	0	0	0.459	0.891
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
RSSPERC	Pearson Correlation	-0.173	0.193	-0.266	.520(*)	-0.098	.541(*)	-0.202	1	0.201	-.762(**)	-0.455	-0.131	.827(**)	.764(**)
	Sig. (2-tailed)	0.538	0.491	0.338	0.047	0.727	0.037	0.469	.	0.472	0.001	0.088	0.642	0	0.001
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
RSHIMP	Pearson Correlation	0.048	-0.3	-0.025	0.031	-0.34	0.131	-0.471	0.201	1	-0.391	-.552(*)	-0.501	0.42	-0.18
	Sig. (2-tailed)	0.865	0.277	0.931	0.912	0.215	0.641	0.077	0.472	.	0.15	0.033	0.057	0.119	0.521
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
RSSIMP	Pearson Correlation	-0.201	-0.01	0.058	-0.402	0.403	-0.459	0.369	-.762(**)	-0.391	1	0.512	0.446	-.919(**)	-0.31
	Sig. (2-tailed)	0.473	0.973	0.839	0.138	0.136	0.085	0.176	0.001	0.15	.	0.051	0.095	0	0.26
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
rating scale hh	Pearson Correlation	0.175	-0.079	0.154	-0.406	0.37	-0.449	.891(**)	-0.455	-.552(*)	0.512	1	.710(**)	-0.434	-0.191

	Sig. (2-tailed)	0.534	0.779	0.583	0.133	0.175	0.093	0	0.088	0.033	0.051		0.003	0.106	0.496
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
rating scale hi	Pearson Correlation	0.023	-0.059	0.12	-0.332	.607(*)	-0.374	.853(**)	-0.131	-0.501	0.446	.710(**)	1	-0.277	0.126
	Sig. (2-tailed)	0.935	0.834	0.67	0.226	0.016	0.169	0	0.642	0.057	0.095	0.003	.	0.317	0.655
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
rating scale sh	Pearson Correlation	0.183	-0.114	-0.049	0.381	-0.245	0.432	-0.207	.827(**)	0.42	-.919(**)	-0.434	-0.277	1	0.304
	Sig. (2-tailed)	0.514	0.685	0.862	0.162	0.379	0.108	0.459	0	0.119	0	0.106	0.317	.	0.271
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15
rating scale si	Pearson Correlation	-0.494	0.367	-0.381	0.416	0.116	0.404	-0.039	.764(**)	-0.18	-0.31	-0.191	0.126	0.304	1
	Sig. (2-tailed)	0.061	0.178	0.162	0.123	0.68	0.135	0.891	0.001	0.521	0.26	0.496	0.655	0.271	.
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

F.36 Correlations between experimental variables (inattentive, distractibility, and impulsive errors) and demographic variables for unmedicated ADHD children

Correlations(a)

		AGE	GRADE	FSIQ	HAND	SEX	RSHPERC	RSSPERC	RSHIMP	RSSIMP	INATT	DIST	PREM	rating scale hh	rating scale hi	rating scale sh	rating scale si
AGE	Pearson Correlation	1.000	.979(**)	.016	.149	-.128	-.426	.520(*)	.031	-.402	-.332	-.402	-.407	-.406	-.332	.381	.416
	Sig. (2-tailed)	.	.000	.954	.597	.649	.114	.047	.912	.138	.226	.137	.132	.133	.226	.162	.123
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
GRADE	Pearson Correlation	.979(**)	1.000	.050	.129	-.104	-.456	.541(*)	.131	-.459	-.224	-.288	-.335	-.449	-.374	.432	.404
	Sig. (2-tailed)	.000	.	.859	.646	.713	.088	.037	.641	.085	.423	.298	.222	.093	.169	.108	.135
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
FSIQ	Pearson Correlation	.016	.050	1.000	-.171	-.421	.416	-.098	-.340	.403	-.124	.160	.242	.370	.607(*)	-.245	.116
	Sig. (2-tailed)	.954	.859	.	.542	.118	.123	.727	.215	.136	.661	.570	.384	.175	.016	.379	.680
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
HAND	Pearson Correlation	.149	.129	-.171	1.000	-.200	.118	-.128	-.134	.068	-.151	-.423	-.254	.428	.022	-.093	-.028

	Sig. (2-tailed)	.597	.646	.542	.	.475	.676	.648	.634	.811	.592	.116	.360	.112	.937	.742	.920
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
SEX	Pearson Correlation	-.128	-.104	-.421	-.200	1.000	-.403	.084	-.061	-.398	.375	.136	.345	-.305	-.577(*)	.116	.057
	Sig. (2-tailed)	.649	.713	.118	.475	.	.137	.765	.829	.142	.168	.629	.208	.268	.024	.680	.841
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
RSHPERC	Pearson Correlation	-.426	-.456	.416	.118	-.403	1.000	-.202	-.471	.369	-.278	-.171	-.143	.891(**)	.853(**)	-.207	-.039
	Sig. (2-tailed)	.114	.088	.123	.676	.137	.	.469	.077	.176	.317	.542	.610	.000	.000	.459	.891
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
RSSPERC	Pearson Correlation	.520(*)	.541(*)	-.098	-.128	.084	-.202	1.000	.201	-.762(**)	-.174	-.424	-.361	-.455	-.131	.827(**)	.764(**)
	Sig. (2-tailed)	.047	.037	.727	.648	.765	.469	.	.472	.001	.534	.115	.186	.088	.642	.000	.001
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
RSHIMP	Pearson Correlation	.031	.131	-.340	-.134	-.061	-.471	.201	1.000	-.391	.456	.324	.162	-.552(*)	-.501	.420	-.180

	Sig. (2-tailed)	.912	.641	.215	.634	.829	.077	.472	.	.150	.087	.238	.564	.033	.057	.119	.521
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
RSSIMP	Pearson Correlation	-.402	-.459	.403	.068	-.398	.369	-.762(**)	-.391	1.000	-.221	.273	.188	.512	.446	-.919(**)	-.310
	Sig. (2-tailed)	.138	.085	.136	.811	.142	.176	.001	.150	.	.428	.325	.501	.051	.095	.000	.260
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
INATT	Pearson Correlation	-.332	-.224	-.124	-.151	.375	-.278	-.174	.456	-.221	1.000	.685(**)	.753(**)	-.214	-.473	.206	-.476
	Sig. (2-tailed)	.226	.423	.661	.592	.168	.317	.534	.087	.428	.	.005	.001	.443	.075	.461	.073
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
DIST	Pearson Correlation	-.402	-.288	.160	-.423	.136	-.171	-.424	.324	.273	.685(**)	1.000	.692(**)	-.181	-.263	-.237	-.502
	Sig. (2-tailed)	.137	.298	.570	.116	.629	.542	.115	.238	.325	.005	.	.004	.518	.343	.395	.056
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
PREM	Pearson Correlation	-.407	.335	.242	-.254	.345	-.143	-.361	.162	.188	.753(**)	.692(**)	1.000	-.021	-.285	-.176	-.390

	Sig. (2-tailed)	.132	.222	.384	.360	.208	.610	.186	.564	.501	.001	.004	.	.942	.303	.530	.151
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
rating scale hh	Pearson Correlation	-.406	-.449	.370	.428	-.305	.891(**)	-.455	-.552(*)	.512	-.214	-.181	-.021	1.000	.710(**)	-.434	-.191
	Sig. (2-tailed)	.133	.093	.175	.112	.268	.000	.088	.033	.051	.443	.518	.942	.	.003	.106	.496
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
rating scale hi	Pearson Correlation	-.332	-.374	.607(*)	.022	-.577(*)	.853(**)	-.131	-.501	.446	-.473	-.263	-.285	.710(**)	1.000	-.277	.126
	Sig. (2-tailed)	.226	.169	.016	.937	.024	.000	.642	.057	.095	.075	.343	.303	.003	.	.317	.655
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
rating scale sh	Pearson Correlation	.381	.432	-.245	-.093	.116	-.207	.827(**)	.420	-.919(**)	.206	-.237	-.176	-.434	-.277	1.000	.304
	Sig. (2-tailed)	.162	.108	.379	.742	.680	.459	.000	.119	.000	.461	.395	.530	.106	.317	.	.271
	N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
rating scale si	Pearson Correlation	.416	.404	.116	-.028	.057	-.039	.764(**)	-.180	-.310	-.476	-.502	-.390	-.191	.126	.304	1.000

Sig. (2-tailed)	.123	.135	.680	.920	.841	.891	.001	.521	.260	.073	.056	.151	.496	.655	.271	.
N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Key to Correlations Tables:

Reach rt	reach reaction time	INATT	inattentive type errors
Reach mt	reach movement time	DIST	distractibility errors
No reach rt	no-reach reaction time	PREM	premature responses/ impulsive errors
FSIQ	full scale IQ		
RSHPERC	rating scale home percentile rank		
RSSPERC	rating scale school percentile rank		
RSHIMP	rating scale home impulsiveness		
RSSIMP	rating scale school impulsiveness		
Rating scale hh	rating scale home hyperactivity-impulsivity scale		
Rating scale hi	rating scale home inattentiveness scale		
Rating scale sh	rating scale school hyperactivity-impulsivity scale		
Rating scale si	rating scale school inattentiveness scale		

APPENDIX G: ANALYSES FOR EXPERIMENT 2

Analyses for demographic data

Descriptive Statistics

		N	Mean	Std. Deviation	Std. Error
AGE	medicated	7	11.178543	2.164773	.818207
	controls	7	10.988071	2.058431	.778014
GRADE	medicated	7	5.0000	1.9149	.7237
	controls	7	5.1429	2.1931	.8289
FSIQ	medicated	7	99.7143	11.7433	4.4385
	controls	7	104.4286	12.7914	4.8347
Rating scale home percentile rank	medicated	7	2.4286	2.8785	1.0880
	controls	7	67.7143	27.9923	10.5801
Rating scale school percentile rank	medicated	6	44.5000	35.4894	14.4885
	controls	7	81.2857	15.2065	5.7475
Rating scale home impulsiveness	medicated	7	24.4286	3.7796	1.4286
	controls	7	5.5714	4.7909	1.8108
Rating scale school impulsiveness	medicated	6	17.8333	20.6341	8.4238
	controls	7	2.0000	4.0415	1.5275
Rating scale home hyperactivity-impulsivity scale	medicated	7	2.4286	1.9024	.7190
	controls	7	11.1429	1.8645	.7047
Rating scale home inattentiveness scale	medicated	7	1.7143	.7559	.2857
	controls	7	11.4286	2.4398	.9221
Rating scale school hyperactivity-impulsivity scale	medicated	6	8.1667	5.6362	2.3010
	controls	7	12.7143	.9512	.3595
Rating scale school inattentiveness scale	medicated	6	7.5000	5.2058	2.1252
	controls	7	12.4286	1.2724	.4809

One-way ANOVAs

		Sum of Squares	df	Mean Square	F	Sig.
AGE	Between Groups	.127	1	.127	.028	.869
	Within Groups	53.540	12	4.462		
	Total	53.667	13			
GRADE	Between Groups	7.143E-02	1	7.143E-02	.017	.899
	Within Groups	50.857	12	4.238		
	Total	50.929	13			
FSIQ	Between Groups	77.786	1	77.786	.516	.486
	Within Groups	1809.143	12	150.762		
	Total	1886.929	13			
Rating scale home percentile rank	Between Groups	14917.786	1	14917.786	37.678	.000
	Within Groups	4751.143	12	395.929		
	Total	19668.929	13			
Rating scale school percentile rank	Between Groups	4371.841	1	4371.841	6.258	.029
	Within Groups	7684.929	11	698.630		
	Total	12056.769	12			
Rating scale home impulsiveness	Between Groups	1244.571	1	1244.571	66.844	.000
	Within Groups	223.429	12	18.619		
	Total	1468.000	13			

Rating scale school impulsiveness	Between Groups	809.936	1	809.936	4.001	.071
	Within Groups	2226.833	11	202.439		
	Total	3036.769	12			
Rating scale home hyperactivity-impulsivity scale	Between Groups	265.786	1	265.786	74.919	.000
	Within Groups	42.571	12	3.548		
	Total	308.357	13			
Rating scale home inattentiveness scale	Between Groups	330.286	1	330.286	101.255	.000
	Within Groups	39.143	12	3.262		
	Total	369.429	13			
Rating scale school hyperactivity-impulsivity scale	Between Groups	66.815	1	66.815	4.474	.058
	Within Groups	164.262	11	14.933		
	Total	231.077	12			
Rating scale school inattentiveness scale	Between Groups	78.478	1	78.478	5.945	.033
	Within Groups	145.214	11	13.201		
	Total	223.692	12			

Analyses of reaction time data for the reach task

G.1 Three-way ANOVA: Group (medicated ADHD, controls) x set (maintain, change) x distractor (absent, present) for reaction time data (collapsed across start position and target location) in the reach task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach rt maintain-set distractor absent	medicated	500.493	45.027	7
	controls	500.700	100.152	7
reach rt maintain-set distrator present	medicated	514.591	45.431	7
	controls	508.683	79.548	7
reach rt change-set distractor absent	medicated	488.686	62.883	7
	controls	574.331	135.245	7
reach rt change-set distractor present	medicated	507.552	70.039	7
	controls	590.729	145.582	7

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	16382.369	1	16382.369	2.742	0.124
SET x GROUP	Huynh-Feldt	26650.514	1	26650.514	4.461	0.056
Error(SET)	Huynh-Feldt	71695.249	12	5974.604		
DIST	Huynh-Feldt	2877.416	1	2877.416	4.069	0.067
DIST x GROUP	Huynh-Feldt	64.464	1	64.464	0.091	0.768
Error(DIST)	Huynh-Feldt	8486.022	12	707.168		
SET x DIST	Huynh-Feldt	152.075	1	152.075	0.160	0.696
SET x DIST x GROUP	Huynh-Feldt	11.627	1	11.627	0.012	0.914
Error(SETxDIST)	Huynh-Feldt	11402.885	12	950.240		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	15330544.821	1	15330544.821	572.775	0.000
GROUP	23282.523	1	23282.523	0.870	0.369
Error	321184.738	12	26765.395		

Analyses of movement time data for the reach task

G.2 Three-way ANOVA: Group (medicated ADHD, controls) x set (maintain, change) x distractor (absent, present) for movement time data (collapsed across start position and target location) in the reach task.

Descriptive Statistics

	MED	Mean	Std. Deviation	N
reach mt maintain-set distractor absent	medicated	300.679	67.922	7
	controls	342.352	83.004	7
reach mt maintain-set distractor present	medicated	303.850	67.166	7
	controls	343.930	86.568	7
reach mt change-set distractor absent	medicated	276.067	80.088	7
	controls	404.229	97.847	7
reach mt change-set distractor present	medicated	278.257	80.333	7
	controls	419.979	119.435	7

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	6732.437	1	6732.437	1.647	0.224
SET x GROUP	Huynh-Feldt	30967.531	1	30967.531	7.578	0.018
Error(SET)	Huynh-Feldt	49040.755	12	4086.730		
DIST	Huynh-Feldt	450.595	1	450.595	1.016	0.333
DIST x GROUP	Huynh-Feldt	125.351	1	125.351	0.283	0.605
Error(DIST)	Huynh-Feldt	5322.674	12	443.556		
SET x DIST	Huynh-Feldt	152.185	1	152.185	1.128	0.309
SET x DIST x GROUP	Huynh-Feldt	200.832	1	200.832	1.489	0.246
Error(SETxDIST)	Huynh-Feldt	1618.813	12	134.901		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	6234728.498	1	6234728.498	245.058	0.000
GROUP	108194.650	1	108194.650	4.253	0.062
Error	305302.429	12	25441.869		

Subanalyses of the group x set interaction

G.3 One-way ANOVA for set (maintain, change) in medicated ADHD children.

Descriptive Statistics

	Mean	Std. Deviation	N
reach mt maintain-set (collapse dist)	302.264	67.442	7
reach mt change-set (collapse dist)	277.162	79.394	7

ANOVA table

Source		Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	2205.454	1	2205.454	3.445	0.113
Error(SET)	Huynh-Feldt	3840.709	6	640.118		

G.4 One-way ANOVA for set (maintain, change) in control children.

Descriptive statistics

	Mean	Std. Deviation	N
reach mt no-change set (collapse dist)	343.1429	83.6679	7
reach mt change-set (collapse dist)	412.1036	108.0576	7

a GROUP = control

ANOVA table

Tests of Within-Subjects Effects(a)

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	16644.530	1.000	16644.530	4.829	.070
Error(SET)	Huynh-Feldt	20679.668	6.000	3446.611		

a GROUP = control

Analyses of reaction time data for the no-reach task

G.5 Three-way ANOVA: Group (medicated ADHD, controls) x set (maintain, change) x distractor (absent, present) for reaction time data (collapsed across start and target location) in the no-reach task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no-reach reaction time maintain-set	medicated	620.598	134.775	7
distractor absent	controls	674.383	208.451	7
no reach reaction time maintain-set	medicated	593.102	146.049	7
distractor present	controls	664.560	212.873	7
no reach rt change-set distractor	medicated	630.367	106.100	7
absent	controls	692.900	163.887	7
no reach rt change-set distractor	medicated	617.531	114.862	7
present	controls	657.521	148.044	7

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	1825.525	1	1825.525	0.272	0.611
SET x GROUP	Huynh-Feldt	451.636	1	451.636	0.067	0.800
Error(SET)	Huynh-Feldt	80525.355	12	6710.446		

DIST	Huynh-Feldt	6401.456	1	6401.456	3.188	0.099
DIST x GROUP	Huynh-Feldt	20.764	1	20.764	0.010	0.921
Error(DIST)	Huynh-Feldt	24098.452	12	2008.204		
SET x DIST	Huynh-Feldt	103.868	1	103.868	0.096	0.762
SET x DIST x GROUP	Huynh-Feldt	1415.040	1	1415.040	1.309	0.275
Error(SETxDIST)	Huynh-Feldt	12967.764	12	1080.647		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	23215857.598	1	23215857.598	255.275	0.000
GROUP	45392.951	1	45392.951	0.499	0.493
Error	1091334.126	12	90944.510		

Analyses of spatial biases/ performance for right-handed medicated ADHD children and their matched controls

G.6 Three-way ANOVA: Group (medicated right-handed ADHD, right-handed controls) x target (left, right) x distractor (absent, present), for centre-start reaction-time data, in the reach condition, maintain-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left target only rt	medicated	487.917	88.060	6
	controls	492.833	112.543	6
reach centre start left target right distractor rt	medicated	514.850	90.747	6
	controls	526.800	96.399	6
reach centre start right target only rt	medicated	500.750	66.205	6
	controls	523.017	118.814	6

reach centre start right target left distractor rt	medicated	541.100	120.828	6
	controls	499.517	87.830	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET	Huynh-Feldt	1321.950	1	1321.950	1.702	0.221
TARGET x GROUP	Huynh-Feldt	981.926	1	981.926	1.264	0.287
Error(TARGET)	Huynh-Feldt	7767.860	10	776.786		
DIST	Huynh-Feldt	4533.797	1	4533.797	1.057	0.328
DIST x GROUP	Huynh-Feldt	2421.098	1	2421.098	0.565	0.470
Error(DIST)	Huynh-Feldt	42887.666	10	4288.767		
TARGET x DIST	Huynh-Feldt	1455.305	1	1455.305	0.508	0.492
TARGET x DIST x GROUP	Huynh-Feldt	3768.337	1	3768.337	1.315	0.278
Error(TARGETxDIST)	Huynh-Feldt	28647.108	10	2864.711		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	12526348.610	1	12526348.610	398.288	0
GROUP	4.502	1	4.502	0.000	0.991
Error	314504.904	10	31450.490		

G.7 Three-way ANOVA: Group (medicated right-handed ADHD, right-handed controls) x target (left, right) x distractor (absent, present), for centre-start reaction-time data, in the no-reach condition, maintain-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left target only rt	medicated	608.450	131.517	6
	controls	717.717	189.302	6
no reach centre start left target right distractor rt	medicated	666.500	189.624	6
	controls	701.283	228.119	6
no reach centre start right target only rt	medicated	621.467	158.915	6
	controls	708.817	226.141	6
no reach centre start right target left distractor rt	medicated	596.633	142.399	6
	controls	663.800	243.989	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET	Huynh-Feldt	7992.837	1	7992.837	5.887	0.036
TARGET x GROUP	Huynh-Feldt	82.163	1	82.163	0.061	0.811
Error(TARGET)	Huynh-Feldt	13576.532	10	1357.653		
DIST	Huynh-Feldt	597.839	1	597.839	0.195	0.669
DIST x GROUP	Huynh-Feldt	6721.331	1	6721.331	2.188	0.170
Error(DIST)	Huynh-Feldt	30723.350	10	3072.335		
TARGET x DIST	Huynh-Feldt	9318.613	1	9318.613	3.737	0.082
TARGET x DIST x GROUP	Huynh-Feldt	2211.370	1	2211.370	0.887	0.369
Error(TARGETxDIST)	Huynh-Feldt	24935.441	10	2493.544		

Tests of between-subjects effects

Sum of Squares	df	Mean Square	F	Sig.
20945776.480	1	20945776.480	147.775	0.000
66856.542	1	66856.542	0.472	0.508
1417412.808	10	141741.281		

G.8 Three-way ANOVA: Group (medicated right-handed ADHD, right-handed controls) x target (left, right) x distractor (absent, present), for centre-start movement-time data, in the reach condition, maintain-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left target only mt	medicated	275.567	79.332	6
	controls	291.817	87.591	6
reach centre start left target right distractor mt	medicated	289.083	88.751	6
	controls	308.367	78.214	6
reach centre start right target only mt	medicated	278.550	84.882	6
	controls	291.950	88.593	6
reach centre start right target left distractor mt	medicated	281.017	71.974	6
	controls	287.617	66.099	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET	Huynh-Feldt	495.367	1	495.367	0.294	0.599
TARGET x GROUP	Huynh-Feldt	180.964	1	180.964	0.107	0.750
Error(TARGET)	Huynh-Feldt	16838.348	10	1683.835		
DIST	Huynh-Feldt	596.430	1	596.430	0.979	0.346
DIST x GROUP	Huynh-Feldt	10.641	1	10.641	0.017	0 897
Error(DIST)						

	Huynh-Feldt	6091.886	10	609.189		
TARGET x DIST	Huynh-Feldt	764.804	1	764.804	0.987	0.344
TARGET x DISTx GROUP	Huynh-Feldt	72.521	1	72.521	0.094	0.766
Error(TARGETxDIST)	Huynh-Feldt	7750.955	10	775.095		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	3981196.786	1	3981196.786	171.505	0.000
GROUP	2312.963	1	2312.963	0.100	0.759
Error	232133.161	10	23213.316		

G.9 Three-way ANOVA: Group (medicated right-handed ADHD, right-handed controls) x target (left, right) x distractor (absent, present), for centre-start reaction-time data, in the reach condition, change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left target only	medicated	662.4833	181.7905	6
reaction time change set	controls	712.6333	182.818	6
no reach centre start left target right	medicated	578.7	149.4512	6
distractor reaction time change set	controls	689.95	124.9349	6
no reach centre start right target only	medicated	626.6833	85.0537	6
reaction time change set	controls	733.3	161.1783	6
no reach centre start right target left	medicated	631	149.0112	6
distractor reaction time change set	controls	681.1333	181.4716	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET	Huynh-Feldt	6780.631	1	6780.631	0.988	0.344
TARGET x GROUP	Huynh-Feldt	14355.540	1	14355.540	2.092	0.179
Error(TARGET)	Huynh-Feldt	68604.851	10	6860.485		
DIST	Huynh-Feldt	8.755	1	8.755	0.002	0.966
DIST x GROUP	Huynh-Feldt	2887.656	1	2887.656	0.635	0.444
Error(DIST)	Huynh-Feldt	45468.126	10	4546.813		
TARGET x DIST	Huynh-Feldt	11368.290	1	11368.290	5.835	0.036
TARGET x DIST x GROUP	Huynh-Feldt	182.130	1	182.130	0.093	0.766
Error(TARGETxDIST)	Huynh-Feldt	19482.992	10	1948.299		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	14841752.704	1	14841752.704	233.885	0.000
GROUP	178864.277	1	178864.277	2.819	0.124
Error	634575.250	10	63457.525		

G.10 Three-way ANOVA: Group (medicated right-handed ADHD, right-handed controls) x target (left, right) x distractor (absent, present), for centre-start reaction-time data, in the no-reach condition, change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left target only	medicated	662.4833	181.7905	6
reaction time change set	controls	712.6333	182.818	6
no reach centre start left target right	medicated	578.7	149.4512	6
distractor reaction time change set	controls	689.95	124.9349	6
no reach centre start right target only	medicated	626.6833	85.0537	6
reaction time change set	controls	733.3	161.1783	6
no reach centre start right target left	medicated	631	149.0112	6
distractor reaction time change set	controls	681.1333	181.4716	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET	Huynh-Feldt	602.792	1	602.792	0.088	0.773
TARGET x GROUP	Huynh-Feldt	16.217	1	16.217	0.002	0.962
Error(TARGET)	Huynh-Feldt	68708.853	10	6870.885		
DIST	Huynh-Feldt	17860.221	1	17860.221	3.032	0.112
DIST x GROUP	Huynh-Feldt	15.985	1	15.985	0.003	0.959
Error(DIST)	Huynh-Feldt	58905.969	10	5890.597		
TARGET x DIST	Huynh-Feldt	2576.937	1	2576.937	0.558	0.472
TARGET x DIST x GROUP	Huynh-Feldt	10369.375	1	10369.375	2.244	0.165
Error(TARGETxDIST)	Huynh-Feldt	46204.828	10	4620.483		

Tests of between-subjects effects

Source	Type III Sum of Squares	d	Mean Square	F	Sig.
Intercept	21193961.86	1	21193961.86	268.279	0
MED	75914.564	1	75914.564	0.961	0.35
Error	789997.715	10	78999.771		

G.11 Three-way ANOVA: Group (medicated right-handed ADHD, right-handed controls) x target (left, right) x distractor (absent, present), for centre-start movement-time data, in the reach condition, change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left target only mt	medicated	275.567	79.332	6
	controls	291.817	87.591	6
reach centre start left target right distractor mt	medicated	289.083	88.751	6
	controls	308.367	78.214	6
reach centre start right target only mt	medicated	278.550	84.882	6
	controls	291.950	88.593	6
reach centre start right target left distractor mt	medicated	281.017	71.974	6
	controls	287.617	66.099	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET	Huynh-Feldt	495.367	1	495.367	0.294	0.599
TARGET x GROUP	Huynh-Feldt	180.964	1	180.964	0.107	0.750
Error(TARGET)	Huynh-Feldt	16838.348	10	1683.835		
DIST						

	Huynh-Feldt	596.43	1	596.43	0.979 0.346
DIST x GROUP	Huynh-Feldt	10.641	1	10.641	0.017 0.897
Error(DIST)	Huynh-Feldt	6091.886	10	609.189	
TARGET x DIST	Huynh-Feldt	764.804	1	764.804	0.987 0.344
TARGET x DIST x GROUP	Huynh-Feldt	72.521	1	72.521	0.094 0.766
Error(TARGETxDIST)	Huynh-Feldt	7750.955	10	775.095	

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	3981196.786	1	3981196.786	171.505	0
GROUP	2312.963	1	2312.963	0.1	0.759
Error	232133.161	10	23213.316		

Analyses of error data

Analyses of inattentive error data

G.12 Three-way ANOVA: Group (medicated ADHD, controls) x set (maintain, change) x distractor (absent, present) for inattentive errors (collapsed across start and target conditions) in the reach task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
Maintain set reach distractor absent inatt	clinical	0.143	0.150	7
	control	0.119	0.126	7
Maintain set reach distractor present inatt	clinical	0.167	0.136	7
	control	7.14E-02	8.91E-02	7
change-set reach distractor absent inatt	clinical	0.286	0.230	7
	control	0.214	0.427	7
change-set reach distractor present inatt	clinical	0.286	0.438	7
	control	0.167	0.236	7

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	0.179	1	0.179	1.733	0.213
SET x GROUP						
	Huynh-Feldt	4.46E-03	1	4.46E-03	0.043	0.839
Error(SET)						
	Huynh-Feldt	1.24	12	0.103		
DIST						
	Huynh-Feldt	4.46E-03	1	4.46E-03	0.153	0.703
DIST x GROUP						
	Huynh-Feldt	1.24E-02	1	1.24E-02	0.424	0.527
Error(DIST)						
	Huynh-Feldt	0.351	12	2.93E-02		
SET x DIST						
	Huynh-Feldt	4.96E-04	1	4.96E-04	0.011	0.92
SET x DIST x GROUP						
	Huynh-Feldt	4.96E-04	1	4.96E-04	0.011	0.92
Error(SETxDIST)						
	Huynh-Feldt	0.562	12	4.68E-02		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	1.846	1	1.846	19.55	0.001
GROUP	8.38E-02	1	8.38E-02	0.888	0.365
Error	1.133	12	9.44E-02		

G.13 Three-way ANOVA: Group (medicated ADHD, controls) x set (maintain, change) x distractor (absent, present) for inattentive errors (collapsed across start and target conditions) in the no-reach task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
Maintain-set no-reach distractor absent inatt	clinical	0.119	0.159	7
	control	0.167	0.255	7

Maintain-set no-reach distractor present inatt	clinical	9.52E-02	0.131	7
	control	0.143	0.244	7
change-set no-reach distractor absent	clinical	0.762	0.700	7
	control	0.333	0.333	7
change-set no-reach distractor present inatt	clinical	0.286	0.159	7
	control	0.119	0.159	7

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	0.834	1	0.834	8.635	0.012
SET x GROUP						
	Huynh-Feldt	0.417	1	0.417	4.32	0.06
Error(SET)						
	Huynh-Feldt	1.159	12	9.66E-02		
DIST						
	Huynh-Feldt	0.477	1	0.477	7.244	0.02
DIST x GROUP						
	Huynh-Feldt	6.00E-02	1	6.00E-02	0.912	0.358
Error(DIST)						
	Huynh-Feldt	0.79	12	6.58E-02		
SET x DIST						
	Huynh-Feldt	0.362	1	0.362	8.412	0.013
SET x DIST x GROUP						
	Huynh-Feldt	6.00E-02	1	6.00E-02	1.396	0.26
Error(SETxDIST)						
	Huynh-Feldt	0.516	12	4.30E-02		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	3.584	1	3.584	17.622	0.001
GROUP	0.219	1	0.219	1.076	0.32
Error	2.44	12	0.203		

Subanalyses for the set x distractor interaction

G.14 One-way ANOVA for distractor (absent, present) in the maintain-set condition.

Descriptive Statistics

	Mean	Std. Deviation	N
Maintain-set no-reach distractor absent inatt	0.143	0.205	14
Maintain-set no-reach distractor present inatt	0.119	0.190	14

ANOVA

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	3.97E-03	1	3.97E-03	0.65	0.435
Error(DIST)						
	Huynh-Feldt	7.94E-02	13	6.11E-03		

G.15 One-way ANOVA for distractor (absent, present) in the change-set condition.

Descriptive Statistics

	Mean	Std. Deviation	N
change-set no-reach distractor absent	0.548	0.572	14
change-set no-reach distractor present inatt	0.202	0.175	14

ANOVA

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	0.834	1	0.834	8.057	0.014
Error(DIST)						
	Huynh-Feldt	1.346	13	0.104		

Analyses of spatial biases/ performance asymmetries for the inattentive error data

G.16 Three-way ANOVA: Group (right-handed medicated ADHD, controls) x target (left, right) x distractor (absent, present) for centre-start inattentive error data in the reach condition, for the maintain-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left target only inatt errors	clinical	0.000	0.000	6
	control	0.167	0.408	6
reach centre start left target right distractor inatt errors	clinical	0.167	0.408	6
	control	0.000	0.000	6
reach centre start right target only inatt errors	clinical	0.333	0.816	6
	control	0.167	0.408	6
reach centre start right target left distractor inatt errors	clinical	0.333	0.516	6
	control	0.000	0.000	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET						
	Huynh-Feldt	0.187	1	0.187	1.364	0.27
TARGET x GROUP						
	Huynh-Feldt	0.187	1	0.187	1.364	0.27
Error(TARGET)						
	Huynh-Feldt	1.375	10	0.137		
DIST						
	Huynh-Feldt	2.08E-02	1	2.08E-02	0.082	0.78
DIST x GROUP						
	Huynh-Feldt	0.187	1	0.187	0.738	0.41
Error(DIST)						
	Huynh-Feldt	2.542	10	0.254		
TARGET x DIST						
	Huynh-Feldt	2.08E-02	1	2.08E-02	0.122	0.73

TARGET x DIST x GROUP						
	Huynh-Feldt	2.08E-02	1	2.08E-02	0.122	0.73
Error(TARGETxDIST)						
	Huynh-Feldt	1.708	10	0.171		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	1.021	1	1.021	6.622	0.028
GROUP	0.187	1	0.187	1.216	0.296
Error	1.542	10	0.154		

G.17 Three-way ANOVA: Group (right-handed medicated ADHD, right-handed controls) x target (left, right) x distractor (absent, present) for centre-start inattentive error data in the no-reach condition, for the maintain-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left target only inatt error	clinical	0.000	0.000	6
	control	0.333	0.816	6
no reach centre start left target right distractor inatt error	clinical	0.167	0.408	6
	control	0.000	0.000	6
no reach centre start right target only inatt error	clinical	0.167	0.408	6
	control	0.167	0.408	6
no reach centre start right target left distractor inatt error	clinical	0.000	0.000	6
	control	0.333	0.516	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET						
	Huynh-Feldt	2.08E-02	1	2.08E-02	1	0.341

TARGET x GROUP						
	Huynh-Feldt	2.08E-02	1	2.08E-02	1	0.341
Error(TARGET)						
	Huynh-Feldt	0.208	10	2.08E-02		
DIST						
	Huynh-Feldt	2.08E-02	1	2.08E-02	0.172	0.687
DIST x GROUP						
	Huynh-Feldt	2.08E-02	1	2.08E-02	0.172	0.687
Error(DIST)						
	Huynh-Feldt	1.208	10	0.121		
TARGET x DIST						
	Huynh-Feldt	2.08E-02	1	2.08E-02	0.122	0.734
TARGET x DIST x GROUP						
	Huynh-Feldt	0.521	1	0.521	3.049	0.111
Error(TARGETxDIST)						
	Huynh-Feldt	1.708	10	0.171		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	1.021	1	1.021	2.526	0.143
GROUP	0.187	1	0.187	0.464	0.511
Error	4.042	10	0.404		

G.18 Three-way ANOVA: Group (right-handed medicated ADHD, right-handed controls) x target (left, right) x distractor (absent, present) for centre-start inattentive error data in the reach condition, for the change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left target only inatt errors change set	clinical	0.500	0.837	6
	control	0.500	0.837	6
reach centre start left target right distractor inatt errors change set	clinical	0.167	0.408	6
	control	0.167	0.408	6

reach centre start right target onlt inatt errors change set	clinical	0.333	0.516	6
	control	0.500	1.225	6
reach centre start right target left distractor inatt errors change set	clinical	0.333	0.816	6
	control	0.333	0.516	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET						
	Huynh-Feldt	2.08E-02	1	2.08E-02	0.077	0.787
TARGET x GROUP						
	Huynh-Feldt	2.08E-02	1	2.08E-02	0.077	0.787
Error(TARGET)						
	Huynh-Feldt	2.708	10	0.271		
DIST						
	Huynh-Feldt	0.521	1	0.521	0.839	0.381
DIST x GROUP						
	Huynh-Feldt	2.08E-02	1	2.08E-02	0.034	0.858
Error(DIST)						
	Huynh-Feldt	6.208	10	0.621		
TARGET x DIST						
	Huynh-Feldt	0.188	1	0.188	3.462	0.092
TARGET x DIST x GROUP						
	Huynh-Feldt	2.08E-02	1	2.08E-02	0.385	0.549
Error(TARGETxDIST)						
	Huynh-Feldt	0.542	10	5.42E-02		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	6.021	1	6.021	4.738	0.055
GROUP	2.08E-02	1	2.08E-02	0.016	0.901
Error	12.708	10	1.271		

G.19 Three-way ANOVA: Group (right-handed medicated ADHD, right-handed controls) x target (left, right) x distractor (absent, present) for centre-start inattentive error data in the no-reach condition, for the change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left target only inatt error change set	clinical	0.833	1.329	6
	control	0.333	0.516	6
no reach centre start left target right distractor inatt error change set	clinical	0.000	0.000	6
	control	0.000	0.000	6
no reach centre start right target only inatt error change set	clinical	1.000	0.894	6
	control	0.167	0.408	6
no reach centre start right target left distractor inatt error change set	clinical	0.500	0.837	6
	control	0.333	0.516	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET						
	Huynh-Feldt	0.521	1	0.521	2.049	0.183
TARGET x GROUP						
	Huynh-Feldt	0.187	1	0.187	0.738	0.411
Error(TARGET)						
	Huynh-Feldt	2.542	10	0.254		
DIST						
	Huynh-Feldt	1.687	1	1.687	3.045	0.112
DIST x GROUP						
	Huynh-Feldt	1.021	1	1.021	1.842	0.205
Error(DIST)						
	Huynh-Feldt	5.542	10	0.554		
TARGET x DIST						
	Huynh-Feldt	0.521	1	0.521	1.923	0.196
TARGET x DIST x GROUP						

	Huynh-Feldt	2.08E-02	1	2.08E-02	0.077	0.787
Error(TARGET xDIST)						
	Huynh-Feldt	2.708	10	0.271		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	7.521	1	7.521	8.318	0.016
GROUP	1.687	1	1.687	1.866	0.202
Error	9.042	10	0.904		

Analyses of impulsive errors

G.20 Three-way ANOVA: Group (medicated ADHD, controls) x set (maintain, change) x reach (reach, no-reach) for impulsive error data collapsed across start, target and distractor conditions.

Descriptive Statistics

Descriptive Statistics

	group	Mean	Std. Deviation	N
impulsive errors - reach maintain-set	medicated	2.4286	2.5071	7
	controls	.1429	.3780	7
impulsive errors - no reach maintain-set	medicated	2.1429	1.0690	7
	controls	.4286	.5345	7
impulsive errors - reach change set	medicated	1.8571	1.4639	7
	controls	1.0000	1.5275	7
impulsive errors - no reach change set	medicated	.5714	.9759	7
	controls	.0000	.0000	7

Tests of within-subjects effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	2.571	1.000	2.571	1.655	.223
SET * GROUP	Huynh-Feldt	5.786	1.000	5.786	3.724	.078
Error(SET)	Huynh-Feldt	18.643	12.000	1.554		
REACH	Huynh-Feldt	4.571	1.000	4.571	2.518	.139
REACH * GROUP	Huynh-Feldt	.643	1.000	.643	.354	.563
Error(REACH)	Huynh-Feldt	21.786	12.000	1.815		
SET * REACH	Huynh-Feldt	4.571	1.000	4.571	6.564	.025
SET * REACH * GROUP	Huynh-Feldt	7.143E-02	1.000	7.143E-02	.103	.754
Error(SET*REACH)	Huynh-Feldt	8.357	12.000	.696		

a Computed using alpha = .05

Tests of between-subjects effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	64.286	1	64.286	24.942	.000
GROUP	25.786	1	25.786	10.005	.008
Error	30.929	12	2.577		

a Computed using alpha = .05

Analyses of distractibility errors

G.21 Three-way ANOVA: Group (medicated ADHD, controls) x set (maintain, change) x target (absent, present) for distractibility errors (collapsed across start position and distractor location) in the reach task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
Maintain-set reach target absent	clinical	1.905	1.726	7
	control	1.095	1.022	7
Maintain-set reach target present	clinical	9.52E-02	0.189	7
	control	7.14E-02	8.91E-02	7
change-set reach target absent	clinical	1.452	1.413	7
	control	0.738	0.543	7
change-set reach target present	clinical	0.691	0.539	7
	control	0.429	0.460	7

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	1.79E-02	1	1.79E-02	0.106	0.75
SET x GROUP						
	Huynh-Feldt	1.79E-02	1	1.79E-02	0.106	0.75
Error(SET)						
	Huynh-Feldt	2.02	12	0.168		
TARGET						
	Huynh-Feldt	13.341	1	13.341	11.074	0.006
TARGET x GROUP						
	Huynh-Feldt	1.341	1	1.341	1.113	0.312
Error(TARGET)						
	Huynh-Feldt	14.456	12	1.205		
SET x TARGET						
	Huynh-Feldt	2.716	1	2.716	8.842	0.012
SET x TARGET x GROUP						
	Huynh-Feldt	9.72E-02	1	9.72E-02	0.316	0.584
Error(SETxTARGET)						
	Huynh-Feldt	3.687	12	0.307		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	36.698	1	36.698	20.951	0.001
GROUP	2.865	1	2.865	1.636	0.225
Error	21.02	12	1.752		

Subanalyses of the target x set interaction

G.22 One-way ANOVA for target (absent, present) in the maintain-set condition.

Descriptive statistics

	Mean	Std. Deviation	N
Maintain-set reach target absent	1.5	1.426	14
Maintain-set reach target present	8.33E-02	0.143	14

ANOVA

Source		Sum of Squares	df	Mean Square	F	Sig.
TARG						
	Huynh-Feldt	14.049	1	14.049	13.82	0.003
Error(TARG)						
	Huynh-Feldt	13.215	13	1.017		

G.23 One-way ANOVA for target (absent, present) in the change-set condition.

Descriptive statistics

	Mean	Std. Deviation	N
change-set reach target absent	1.095	1.093	14
change-set reach target present	0.560	0.501	14

ANOVA

Source		Sum of Squares	df	Mean Square	F	Sig.
TARG						
	Huynh-Feldt	2.009	1	2.009	4.102	0.064
Error(TARG)						
	Huynh-Feldt	6.366	13	0.490		

G.24 Two-way ANOVA: Group (medicated ADHD, controls) x set (maintain, change) for distractibility errors (collapsed across start position and distractor location) made in the no-reach task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
Maintain-set no-reach	clinical	2.286	2.103	7
	control	0.571	0.429	7
change-set no-reach	clinical	2.310	2.354	7
	control	0.738	0.543	7

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	6.35E-02	1	6.35E-02	0.119	0.737
SET x GROUP						
	Huynh-Feldt	3.57E-02	1	3.57E-02	0.067	0.801
Error(SET)						
	Huynh-Feldt	6.429	12	0.536		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	61.016	1	61.016	13.021	0.004
GROUP	18.893	1	18.893	4.032	0.068
Error	56.23	12	4.686		

Analyses of spatial biases/ performance asymmetries for distractibility errors

G.25 Three-way ANOVA: Group (right-handed medicated ADHD, right-handed controls) x target (absent, present) x distractor (left, right) for centre-start distractibility errors in the reach condition of the maintain-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left distractor distractibility errors	clinical	2.500	3.834	6
	control	2.333	2.251	6

reach centre start right target left distractor distractibility errors	clinical	0.333	0.816	6
	control	0.167	0.408	6
reach centre start right distractor distractibility errors	clinical	2.667	4.227	6
	control	1.000	1.549	6
reach centre start left target right distractor distractibility errors	clinical	0.000	0.000	6
	control	0.000	0.000	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	2.083	1	2.083	1.479	0.252
DIST x GROUP						
	Huynh-Feldt	1.333	1	1.333	0.947	0.353
Error(DIST)						
	Huynh-Feldt	14.083	10	1.408		
TARG						
	Huynh-Feldt	48	1	48	5.194	0.046
TARG x GROUP						
	Huynh-Feldt	2.083	1	2.083	0.225	0.645
Error(TARG)						
	Huynh-Feldt	92.417	10	9.242		
DIST x TARG						
	Huynh-Feldt	0.333	1	0.333	0.301	0.595
DIST x TARG x GROUP						
	Huynh-Feldt	2.083	1	2.083	1.88	0.2
Error(DISTxTARG)						
	Huynh-Feldt	11.083	10	1.108		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	60.75	1	60.75	7.003	0.024
GROUP	3	1	3	0.346	0.57
Error	86.75	10	8.675		

G.26 Two-way ANOVA: Group (right-handed medicated ADHD, right-handed controls) x distractor (left, right) for centre-start distractibility errors in the no-reach condition of the maintain-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left distractor distractibility error	clinical	1.667	1.966	6
	control	0.500	1.225	6
no reach centre start right distractor distractibility error	clinical	2.000	2.191	6
	control	0.667	0.816	6

Tests of within-subjects effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	0.375	1	0.375	0.287	0.604
DIST x GROUP						
	Huynh-Feldt	4.17E-02	1	4.17E-02	0.032	0.862
Error(DIST)						
	Huynh-Feldt	13.083	10	1.308		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	35.042	1	35.042	8.529	0.015
GROUP	9.375	1	9.375	2.282	0.162
Error	41.083	10	4.108		

G.27 Three-way ANOVA: Group (right-handed medicated ADHD, right-handed controls) x target (absent, present) x distractor (left, right) for centre-start distractibility errors in the reach condition of the change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
reach centre start left distractor distractibility errors	clinical	2.500	3.834	6
	control	2.333	2.251	6
reach centre start right target left distractor distractibility errors	clinical	0.333	0.816	6
	control	0.167	0.408	6
reach centre start right distractor distractibility errors	clinical	2.667	4.227	6
	control	1.000	1.549	6
reach centre start left target right distractor distractibility errors	clinical	0.000	0.000	6
	control	0.000	0.000	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	0.333	1	0.333	0.471	0.508
DIST x GROUP						
	Huynh-Feldt	8.33E-02	1	8.33E-02	0.118	0.739
Error(DIST)						
	Huynh-Feldt	7.083	10	0.708		
TARG						
	Huynh-Feldt	1.333	1	1.333	1.168	0.305
TARG x GROUP						
	Huynh-Feldt	0.75	1	0.75	0.657	0.437
Error(TARG)						
	Huynh-Feldt	11.417	10	1.142		
DIST x TARG						
	Huynh-Feldt	0.333	1	0.333	0.548	0.476
DIST x TARG x GROUP						
	Huynh-Feldt	2.083	1	2.083	3.425	0.094
Error(DISTxTARG)						
	Huynh-Feldt	6.083	10	0.608		

Tests of between-subject effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	40.333	1	40.333	13.407	0.004
GROUP	2.083	1	2.083	0.693	0.425
Error	30.083	10	3.008		

G.28 Two-way ANOVA: Group (right-handed medicated ADHD, right-handed controls) x distractor (left, right) for centre-start distractibility errors in the no-reach condition of the change-set task.

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
no reach centre start left distractor distractibility error change set	clinical	2.333	3.266	6
	control	0.667	1.211	6
no reach centre start right distractor distractibility error change set	clinical	3.333	4.546	6
	control	0.500	1.225	6

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	1.042	1	1.042	0.723	0.415
DIST x GROUP						
	Huynh-Feldt	2.042	1	2.042	1.416	0.262
Error(DIST)						
	Huynh-Feldt	14.417	10	1.442		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	70.042	1	70.042	4.459	0.061
GROUP	30.375	1	30.375	1.934	0.195
Error	157.083	10	15.708		

Analyses of proportional errors

G.29 Four-way ANOVA: Group (medicated ADHD, controls) x set (maintain, change) x reach (reach, no-reach) x error type (inattentive, impulsive, distractibility) for error data converted to proportions of total errors made.

Descriptive Statistics

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
maintain-set reach distprop errors	clinical	.6871	.1138	7
	control	.6749	.3303	7
maintain-set reach inattprop errors	clinical	.1163	7.262E-02	7
	control	.1994	.2436	7
maintain-set reach impulseprop errors	clinical	.1429	.1383	7
	control	2.857E-02	7.559E-02	7
maintain-set no-reach distprop errors	clinical	.7625	9.486E-02	7
	control	.7095	.3675	7
maintain-set no-reach inattprop errors	clinical	6.362E-02	8.310E-02	7
	control	.2131	.3320	7
maintain-set no-reach impulseprop errors	clinical	.1738	8.783E-02	7
	control	7.738E-02	.1237	7
change-set reach distprop errors	clinical	.6273	.1180	7
	control	.6611	.3483	7

	clinical	.1793	.1701	7
change-set reach inattprop errors	control	8.885E-02	.1067	7
	clinical	.1525	.1710	7
change-set reach impulseprop errors	control	6.776E-02	9.437E-02	7
	clinical	.6975	.2175	7
change-set no-reach distprop errors	control	.7196	.2536	7
	clinical	.2833	.1946	7
change-set no-reach inattprop errors	control	.2804	.2536	7
	clinical	1.921E-02	3.787E-02	7
change-set no-reach impulseprop errors	control	.0000	.0000	7

Tests of within-subjects effects

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	1.534E-03	1.000	1.534E-03	.194	.667
SET * GROUP	Huynh-Feldt	2.792E-03	1.000	2.792E-03	.354	.563
Error(SET)	Huynh-Feldt	9.479E-02	12.000	7.899E-03		
REACH	Huynh-Feldt	4.077E-02	1.000	4.077E-02	7.414	.019
REACH * GROUP	Huynh-	9.975E-03	1.000	9.975E-03	1.814	.203

	Feldt					
Error(REACH)	Huynh-Feldt	6.599E-02	12.000	5.499E-03		
ERROR	Huynh-Feldt	12.047	1.357	8.879	92.692	.000
ERROR * GROUP	Huynh-Feldt	9.374E-02	1.357	6.909E-02	.721	.449
Error(ERROR)	Huynh-Feldt	1.560	16.282	9.579E-02		
SET * REACH	Huynh-Feldt	1.534E-03	1.000	1.534E-03	.194	.667
SET * REACH * GROUP	Huynh-Feldt	2.792E-03	1.000	2.792E-03	.354	.563
Error(SET*REACH)	Huynh-Feldt	9.479E-02	12.000	7.899E-03		
SET * ERROR	Huynh-Feldt	9.248E-02	1.785	5.180E-02	.906	.409
SET * ERROR * GROUP	Huynh-Feldt	.113	1.785	6.332E-02	1.107	.342
Error(SET*ERROR)	Huynh-Feldt	1.225	21.422	5.720E-02		
REACH * ERROR	Huynh-Feldt	7.953E-02	1.509	5.270E-02	.707	.468
REACH * ERROR * GROUP	Huynh-Feldt	1.925E-02	1.509	1.275E-02	.171	.784
Error(REACH*ERROR)	Huynh-Feldt	1.350	18.108	7.453E-02		
SET * REACH * ERROR	Huynh-Feldt	.166	1.858	8.918E-02	1.821	.187
SET * REACH * ERROR * GROUP	Huynh-Feldt	3.209E-04	1.858	1.727E-04	.004	.995
Error(SET*REACH*ERROR)	Huynh-Feldt	1.092	22.295	4.898E-02		

a Computed using alpha = .05

Tests of between-subjects effects

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	16.963	1	16.963	3084.465	.000
GROUP	9.975E-03	1	9.975E-03	1.814	.203
Error	6.599E-02	12	5.499E-03		

a Computed using alpha = .05

Post-hoc tests for error type

Descriptive Statistics

Estimates

ERROR	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1. distractibility errors	.692	.038	.609	.776
2. inattentive errors	.178	.028	.117	.239
3. impulsive errors	8.277E-02	.013	5.399E-02	.112

Pairwise Comparisons

Pairwise Comparisons

(I) ERROR	(J) ERROR	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a) Lower Bound	Upper Bound
1	2	.514(*)	.064	.000	.337	.692
	3	.610(*)	.046	.000	.483	.736
2	1	-.514(*)	.064	.000	-.692	-.337
	3	9.528E-02(*)	.028	.017	1.666E-02	.174
3	1	-.610(*)	.046	.000	-.736	-.483
	2	-9.528E-02(*)	.028	.017	-.174	-1.666E-02

Based on estimated marginal means

* The mean difference is significant at the .05 level.

a Adjustment for multiple comparisons: Bonferroni.

APPENDIX H: ANALYSES FOR EXPERIMENT 3

Analyses of demographic data

Demographic details of the 7-8, 9-10, and 11-12 year-old children

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
	7-8yo	12	106.250	14.104	4.072	97.289	115.212
FSIQ	9-10yo	12	115.167	13.750	3.969	106.430	123.903
	11-12yo	16	104.688	11.982	2.995	98.303	111.072
	7-8yo	8	52.500	19.842	7.015	35.912	69.089
RSHPERC	9-10yo	10	52.200	20.154	6.373	37.783	66.617
	11-12yo	15	57.800	19.847	5.124	46.809	68.791
	7-8yo	9	66.778	25.587	8.529	47.110	86.446
RSSPERC	9-10yo	11	68.909	22.305	6.725	53.925	83.894
	11-12yo	11	88.455	16.765	5.055	77.192	99.718

One-way ANOVAs for demographic variables

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	825.046	2	412.523	2.377	.107
FSIQ	Within Groups	6421.354	37	173.550		
	Total	7246.400	39			
	Between Groups	244.909	2	122.455	.308	.737
RSHPERC	Within Groups	11926.000	30	397.533		
	Total	12170.909	32			
	Between Groups	3006.227	2	1503.114	3.232	.055
RSSPERC	Within Groups	13023.192	28	465.114		
	Total	16029.419	30			

Analyses for reaction time data in the reach task

H.1 Three-way ANOVA: Group (7-8, 9-10, 11-12) x set (maintain, change) x distractor (absent, present) for reaction time data (collapsed across start position and target location) in the reach task.

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	6884.884	1	6884.884	1.975	0.168
SET x GROUP						
	Huynh-Feldt	4214.861	2	2107.43	0.605	0.552
Error(SET)						
	Huynh-Feldt	128969.945	37	3485.674		
DIST						
	Huynh-Feldt	7799.93	1	7799.93	18.326	0.000
DIST x GROUP						
	Huynh-Feldt	2115.001	2	1057.5	2.485	0.097
Error(DIST)						
	Huynh-Feldt	15747.705	37	425.614		
SET x DIST						
	Huynh-Feldt	259.643	1	259.643	0.474	0.495
SET x DIST x GROUP						
	Huynh-Feldt	2571.892	2	1285.946	2.348	0.11
Error(SETxDIST)						
	Huynh-Feldt	20263.015	37	547.649		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	47674079.65	1	47674079.65	1940.299	0
GROUP	728089.596	2	364044.798	14.816	.000
Error	909107.613	37	24570.476		

Post hoc tests with Bonferroni corrections

Descriptives

Estimates				
			95% Confidence Interval	
group	Mean	Std. Error	Lower Bound	Upper Bound
7-8yo	643.157	22.625	597.315	688.999
9-10yo	527.054	22.625	481.212	572.897
11-12yo	482.462	19.594	442.761	522.162

Pairwise Comparisons

Multiple Comparisons					
	(I) OLD2	(J) OLD2	Mean Difference (I-J)	Std. Error	Sig.
Bonferroni	7-8yo	9-10yo	116.1028(*)	31.9964	0.003
		11-12yo	160.6952(*)	29.9299	0.000
	9-10yo	7-8yo	-116.1028(*)	31.9964	0.003
		11-12yo	44.5924	29.9299	0.434
	11-12yo	7-8yo	-160.6952(*)	29.9299	0.000
		9-10yo	-44.5924	29.9299	0.434

Based on observed means.
* The mean difference is significant at the .05 level.

Analyses of movement time data in the reach task

H.2 Three-way ANOVA: Group (7-8, 9-10, 11-12) x set (maintain, change) x distractor (absent, present) for movement time data (collapsed across start position and target location) in the reach task.

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	60833.714	1	60833.714	15.256	0.000
SET x GROUP						
	Huynh-Feldt	1524.457	2	762.228	0.191	0.827
Error(SET)						
	Huynh-Feldt	147538.549	37	3987.528		
DIST						
	Huynh-Feldt	17086.362	1	17086.362	32.958	0.000
DIST x GROUP						
	Huynh-Feldt	6513.157	2	3256.579	6.282	0.004
Error(DIST)						
	Huynh-Feldt	19181.84	37	518.428		
SET x DIST						
	Huynh-Feldt	3811.603	1	3811.603	6.971	0.012
SET x DIST x GROUP						
	Huynh-Feldt	589.543	2	294.772	0.539	0.588
Error(SETxDIST)						
	Huynh-Feldt	20230.408	37	546.768		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	16605043.28	1	16605043.28	568.4	0
GROUP	126050.891	2	63025.446	2.157	0.13
Error	1080904.927	37	29213.647		

Subanalyses of the group x distractor interaction

H.3 Three repeated-measures one-way ANOVAs for distractor (absent, present) in the 7-8 year-old, 9-10 year-old, and 11-12 year-old groups.

GROUP	Source		Sum of Squares	df	Mean Square	F	Sig.
7-8yo	DIST						
		Huynh-Feldt	8528.054	1	8528.054	13.112	0.004
	Error(DIST)						
		Huynh-Feldt	7154.342	11	650.395		

9-10yo	DIST						
		Huynh-Feldt	1920.67	1	1920.67	12.903	0.004
	Error(DIST)						
		Huynh-Feldt	1637.369	11	148.852		
11-12yo	DIST						
		Huynh-Feldt	390.053	1	390.053	7.321	0.016
	Error(DIST)						
		Huynh-Feldt	799.209	15	53.281		

Subanalyses of the set x distractor interaction

H.4 Repeated-measures one-way ANOVA for distractor (absent, present) in the maintain-set task.

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	1999.097	1	1999.097	6.643	0.014
Error(DIST)						
	Huynh-Feldt	11736.217	39	300.929		

H.5 Repeated-measures one-way ANOVA for distractor (absent, present) in the change-set task.

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	16754.812	1	16754.812	18.788	0.00
Error(DIST)						
	Huynh-Feldt	34778.731	39	891.762		

Analyses of reaction time data in the no-reach task

H.6 Three-way ANOVA: Group (7-8, 9-10, 11-12) x set (maintain, change) x distractor (absent, present) for reaction time data (collapsed across start position and target location in the no-reach task.

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	5285.381	1	5285.381	0.611	0.440
SET x GROUP	Huynh-Feldt	560.27	2	280.135	0.032	0.968
Error(SET)	Huynh-Feldt	320238.716	37	8655.1		
DIST	Huynh-Feldt	13133.92	1	13133.92	9.067	0.005
DIST x GROUP	Huynh-Feldt	3470.727	2	1735.363	1.198	0.313
Error(DIST)	Huynh-Feldt	53598.249	37	1448.601		
SET x DIST	Huynh-Feldt	21271.025	1	21271.025	30.332	0.000
SET x DIST x GROUP	Huynh-Feldt	6988.308	2	3494.154	4.983	0.012
Error(SETxDIST)	Huynh-Feldt	25947.08	37	701.272		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	63605288.42	1	63605288.42	1045.888	0
GROUP	1222340.226	2	611170.113	10.05	0.00
Error	2250140.459	37	60814.607		

Post-hoc tests for group

Multiple Comparisons					
	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.
Bonferroni	7-8yo	9-10yo	140.2108(*)	50.3383	0.025
		11-12yo	209.9083(*)	47.0871	0.000
	9-10yo	7-8yo	-140.2108(*)	50.3383	0.025
		11-12yo	69.6976	47.0871	0.442
	11-12yo	7-8yo	-209.9083(*)	47.0871	0.000
		9-10yo	-69.6976	47.0871	0.442

Based on observed means.

*.The mean difference is significant at the .05 level.

Subanalyses for the set x distractor x group interaction

H.7 Two-way repeated measures ANOVA: Distractor (absent, present) and set (maintain-set, change-set) for reaction times in the no-reach task, for the 7-8 year-old group.

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	12162.99	1	12162.99	4.147	0.067
Error(DIST)						
	Huynh-Feldt	32262.569	11	2932.961		
SET						
	Huynh-Feldt	992.052	1	992.052	0.072	0.793
Error(SET)						
	Huynh-Feldt	151451.048	11	13768.277		
DIST x SET						
	Huynh-Feldt	21489.108	1	21489.108	19.543	0.001
Error(DISTxSET)						
	Huynh-Feldt	12095.151	11	1099.559		

H.8 Two-way repeated measures ANOVA: Distractor (absent, present) and set (maintain-set, change-set) for reaction times in the no-reach task, for the 9-10 year-old group.

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	1135.232	1	1135.232	1.1	0.317
Error(DIST)						
	Huynh-Feldt	11353.518	11	1032.138		
SET						
	Huynh-Feldt	975.604	1	975.604	0.082	0.78
Error(SET)						
	Huynh-Feldt	131055.007	11	11914.092		
DIST x SET						
	Huynh-Feldt	2712.015	1	2712.015	4.448	0.059
Error(DISTxSET)						
	Huynh-Feldt	6707.545	11	609.777		

H.9 Two-way repeated measures ANOVA: Distractor (absent, present) and set (maintain-set, change-set) for reaction times in the no-reach task, for the 11-12 year-old group.

Source		Sum of Squares	df	Mean Square	F	Sig.
DIST						
	Huynh-Feldt	2829.797	1	2829.797	4.252	0.057
Error(DIST)						
	Huynh-Feldt	9982.162	15	665.477		
SET						
	Huynh-Feldt	4458.899	1	4458.899	1.773	0.203
Error(SET)						
	Huynh-Feldt	37732.661	15	2515.511		
DIST * SET						
	Huynh-Feldt	2487.1	1	2487.1	5.222	0.037
Error(DIST*SET)						
	Huynh-Feldt	7144.384	15	476.292		

Analyses of error data

Analyses of inattentive errors

H.10 Three-way ANOVA: Group (7-8, 9-10, 11-12 year olds) x set (maintain, change) x distractor (absent, present) for inattentive errors made in the reach task (collapsed across start and target conditions) in the reach task.

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	0.696	1	0.696	3.909	0.056
SET x GROUP						
	Huynh-Feldt	0.788	2	0.394	2.214	0.124
Error(SET)						
	Huynh-Feldt	6.586	37	0.178		
DIST						
	Huynh-Feldt	0.111	1	0.111	2.628	0.113
DIST x GROUP						
	Huynh-Feldt	9.68E-02	2	4.84E-02	1.142	0.33
Error(DIST)						
	Huynh-Feldt	1.567	37	4.24E-02		
SET x DIST						
	Huynh-Feldt	0.243	1	0.243	10.922	0.002
SET x DIST x GROUP						
	Huynh-Feldt	0.873	2	0.437	19.602	0.000
Error(SETxDIST)						
	Huynh-Feldt	0.824	37	2.23E-02		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	7.798	1	7.798	34.212	0
GROUP	7.108	2	3.554	15.591	0.00
Error	8.433	37	0.228		

Post hoc tests for group

Multiple Comparisons

	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.
Bonferroni	7-8yo	9-10yo	.4444(*)	9.75E-02	0.000
		11-12yo	.4705(*)	9.12E-02	0.000
	9-10yo	7-8yo	-.4444(*)	9.75E-02	0.000
		11-12yo	2.60E-02	9.12E-02	1.000
	11-12yo	7-8yo	-.4705(*)	9.12E-02	0.000
		9-10yo	-2.60E-02	9.12E-02	1.000

Based on observed means.

* The mean difference is significant at the .05 level.

Subanalyses for set x distractor x group interaction

H.11 Two-way ANOVA: Set (maintain, change) x distractor (absent, present) for inattentive errors made in the reach task by 7-8 year-old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	1.333	1	1.333	2.614	0.134
Error(SET)						
	Huynh-Feldt	5.611	11	0.51		
DIST						
	Huynh-Feldt	0.187	1	0.187	1.571	0.236
Error(DIST)						
	Huynh-Feldt	1.312	11	0.119		
SET x DIST						
	Huynh-Feldt	1.021	1	1.021	19.024	0.001
Error(SETxDIST)						
	Huynh-Feldt	0.59	11	5.37E-02		

H.12 Two-way ANOVA: Set (maintain, change) x distractor (absent, present) for inattentive errors made in the reach task by 9-10 year-old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	3.70E-02	1	3.70E-02	0.662	0.433
Error(SET)						
	Huynh-Feldt	0.616	11	5.60E-02		
DIST						
	Huynh-Feldt	2.32E-03	1	2.32E-03	0.268	0.615
Error(DIST)						
	Huynh-Feldt	9.49E-02	11	8.63E-03		
SET x DIST						
	Huynh-Feldt	2.32E-03	1	2.32E-03	0.208	0.658
Error(SETxDIST)						
	Huynh-Feldt	0.123	11	1.12E-02		

H.13 Two-way ANOVA: Set (maintain, change) x distractor (absent, present) for inattentive errors made in the reach task by 11-12 year-old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	1.74E-03	1	1.74E-03	0.072	0.791
Error(SET)						
	Huynh-Feldt	0.359	15	2.40E-02		
DIST						
	Huynh-Feldt	6.94E-03	1	6.94E-03	0.652	0.432
Error(DIST)						
	Huynh-Feldt	0.16	15	1.07E-02		
SET x DIST						
	Huynh-Feldt	2.78E-02	1	2.78E-02	3.75	0.072
Error(SETxDIST)						
	Huynh-Feldt	0.111	15	7.41E-03		

Subanalyses of set x distractor interaction for the 7-8 year-old group

H.14 One-way ANOVA: Distractor (absent, present) for inattentive errors made in the reach condition of the maintain-set task.

Tests of Within-Subjects Effects(a)

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
DIST	Huynh-Feldt	.167	1.000	.167	6.000	.032	.353
Error(DIST)	Huynh-Feldt	.306	11.000	2.778E-02			

a group = 7-8yo

H.15 One-way ANOVA: Distractor (absent, present) for inattentive errors made in the reach condition of the change-set task.

Tests of Within-Subjects Effects(a)

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
DIST	Huynh-Feldt	1.042	1.000	1.042	7.174	.021	.395

Error(DIST)	Huynh-Feldt	1.597	11.000	.145

a group = 7-8yo

H.16 Three-way ANOVA: Group (7-8, 9-10, 11-12 year olds) x set (maintain, change) x distractor (absent, present) for inattentive errors made in the no-reach task (collapsed across start and target conditions) in the no-reach task.

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	5.643	1	5.643	13.286	0.001
SET x GROUP						
	Huynh-Feldt	6.613	2	3.306	7.785	0.002
Error(SET)						
	Huynh-Feldt	15.714	37	0.425		
DIST						
	Huynh-Feldt	4.563	1	4.563	19.868	0.000
DIST x GROUP						
	Huynh-Feldt	5.385	2	2.692	11.723	0.000
Error(DIST)						
	Huynh-Feldt	8.497	37	0.23		
SET x DIST						
	Huynh-Feldt	3.223	1	3.223	11.803	0.001
SET x DIST x GROUP						
	Huynh-Feldt	5.358	2	2.679	9.812	0.000
Error(SETxDIST)						
	Huynh-Feldt	10.103	37	0.273		

Tests of between-subjects effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	25.963	1	25.963	36.172	.000
group	22.017	2	11.009	15.337	.000
Error	26.557	37	.718		

Post hoc tests for group

Pairwise Comparisons						
					95% Confidence Interval for Difference(a)	
(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.(a)	Lower Bound	Upper Bound
7-8yo	9-10	.792(*)	.173	.000	.358	1.225
	11-12	.822(*)	.162	.000	.416	1.228
9-10	7-8yo	-.792(*)	.173	.000	-1.225	-.358
	11-12	3.038E-02	.162	1.000	-.375	.436
11-12	7-8yo	-.822(*)	.162	.000	-1.228	-.416
	9-10	-3.038E-02	.162	1.000	-.436	.375

Based on estimated marginal means

* The mean difference is significant at the .05 level.

a Adjustment for multiple comparisons: Bonferroni.

Subanalyses for set x distractor x group interaction

H.17 Two-way ANOVA: Set (maintain, change) x distractor (absent, present) for no-reach inattentive errors in the 7-8 year-old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	11.343	1	11.343	8.602	0.014
Error(SET)						
	Huynh-Feldt	14.505	11	1.319		
DIST						
	Huynh-Feldt	9.188	1	9.188	13.052	0.004
Error(DIST)						
	Huynh-Feldt	7.743	11	0.704		
SET x DIST						
	Huynh-Feldt	8.058	1	8.058	9.106	0.012
Error(SETxDIST)						
	Huynh-Feldt	9.734	11	0.885		

H.18 Two-way ANOVA: Set (maintain, change) x distractor (absent, present) for no-reach inattentive errors in the 9-10 year-old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	3.70E-02	1	3.70E-02	0.83	0.382
Error(SET)						
	Huynh-Feldt	0.491	11	4.46E-02		
DIST						
	Huynh-Feldt	5.79E-02	1	5.79E-02	2.895	0.117
Error(DIST)						
	Huynh-Feldt	0.22	11	2.00E-02		
SET * DIST						
	Huynh-Feldt	2.32E-03	1	2.32E-03	0.133	0.723
Error(SET*DIST)						
	Huynh-Feldt	0.192	11	1.75E-02		

H.19 Two-way ANOVA: Set (maintain, change) x distractor (absent, present) for no-reach inattentive errors in the 11-12 year-old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	0.191	1	0.191	3.997	0.064
Error(SET)						
	Huynh-Feldt	0.718	15	4.79E-02		
DIST						
	Huynh-Feldt	9.77E-02	1	9.77E-02	2.742	0.119
Error(DIST)						
	Huynh-Feldt	0.534	15	3.56E-02		
SET x DIST						
	Huynh-Feldt	1.09E-02	1	1.09E-02	0.921	0.352
Error(SETxDIST)						
	Huynh-Feldt	0.177	15	1.18E-02		

Analyses of impulsive errors

H.20 Three-way ANOVA: Group (7-8, 9-10, 11-12 year olds) x set (maintain, change) x reach (reach, no-reach) for impulsive errors (collapsed across start, target and distractor conditions).

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	9.28	1	9.28	5.625	0.023
SET x GROUP						
	Huynh-Feldt	4.858	2	2.429	1.472	0.242
Error(SET)						
	Huynh-Feldt	61.042	37	1.65		
REACH						
	Huynh-Feldt	1.002	1	1.002	0.671	0.418
REACH x GROUP						
	Huynh-Feldt	0.871	2	0.435	0.292	0.749
Error(REACH)						
	Huynh-Feldt	55.229	37	1.493		

SET x REACH						
	Huynh-Feldt	5.729	1	5.729	1.539	0.223
SET x REACH x GROUP						
	Huynh-Feldt	9.046	2	4.523	1.215	0.308
Error(SETxREACH)						
	Huynh-Feldt	137.729	37	3.722		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	350.189	1	350.189	26.068	0
GROUP	288.933	2	144.467	10.754	0.00
Error	497.042	37	13.434		

Post hoc tests for group

Pairwise Comparisons						
					95% Confidence Interval for Difference(a)	
(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.(a)	Lower Bound	Upper Bound
7-8yo	9-10yo	2.833(*)	.748	.002	.957	4.710
	11-12yo	3.000(*)	.700	.000	1.245	4.755
9-10yo	7-8yo	-2.833(*)	.748	.002	-4.710	-.957
	11-12yo	.167	.700	1.000	-1.588	1.922
11-12yo	7-8yo	-3.000(*)	.700	.000	-4.755	-1.245
	9-10yo	-.167	.700	1.000	-1.922	1.588

Based on estimated marginal means

* The mean difference is significant at the .05 level.

a Adjustment for multiple comparisons: Bonferroni.

Analyses of distractibility errors

H.21 Three-way ANOVA: Group (7-8, 9-10, 11-12 year-old) x set (maintain, change) x target (absent, present) for distractibility errors (collapsed across start position and distractor location) in the reach task.

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	3.223	1	3.223	4.253	0.046
SET x GROUP						
	Huynh-Feldt	4.966	2	2.483	3.277	0.049
Error(SET)						
	Huynh-Feldt	28.037	37	0.758		
TARGET						
	Huynh-Feldt	29.79	1	29.79	105.305	0.000
TARGET x GROUP						
	Huynh-Feldt	7.994	2	3.997	14.128	0.000
Error(TARGET)						
	Huynh-Feldt	10.467	37	0.283		
SET x TARGET						
	Huynh-Feldt	4.27E-02	1	4.27E-02	0.151	0.7
SET x TARGET x GROUP						
	Huynh-Feldt	1.158	2	0.579	2.043	0.144
Error(SETxTARGET)						
	Huynh-Feldt	10.481	37	0.283		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	85.725	1	85.725	97.277	0
GROUP	28.13	2	14.065	15.96	0.00
Error	32.606	37	0.881		

Post-hoc tests for group

Pairwise Comparisons						
					95% Confidence Interval for Difference(a)	
(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.(a)	Lower Bound	Upper Bound
7-8yo	9-10yo	.736(*)	.192	.001	.256	1.217
	11-12yo	.996(*)	.179	.000	.546	1.445
9-10yo	7-8yo	-.736(*)	.192	.001	-1.217	-.256
	11-12yo	.260	.179	.468	-.190	.709
11-12yo	7-8yo	-.996(*)	.179	.000	-1.445	-.546
	9-10yo	-.260	.179	.468	-.709	.190

Based on estimated marginal means

* The mean difference is significant at the .05 level.

a Adjustment for multiple comparisons: Bonferroni.

Subanalyses for set x group interaction

H.22 One-way ANOVA: Set (maintain, change) for distractibility errors made in the reach task by 7-8 year old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	3.827	1	3.827	3.416	0.092
Error(SET)	Huynh-Feldt	12.323	11	1.12		

H.23 One-way ANOVA: Set (maintain, change) for distractibility errors made in the reach task by 9-10 year old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	7.23E-03	1	7.23E-03	0.055	0.819
Error(SET)						
	Huynh-Feldt	1.448	11	0.132		

H.24 One-way ANOVA: Set (maintain, change) for distractibility errors made in the reach task by 11-12 year old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	5.43E-03	1	5.43E-03	0.328	0.575
Error(SET)						
	Huynh-Feldt	0.248	15	1.65E-02		

Subanalyses for target x group interaction

H.25 One-way ANOVA: Target (absent, present) for distractibility errors made in the reach task by 7-8 year-old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET						
	Huynh-Feldt	12.882	1	12.882	64.891	0.00
Error(TARGET)						
	Huynh-Feldt	2.184	11	0.199		

H.26 One-way ANOVA: Target (absent, present) for distractibility errors made in the reach task by 9-10 year-old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET						
	Huynh-Feldt	3.438	1	3.438	15.363	0.002
Error(TARGET)						
	Huynh-Feldt	2.462	11	0.224		

H.27 One-way ANOVA: Target (absent, present) for distractibility errors made in the reach task by 11-12 year-old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
TARGET						
	Huynh-Feldt	1.221	1	1.221	31.123	0.00
Error(TARGET)						
	Huynh-Feldt	0.588	15	3.92E-02		

H.28 Two-way ANOVA: Group (7-8, 9-10, 11-12 year-old) x set (maintain, change) for distractibility errors (collapsed across start position and distractor location) in the no-reach task.

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	16.334	1	16.334	6.049	0.019
SET x GROUP						
	Huynh-Feldt	60.381	2	30.191	11.182	0.000
Error(SET)						
	Huynh-Feldt	99.902	37	2.7		

Tests of between-subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	251.811	1	251.811	58.965	0.00
group	91.932	2	45.966	10.764	0.00
Error	158.009	37	4.271		

Post-hoc tests for group

Pairwise Comparisons						
					95% Confidence Interval for Difference(a)	
(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.(a)	Lower Bound	Upper Bound
7-8yo	9-10yo	2.201(*)	.597	.002	.705	3.697
	11-12yo	2.427(*)	.558	.000	1.028	3.826
9-10yo	7-8yo	-2.201(*)	.597	.002	-3.697	-.705
	11-12yo	.226	.558	1.000	-1.174	1.625
11-12yo	7-8yo	-2.427(*)	.558	.000	-3.826	-1.028
	9-10yo	-.226	.558	1.000	-1.625	1.174

Based on estimated marginal means

* The mean difference is significant at the .05 level.

a Adjustment for multiple comparisons: Bonferroni.

Subanalyses for group x set interaction

H.29 One-way ANOVA: Set (maintain, change) for distractibility errors made in the no-reach task by 7-8 year-old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET	Huynh-Feldt	71.185	1	71.185	10.153	0.009
Error(SET)	Huynh-Feldt	77.12	11	7.011		

H.30 One-way ANOVA: Set (maintain, change) for distractibility errors made in the no-reach task by 9-10 year-old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	2.344	1	2.344	2.811	0.122
Error(SET)						
	Huynh-Feldt	9.17	11	0.834		

H.31 One-way ANOVA: Set (maintain, change) for distractibility errors made in the no-reach task by 11-12 year-old children.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	5.56E-02	1	5.56E-02	0.061	0.808
Error(SET)						
	Huynh-Feldt	13.611	15	0.907		

Analyses of proportional errors

H.32 Four-way ANOVA: Group (7-8, 9-10, 11-12 year-old) x set (maintain, change) x reach (reach, no-reach) x error type (inattentive, impulsive, distractibility) for error data converted to proportions of total errors made.

Tests of within-subjects effects

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	5.08E-03	1	5.08E-03	1.722	0.198
SET x GROUP						
	Huynh-Feldt	4.70E-03	2	2.35E-03	0.795	0.459
Error(SET)						
	Huynh-Feldt	0.109	37	2.95E-03		
REACH						
	Huynh-Feldt	4.16E-02	1	4.16E-02	10.579	0.002
REACH x GROUP						

	Huynh-Feldt	4.54E-03	2	2.27E-03	0.578	0.566
Error(REACH)						
	Huynh-Feldt	0.145	37	3.93E-03		
ERROR						
	Huynh-Feldt	32.087	1.985	16.164	251.05	0.000
ERROR x GROUP						
	Huynh-Feldt	1.565	3.97	0.394	6.121	0.000
Error(ERROR)						
	Huynh-Feldt	4.729	73.448	6.44E-02		
SET x REACH						
	Huynh-Feldt	5.08E-03	1	5.08E-03	1.722	0.198
SET x REACH x GROUP						
	Huynh-Feldt	4.70E-03	2	2.35E-03	0.795	0.459
Error(SETxREACH)						
	Huynh-Feldt	0.109	37	2.95E-03		
SET x ERROR						
	Huynh-Feldt	0.676	1.497	0.452	5.96	0.009
SET x ERROR x GROUP						
	Huynh-Feldt	0.415	2.994	0.139	1.832	0.152
Error(SETxERROR)						
	Huynh-Feldt	4.196	55.394	7.58E-02		
REACH x ERROR						
	Huynh-Feldt	0.398	1.517	0.263	3.756	0.041
REACH x ERROR x GROUP						
	Huynh-Feldt	8.55E-02	3.035	2.82E-02	0.403	0.754
Error(REACHxERROR)						
	Huynh-Feldt	3.924	56.144	6.99E-02		
SET x REACH x ERROR						
	Huynh-Feldt	0.139	1.621	8.56E-02	1.513	0.23
SET x REACH x ERROR x GROUP						
	Huynh-Feldt	6.78E-02	3.243	2.09E-02	0.37	0.79
Error(SETxREACHxERRO R)						
	Huynh-Feldt	3.393	59.995	5.66E-02		

Tests of between –subjects effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	49.455	1	49.455	12590.24	0
GROUP	4.54E-03	2	2.27E-03	0.578	0.566
Error	0.145	37	3.93E-03		

Post-hoc tests for error type

Pairwise Comparisons						
					95% Confidence Interval for Difference(a)	
(I) ERROR	(J) ERROR	Mean Difference (I-J)	Std. Error	Sig.(a)	Lower Bound	Upper Bound
1	2	.499(*)	.032	.000	.420	.579
	3	.595(*)	.030	.000	.520	.670
2	1	-.499(*)	.032	.000	-.579	-.420
	3	9.591E-02(*)	.023	.001	3.717E-02	.155
3	1	-.595(*)	.030	.000	-.670	-.520
	2	-9.591E-02(*)	.023	.001	-.155	-3.717E-02

Based on estimated marginal means

* The mean difference is significant at the .05 level.

a Adjustment for multiple comparisons: Bonferroni.

Key:

Error 1 = distractibility errors

Error 2 = inattentive errors

Error 3 = impulsive errors

Subanalyses of error type x group interaction

H.33 One-way ANOVA with factor group (7-8, 9-10, 11-12 year-olds) for the proportion of distractibility errors.

ANOVA

DI

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.241	2	.121	8.266	.001
Within Groups	.540	37	1.460E-02		
Total	.781	39			

Post-hoc tests for group

Multiple Comparisons

Dependent Variable: DI

	(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Bonferroni	7-8 yo	9-10yo	-.1680(*)	4.933E-02	.005	-.2917	-4.4281E-02
		11-12yo	-.1706(*)	4.614E-02	.002	-.2863	-5.4913E-02
	9-10yo	7-8 yo	.1680(*)	4.933E-02	.005	4.428E-02	.2917
		11-12yo	-2.6440E-03	4.614E-02	1.000	-.1183	.1131

11-12yo	7-8 yo	.1706(*)	4.614E-02	.002	5.491E-02	.2863
	9-10yo	2.644E-03	4.614E-02	1.000	-.1131	.1183

* The mean difference is significant at the .05 level.

H.34 One-way ANOVA with factor group (7-8, 9-10, 11-12 year-olds) for the proportion of inattentive errors.

ANOVA

IN

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.111	2	5.558E-02	5.410	.009
Within Groups	.380	37	1.027E-02		
Total	.491	39			

Post-hoc tests for group

Multiple Comparisons

Dependent Variable: IN

	(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Bonferroni	7-8 yo	9-10yo	.1165(*)	4.138E-02	.023	1.276E-02	.2203
		11-12yo	.1139(*)	3.871E-02	.017	1.681E-02	.2109

9-10yo	7-8 yo	-.1165(*)	4.138E-02	.023	-.2203	-1.2762E-02
	11-12yo	-2.6508E-03	3.871E-02	1.000	-9.9717E-02	9.442E-02
11-12yo	7-8 yo	-.1139(*)	3.871E-02	.017	-.2109	-1.6813E-02
	9-10yo	2.651E-03	3.871E-02	1.000	-9.4415E-02	9.972E-02

* The mean difference is significant at the .05 level.

H.35 One-way ANOVA with factor group (7-8, 9-10, 11-12 year-olds) for the proportion of impulsive errors.

ANOVA

IM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.978E-02	2	1.989E-02	2.467	.099
Within Groups	.298	37	8.063E-03		
Total	.338	39			

Subanalyses for error type x set interaction

H.36 One-way ANOVA: Set (maintain, change) for proportion of distractibility errors made.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	5.82E-02	1	5.82E-02	1.796	0.188
Error(SET)						
	Huynh-Feldt	1.263	39	3.24E-02		

H.37 One-way ANOVA: Set (maintain, change) for proportion of inattentive errors made.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	0.205	1	0.205	10.248	0.003
Error(SET)						
	Huynh-Feldt	0.78	39	2.00E-02		

H.38 One-way ANOVA: Set (maintain, change) for proportion of impulsive errors made.

Source		Sum of Squares	df	Mean Square	F	Sig.
SET						
	Huynh-Feldt	9.45E-02	1	9.45E-02	11.517	0.002
Error(SET)						
	Huynh-Feldt	0.32	39	8.20E-03		

H.39 Correlations between experimental variables (rt, mt, inattentive errors, distractibility errors, and premature responses) and demographic variables

		AGE	FSIQ	RSHPERC	RSSPERC	RSHIMP	RSSIMP	REACHRT	REACHMT	NORCHRT	INATT	DIST	IMP	rating scale hh	rating scale hi	rating scale sh	rating scale si
AGE	Pearson Correlation	1.000	-.062	.142	.270	-.321	-.237	-.675(**)	-.330(*)	-.618(**)	-.634(**)	-.630(**)	-.609(**)	.247	.037	.204	.060
	Sig. (2-tailed)	.	.704	.431	.142	.069	.199	.000	.038	.000	.000	.000	.000	.166	.838	.271	.747
	N	40	40	33	31	33	31	40	40	40	40	40	40	33	33	31	31
FSIQ	Pearson Correlation	-.062	1.000	.187	.043	-.067	-.068	-.297	-.207	-.289	-.299	-.309	-.169	.092	.293	.053	.181
	Sig. (2-tailed)	.704	.	.296	.818	.709	.716	.063	.201	.070	.061	.053	.297	.609	.098	.777	.331
	N	40	40	33	31	33	31	40	40	40	40	40	40	33	33	31	31
RSHPERC	Pearson Correlation	.142	.187	1.000	.458(*)	-.735(**)	-.457(*)	-.153	.045	-.241	-.233	-.119	-.195	.865(**)	.828(**)	.376	.343
	Sig. (2-tailed)	.431	.296	.	.016	.000	.016	.396	.805	.177	.192	.510	.276	.000	.000	.053	.080
	N	33	33	33	27	33	27	33	33	33	33	33	33	33	33	27	27

RSSPERC	Pearson Correlation	.270	.043	.458(*)	1.000	-.402(*)	-.821(**)	-.336	-.008	-.289	-.293	-.277	-.431(*)	.437(*)	.382(*)	.853(**)	.895(**)
	Sig. (2-tailed)	.142	.818	.016	.	.038	.000	.064	.967	.114	.109	.132	.016	.023	.049	.000	.000
	N	31	31	27	31	27	31	31	31	31	31	31	31	27	27	31	31
RSHIMP	Pearson Correlation	-.321	-.067	-.735(**)	-.402(*)	1.000	.609(**)	.158	-.243	.166	.201	.129	.217	-.847(**)	-.513(**)	-.452(*)	-.250
	Sig. (2-tailed)	.069	.709	.000	.038	.	.001	.381	.173	.356	.263	.474	.225	.000	.002	.018	.209
	N	33	33	33	27	33	27	33	33	33	33	33	33	33	33	27	27
RSSIMP	Pearson Correlation	-.237	-.068	-.457(*)	-.821(**)	.609(**)	1.000	.268	.049	.235	.291	.218	.380(*)	-.513(**)	-.367	-.944(**)	-.734(**)
	Sig. (2-tailed)	.199	.716	.016	.000	.001	.	.145	.794	.204	.112	.238	.035	.006	.059	.000	.000
	N	31	31	27	31	27	31	31	31	31	31	31	31	27	27	31	31
REACHRT	Pearson Correlation	-.675(**)	-.297	-.153	-.336	.158	.268	1.000	.531(**)	.813(**)	.800(**)	.720(**)	.680(**)	-.197	-.038	-.277	-.113
	Sig. (2-tailed)	.000	.063	.396	.064	.381	.145	.	.000	.000	.000	.000	.000	.271	.834	.132	.543
	N	40	40	33	31	33	31	40	40	40	40	40	40	33	33	31	31

REACHMT	Pearson Correlation	-.330(*)	-.207	.045	-.008	-.243	.049	.531(**)	1.000	.492(**)	.508(**)	.468(**)	.404(**)	.118	.018	-.178	.075
	Sig. (2-tailed)	.038	.201	.805	.967	.173	.794	.000	.	.001	.001	.002	.010	.512	.919	.338	.689
	N	40	40	33	31	33	31	40	40	40	40	40	40	33	33	31	31
NORCHRT	Pearson Correlation	-.618(**)	-.289	-.241	-.289	.166	.235	.813(**)	.492(**)	1.000	.717(**)	.710(**)	.538(**)	-.279	-.039	-.269	-.108
	Sig. (2-tailed)	.000	.070	.177	.114	.356	.204	.000	.001	.	.000	.000	.000	.116	.828	.144	.562
	N	40	40	33	31	33	31	40	40	40	40	40	40	33	33	31	31
INATT	Pearson Correlation	-.634(**)	-.299	-.233	-.293	.201	.291	.800(**)	.508(**)	.717(**)	1.000	.921(**)	.741(**)	-.235	-.119	-.307	-.050
	Sig. (2-tailed)	.000	.061	.192	.109	.263	.112	.000	.001	.000	.	.000	.000	.187	.509	.093	.791
	N	40	40	33	31	33	31	40	40	40	40	40	40	33	33	31	31
DIST	Pearson Correlation	-.630(**)	-.309	-.119	-.277	.129	.218	.720(**)	.468(**)	.710(**)	.921(**)	1.000	.619(**)	-.132	-.021	-.259	-.070
	Sig. (2-tailed)	.000	.053	.510	.132	.474	.238	.000	.002	.000	.000	.	.000	.465	.909	.159	.710
	N	40	40	33	31	33	31	40	40	40	40	40	40	33	33	31	31

IMP	Pearson Correlation	-.609(**)	-.169	-.195	-.431(*)	.217	.380(*)	.680(**)	.404(**)	.538(**)	.741(**)	.619(**)	1.000	-.234	-.047	-.463(**)	-.261
	Sig. (2-tailed)	.000	.297	.276	.016	.225	.035	.000	.010	.000	.000	.000	.	.190	.794	.009	.157
	N	40	40	33	31	33	31	40	40	40	40	40	40	33	33	31	31
rating scale hh	Pearson Correlation	.247	.092	.865(**)	.437(*)	-.847(**)	-.513(**)	-.197	.118	-.279	-.235	-.132	-.234	1.000	.501(**)	.427(*)	.259
	Sig. (2-tailed)	.166	.609	.000	.023	.000	.006	.271	.512	.116	.187	.465	.190	.	.003	.026	.192
	N	33	33	33	27	33	27	33	33	33	33	33	33	33	33	27	27
rating scale hi	Pearson Correlation	.037	.293	.828(**)	.382(*)	-.513(**)	-.367	-.036	.018	-.039	-.119	-.021	-.047	.501(**)	1.000	.257	.408(*)
	Sig. (2-tailed)	.838	.098	.000	.049	.002	.059	.834	.919	.828	.509	.909	.794	.003	.	.195	.034
	N	33	33	33	27	33	27	33	33	33	33	33	33	33	33	27	27
rating scale sh	Pearson Correlation	.204	.053	.376	.853(**)	-.452(*)	-.944(**)	-.277	-.178	-.269	-.307	-.259	-.463(**)	.427(*)	.257	1.000	.760(**)
	Sig. (2-tailed)	.271	.777	.053	.000	.018	.000	.132	.338	.144	.093	.159	.009	.026	.195	.	.000
	N	31	31	27	31	27	31	31	31	31	31	31	31	27	27	31	31

rating scale si	Pearson Correlation	.060	.181	.343	.895(**)	-.250	-.734(**)	-.113	.075	-.108	-.050	-.070	-.261	.259	.408(*)	.760(**)	1.000
	Sig. (2-tailed)	.747	.331	.080	.000	.209	.000	.543	.689	.562	.791	.710	.157	.192	.034	.000	.
	N	31	31	27	31	27	31	31	31	31	31	31	31	27	27	31	31

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Key to Correlations Tables:

Reach rt	reach reaction time
Reach mt	reach movement time
No reach rt	no-reach reaction time
FSIQ	full scale IQ
RSHPERC	rating scale home percentile rank
RSSPERC	rating scale school percentile rank
RSHIMP	rating scale home impulsiveness
RSSIMP	rating scale school impulsiveness
Rating scale hh	rating scale home hyperactivity-impulsivity scale
Rating scale hi	rating scale home inattentiveness scale
Rating scale sh	rating scale school hyperactivity-impulsivity scale
Rating scale si	rating scale school inattentiveness scale
INATT	inattentive type errors
DIST	distractibility errors
PREM	premature responses/ impulsive errors

APPENDIX I: ANALYSES FOR EXPERIMENT 4

I.1 Paired t-tests for reaction time performance (both in the reach and no-reach tasks) on and off medication, and movement time performance on and off medication.

Descriptives

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	OFRRT	614.3333	144	187.1486	15.5957
	ONRRT	502.1250	144	157.1424	13.0952
Pair 2	ONRMT	292.9514	144	123.3098	10.2758
	OFRMT	306.9306	144	153.3618	12.7801
Pair 3	ONNRT	478.6597	144	166.6055	13.8838
	OFNRT	740.4931	144	294.3714	24.5310

T-test

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	OFRRT - ONRRT	112.2083	237.2479	19.7707	5.675	143	.000
Pair 2	ONRMT - OFRMT	-13.9792	206.4483	17.2040	-.813	143	.418
Pair 3	ONNRT - OFNRT	-261.8333	355.1354	29.5946	-8.847	143	.000

APPENDIX J: ANALYSES FOR STUDIES 6-9

Analyses for Study 6

J.1 Paired t-tests between parent and teacher ratings of inattentiveness, hyperactivity-impulsivity and overall percentile rank on the ADDES, for the ADHD children.

Descriptives

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Rating scale home percentile	4.2800	25	6.5417	1.3083
	Rating scale school percentile	29.6800	25	22.9251	4.5850
Pair 2	rating scale home hyper	2.9200	25	2.3791	.4758
	rating scale school hyper	7.5200	25	3.5014	.7003
Pair 3	rating scale home inattentive	2.2000	25	1.8028	.3606
	rating scale school inattentive	7.4400	25	2.9023	.5805

Paired t-tests

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	Rating scale home percentile - Rating scale school percentile	-25.40	24.0399	4.808	-5.283	24	.000

Pair 2	rating scale home hyper - rating scale school hyper	-4.60	4.1433	.8287	-5.551	24	.000
Pair 3	rating scale home inattentive - rating scale school inattentive	-5.24	3.3327	.6665	-7.862	24	.000

J.2 Paired t-tests between parent and teacher ratings of inattentiveness, hyperactivity-impulsivity and overall percentile rank on the ADDES, for the normal children.

Descriptives

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Rating scale home percentile	63.0800	50	23.3997	3.3092
	Rating scale school percentile	78.2000	50	21.1390	2.9895
Pair 2	rating scale home hyper	11.1000	50	1.9509	.2759
	rating scale school hyper	11.8800	50	1.6860	.2384
Pair 3	rating scale home inattentive	10.9600	50	1.9791	.2799
	rating scale school inattentive	12.0600	50	1.7072	.2414

Paired t-tests

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	Rating scale home	-15.12	26.0695	3.6868	-4.101	49	.000

	percentile – Rating scale school percentile						
Pair 2	rating scale home hyper - rating scale school hyper	-.78	2.0533	.2904	-2.686	49	.010
Pair 3	rating scale home inattentive - rating scale school inattentive	-1.10	2.1309	.3014	-3.650	49	.001

J.3 Pearson's r correlations for parent and teacher ratings of inattentiveness, hyperactivity-impulsivity and overall percentile rank on the ADDES, for the ADHD children.

		Rating Scale home percentile	Rating scale school percentile	rating scale home hyper	rating scale home inatt	rating scale school hyper	rating scale school inatt
Rating scale home percentile	Pearson Correlation	1.000	-.003	.832(**)	.830(**)	.085	.063
	Sig. (2-tailed)	.	.991	.000	.000	.701	.775
	N	24	23	24	24	23	23
Rating scale school percentile	Pearson Correlation	-.003	1.000	-.050	-.019	.895(**)	.781(**)
	Sig. (2-tailed)	.991	.	.820	.932	.000	.000
	N	23	24	23	23	24	24
rating scale home hyper	Pearson Correlation	.832(**)	-.050	1.000	.647(**)	.084	-.078

	Sig. (2-tailed)	.000	.820	.	.001	.704	.723
	N	24	23	24	24	23	23
rating scale home inattentive	Pearson Correlation	.830(**)	-.019	.647(**)	1.000	.029	.062
	Sig. (2-tailed)	.000	.932	.001	.	.896	.779
	N	24	23	24	24	23	23
rating scale school hyper	Pearson Correlation	.085	.895(**)	.084	.029	1.000	.689(**)
	Sig. (2-tailed)	.701	.000	.704	.896	.	.000
	N	23	24	23	23	24	24
rating scale school inatt	Pearson Correlation	.063	.781(**)	-.078	.062	.689(**)	1.000
	Sig. (2-tailed)	.775	.000	.723	.779	.000	.
	N	23	24	23	23	24	24

J.4 Pearson's r correlations for parent and teacher ratings of inattentiveness, hyperactivity-impulsivity and overall percentile rank on the ADDES, for the normal children.

		Rating scale home percentile	Rating scale school percentile	rating scale home hyper	rating scale home inatt	rating scale school hyper	rating scale school inatt
Rating scale home percentile	Pearson Correlation	1.000	.318(*)	.868(**)	.844(**)	.296(*)	.275
	Sig. (2-tailed)	.	.024	.000	.000	.037	.053
	N	57	50	57	57	50	50

Rating scale school percentile	Pearson Correlation	.318(*)	1.000	.331(*)	.311(*)	.814(**)	.898(**)
	Sig. (2-tailed)	.024	.	.019	.028	.000	.000
	N	50	54	50	50	54	54
rating scale home hyper	Pearson Correlation	.868(**)	.331(*)	1.000	.624(**)	.370(**)	.206
	Sig. (2-tailed)	.000	.019	.	.000	.008	.150
	N	57	50	57	57	50	50
rating scale home inattentive	Pearson Correlation	.844(**)	.311(*)	.624(**)	1.000	.231	.339(*)
	Sig. (2-tailed)	.000	.028	.000	.	.107	.016
	N	57	50	57	57	50	50
rating scale school hyper	Pearson Correlation	.296(*)	.814(**)	.370(**)	.231	1.000	.705(**)
	Sig. (2-tailed)	.037	.000	.008	.107	.	.000
	N	50	54	50	50	54	54
rating scale school inatt	Pearson Correlation	.275	.898(**)	.206	.339(*)	.705(**)	1.000
	Sig. (2-tailed)	.053	.000	.150	.016	.000	.
	N	50	54	50	50	54	54

Analyses for study 7

J.5 Independent t-tests conducted for self-report measures between ADHD and matched control children.

Descriptives

Group Statistics

	GROUP	N	Mean	Std. Deviation	Std. Error Mean
HAPPY	clinical	25	6.8400	2.9429	.5886
	control	25	7.6800	1.6130	.3226
ANGRY	clinical	25	5.7800	3.7447	.7489
	control	25	6.1400	2.8922	.5784
WORRY	clinical	25	4.8000	3.9078	.7816
	control	25	5.9000	1.7678	.3536
FEAR	clinical	25	6.9200	3.4177	.6835
	control	25	6.8000	2.5000	.5000
SELFPER	clinical	25	6.0800	3.0369	.6074
	control	25	7.7200	1.9044	.3809
OTHERPER	clinical	25	5.5000	3.2787	.6557
	control	25	8.3000	1.4790	.2958
READING	clinical	25	4.7800	4.5164	.9033
	control	25	7.6600	3.1581	.6316
DRAWING	clinical	25	9.1400	2.6869	.5374
	control	25	7.8200	2.4744	.4949
MATHS	clinical	25	4.2800	4.3948	.8790
	control	25	7.2200	3.2018	.6404
WRITING	clinical	25	4.5600	3.6552	.7310
	control	25	6.6800	2.1741	.4348
TIDY	clinical	25	3.5600	4.0551	.8110

	control	25	5.9800	3.1440	.6288
FRIENDS	clinical	25	7.6800	3.3969	.6794
	control	25	9.3400	1.2309	.2462
LOSETHIN	clinical	25	5.0600	4.0371	.8074
	control	25	4.9400	2.8296	.5659
BULLIED	clinical	25	5.3600	4.2020	.8404
	control	25	7.0400	3.1554	.6311
TROUBHOM	clinical	25	3.1600	3.6364	.7273
	control	25	5.1800	2.4447	.4889
TROUBSCH	clinical	25	5.4000	3.5824	.7165
	control	25	7.2600	2.9337	.5867
NOTHINK	clinical	25	4.1400	3.9331	.7866
	control	25	5.0600	3.0968	.6194
CONCENT	clinical	25	3.7800	4.0622	.8124
	control	25	6.4400	2.7813	.5563
TALK	clinical	25	6.6800	4.3178	.8636
	control	25	6.9400	2.7322	.5464
SITSTILL	clinical	25	4.4000	4.4253	.8851
	control	25	7.2200	3.3853	.6771
WORDSMIX	clinical	25	6.1400	3.6444	.7289
	control	25	6.1000	2.9651	.5930
DIRECT	clinical	25	6.5800	4.0612	.8122
	control	25	8.6800	1.6948	.3390

T-tests

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
HAPPY	Equal variances assumed	-1.252	48	.217	-.8400	.6712	-2.1895	.5095
	Equal variances not assumed	-1.252	37.226	.219	-.8400	.6712	-2.1997	.5197
ANGRY	Equal variances assumed	-.380	48	.705	-.3600	.9463	-2.2627	1.5427
	Equal variances not assumed	-.380	45.119	.705	-.3600	.9463	-2.2658	1.5458
WORRY	Equal variances assumed	-1.282	48	.206	-1.1000	.8578	-2.8247	.6247
	Equal variances not assumed	-1.282	33.428	.209	-1.1000	.8578	-2.8444	.6444
FEAR	Equal variances assumed	.142	48	.888	.1200	.8469	-1.5828	1.8228
	Equal variances not assumed	.142	43.967	.888	.1200	.8469	-1.5868	1.8268

SELFPER	Equal variances assumed	-2.288	48	.027	-1.6400	.7169	-3.0815	-.1985
	Equal variances not assumed	-2.288	40.348	.027	-1.6400	.7169	-3.0885	-.1915
OTHERPER	Equal variances assumed	-3.892	48	.000	-2.8000	.7194	-4.2464	-1.3536
	Equal variances not assumed	-3.892	33.379	.000	-2.8000	.7194	-4.2629	-1.3371
READING	Equal variances assumed	-2.613	48	.012	-2.8800	1.1022	-5.0961	-.6639
	Equal variances not assumed	-2.613	42.941	.012	-2.8800	1.1022	-5.1029	-.6571
DRAWING	Equal variances assumed	1.807	48	.077	1.3200	.7305	-.1488	2.7888
	Equal variances not assumed	1.807	47.678	.077	1.3200	.7305	-.1491	2.7891
MATHS	Equal variances assumed	-2.703	48	.009	-2.9400	1.0875	-5.1265	-.7535
	Equal variances not assumed	-2.703	43.878	.010	-2.9400	1.0875	-5.1319	-.7481

WRITING	Equal variances assumed	-2.492	48	.016	-2.1200	.8506	-3.8302	-.4098
	Equal variances not assumed	-2.492	39.092	.017	-2.1200	.8506	-3.8403	-.3997
TIDY	Equal variances assumed	-2.358	48	.022	-2.4200	1.0262	-4.4834	-.3566
	Equal variances not assumed	-2.358	45.195	.023	-2.4200	1.0262	-4.4867	-.3533
FRIENDS	Equal variances assumed	-2.297	48	.026	-1.6600	.7226	-3.1129	-.2071
	Equal variances not assumed	-2.297	30.195	.029	-1.6600	.7226	-3.1354	-.1846
LOSETHIN	Equal variances assumed	.122	48	.904	.1200	.9860	-1.8625	2.1025
	Equal variances not assumed	.122	42.996	.904	.1200	.9860	-1.8635	2.1085
BULLIED	Equal variances assumed	-1.599	48	.116	-1.6800	1.0510	-3.7931	.4331
	Equal variances not assumed	-1.599	44.537	.117	-1.6800	1.0510	-3.7974	.4374

TROUBHOM	Equal variances assumed	-2.305	48	.026	-2.0200	.8764	-3.7820	-.2580
	Equal variances not assumed	-2.305	42.015	.026	-2.0200	.8764	-3.7885	-.2515
TROUBSCH	Equal variances assumed	-2.008	48	.050	-1.8600	.9261	-3.7220	1.982E-03
	Equal variances not assumed	-2.008	46.204	.050	-1.8600	.9261	-3.7239	3.854E-03
NOTHINK	Equal variances assumed	-.919	48	.363	-.9200	1.0012	-2.9330	1.0930
	Equal variances not assumed	-.919	45.496	.363	-.9200	1.0012	-2.9359	1.0959
CONCENT	Equal variances assumed	-2.702	48	.010	-2.6600	.9846	-4.6397	-.6803
	Equal variances not assumed	-2.702	42.448	.010	-2.6600	.9846	-4.6464	-.6736
TALK	Equal variances assumed	-.254	48	.800	-.2600	1.0219	-2.3147	1.7947
	Equal variances not assumed	-.254	40.564	.800	-.2600	1.0219	-2.3245	1.8045

SITSTILL	Equal variances assumed	-2.531	48	.015	-2.8200	1.1143	-5.0605	-.5795
	Equal variances not assumed	-2.531	44.924	.015	-2.8200	1.1143	-5.0645	-.5755
WORDSMIX	Equal variances assumed	.043	48	.966	4.000E-02	.9396	-1.8493	1.9293
	Equal variances not assumed	.043	46.093	.966	4.000E-02	.9396	-1.8513	1.9313
DIRECT	Equal variances assumed	-2.386	48	.021	-2.1000	.8801	-3.8696	-.3304
	Equal variances not assumed	-2.386	32.114	.023	-2.1000	.8801	-3.8925	-.3075

Study 8:

J.6 Pearson's r correlations between home and school rating scale (ADDES) scores and scores on 11 items of the self-report scale for ADHD children.

		Troub HOM	Troub SCH	AGE	FSIQ	RS Home PERC	RS School PERC	RS Home impulsive	RS School impulsive	Read	Maths	Write	Lose Things	NO THINK	CONC	SIT STILL	Direct	TALK	rating scale home hyper	rating scale home inatt	rating scale school hyper	rating scale school inatt
TROUB	Pearson Correlation	1	-0.034	-0.276	-0.253	-0.24	-0.127	0.223	0.038	0.026	-0.123	0.031	.398(*)	.402(*)	0.007	0.058	0.3	0.001	-0.255	-0.215	-0.07	0.092
HOM	Sig. (2-tailed)	.	0.872	0.183	0.223	0.259	0.556	0.294	0.86	0.901	0.559	0.885	0.049	0.046	0.975	0.783	0.146	0.997	0.229	0.312	0.744	0.668
	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24
TROUB	Pearson Correlation	-0.034	1	-0.029	-.435(*)	0.067	0.114	0.116	-0.341	0.201	0.194	-0.081	0.092	-0.046	0.016	0.176	0.286	0.062	-0.05	-0.034	0.152	0.192
SCH	Sig. (2-tailed)	0.872	.	0.889	0.03	0.754	0.596	0.589	0.102	0.334	0.353	0.699	0.662	0.829	0.938	0.4	0.166	0.767	0.818	0.875	0.478	0.369
	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24
AGE	Pearson Correlation	-0.276	-0.029	1	-0.062	-0.313	0.129	-0.216	-0.167	0.01	-0.171	-0.147	-0.015	-0.184	-0.179	-0.032	-0.386	-0.141	-0.185	-0.256	0.028	-0.224
	Sig. (2-tailed)	0.183	0.889	.	0.768	0.137	0.549	0.312	0.437	0.962	0.415	0.482	0.942	0.379	0.391	0.88	0.057	0.502	0.386	0.228	0.898	0.292
	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24
FSIQ	Pearson Correlation	-0.253	-.435(*)	-0.062	1	0.363	0.112	-0.177	0.194	-0.022	-0.074	0.208	-0.123	-0.072	-0.222	-0.182	0.123	0.083	0.348	.429(*)	0.093	0.151
	Sig. (2-tailed)	0.223	0.03	0.768	.	0.081	0.603	0.409	0.364	0.915	0.727	0.317	0.559	0.731	0.285	0.384	0.559	0.695	0.096	0.036	0.665	0.46
	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24
RS	Pearson Correlation	-0.24	0.067	-0.313	0.363	1	-0.003	-.450(*)	0.097	-0.357	-0.135	-0.302	-0.343	-0.271	-0.14	-0.228	0.113	-.414(*)	.832(**)	.830(**)	0.085	0.063

HOME	Sig. (2-tailed)	0.259	0.754	0.137	0.081	.	0.991	0.027	0.66	0.087	0.53	0.151	0.101	0.2	0.515	0.283	0.6	0.044	0	0	0.701	0.775
PERCRS	N	24	24	24	24	24	23	24	23	24	24	24	24	24	24	24	24	24	24	24	23	23
	Pearson Correlation	-0.127	0.114	0.129	0.112	-0.003	1	0.043	-.817(**)	0.398	0.208	-0.069	-0.003	0.079	-0.028	0.148	-0.092	0.34	-0.05	-0.019	.895(**)	.781(**)
SCH	Sig. (2-tailed)	0.556	0.596	0.549	0.603	0.991	.	0.844	0	0.054	0.33	0.75	0.99	0.713	0.896	0.49	0.67	0.104	0.82	0.932	0	0
PERCRS	N	24	24	24	24	23	24	23	24	24	24	24	24	24	24	24	24	24	23	23	24	24
	Pearson Correlation	0.223	0.116	-0.216	-0.177	-.450(*)	0.043	1	0.004	0.138	0.243	0.09	.562(**)	0.286	0.303	.410(*)	0.118	0.198	-.659(**)	-.441(*)	-0.103	0.099
HOME	Sig. (2-tailed)	0.294	0.589	0.312	0.409	0.027	0.844	.	0.987	0.521	0.252	0.675	0.004	0.176	0.15	0.046	0.584	0.355	0	0.031	0.641	0.655
impulsiveRS	N	24	24	24	24	24	23	24	23	24	24	24	24	24	24	24	24	24	24	24	23	23
	Pearson Correlation	0.038	-0.341	-0.167	0.194	0.097	-.817(**)	0.004	1	-0.309	-0.092	0.08	0.104	0.041	-0.056	-0.167	0.184	-0.262	0.064	0.192	-.873(**)	-.553(**)
School	Sig. (2-tailed)	0.86	0.102	0.437	0.364	0.66	0	0.987	.	0.141	0.671	0.71	0.628	0.849	0.796	0.436	0.389	0.216	0.771	0.38	0	0.005
impulsiveREAD	N	24	24	24	24	23	24	23	24	24	24	24	24	24	24	24	24	24	23	23	24	24
	Pearson Correlation	0.026	0.201	0.01	-0.022	-0.357	0.398	0.138	-0.309	1	.579(**)	0.156	0.165	0.184	0.052	0.108	0.351	0.354	-0.359	-0.136	0.319	.504(*)
	Sig. (2-tailed)	0.901	0.334	0.962	0.915	0.087	0.054	0.521	0.141	.	0.002	0.456	0.431	0.378	0.804	0.608	0.086	0.082	0.085	0.527	0.128	0.012
MATHS	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24
	Pearson Correlation	-0.123	0.194	-0.171	-0.074	-0.135	0.208	0.243	-0.092	.579(**)	1	0.214	0.092	0.19	0.365	0.034	0.354	0.279	-0.124	0.038	0.073	0.357
	Sig. (2-tailed)	0.559	0.353	0.415	0.727	0.53	0.33	0.252	0.671	0.002	.	0.304	0.661	0.362	0.073	0.873	0.082	0.176	0.565	0.86	0.735	0.087
WRITE	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24
	Pearson Correlation	0.031	-0.081	-0.147	0.208	-0.302	-0.069	0.09	0.08	0.156	0.214	1	-0.322	0.035	0.177	0.17	0.254	0.347	-0.242	-0.21	-0.108	-0.019
	Sig. (2-tailed)	0.885	0.699	0.482	0.317	0.151	0.75	0.675	0.71	0.456	0.304	.	0.116	0.868	0.397	0.417	0.22	0.089	0.255	0.324	0.615	0.929

	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24
LOSE	Pearson Correlation	.398(*)	0.092	-0.015	-0.123	-0.343	-0.003	.562(**)	0.104	0.165	0.092	-0.322	1	0.055	-0.127	-0.081	0.138	0.21	-0.341	-0.207	-0.099	0.097
THINGS	Sig. (2-tailed)	0.049	0.662	0.942	0.559	0.101	0.99	0.004	0.628	0.431	0.661	0.116	.	0.793	0.544	0.701	0.51	0.313	0.103	0.332	0.644	0.654
	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24
NO	Pearson Correlation	.402(*)	-0.046	-0.184	-0.072	-0.271	0.079	0.286	0.041	0.184	0.19	0.035	0.055	1	0.185	.472(*)	0.153	-0.102	-0.28	-0.216	-0.084	0.196
THINK	Sig. (2-tailed)	0.046	0.829	0.379	0.731	0.2	0.713	0.176	0.849	0.378	0.362	0.868	0.793	.	0.377	0.017	0.465	0.629	0.184	0.31	0.698	0.358
	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24
CONC	Pearson Correlation	0.007	0.016	-0.179	-0.222	-0.14	-0.028	0.303	-0.056	0.052	0.365	0.177	-0.127	0.185	1	0.272	0.319	-0.212	-0.197	-0.128	-0.069	0.047
	Sig. (2-tailed)	0.975	0.938	0.391	0.285	0.515	0.896	0.15	0.796	0.804	0.073	0.397	0.544	0.377	.	0.189	0.12	0.309	0.356	0.551	0.748	0.828
	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24
SIT	Pearson Correlation	0.058	0.176	-0.032	-0.182	-0.228	0.148	.410(*)	-0.167	0.108	0.034	0.17	-0.081	.472(*)	0.272	1	-0.127	-0.244	-0.322	-0.309	0.088	0.21
STILL	Sig. (2-tailed)	0.783	0.4	0.88	0.384	0.283	0.49	0.046	0.436	0.608	0.873	0.417	0.701	0.017	0.189	.	0.545	0.24	0.125	0.142	0.681	0.324
	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24
DIRECT	Pearson Correlation	0.3	0.286	-0.386	0.123	0.113	-0.092	0.118	0.184	0.351	0.354	0.254	0.138	0.153	0.319	-0.127	1	0.107	-0.026	0.175	-0.108	0.267
	Sig. (2-tailed)	0.146	0.166	0.057	0.559	0.6	0.67	0.584	0.389	0.086	0.082	0.22	0.51	0.465	0.12	0.545	.	0.61	0.905	0.413	0.616	0.207
	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24
TALK	Pearson Correlation	0.001	0.062	-0.141	0.083	-.414(*)	0.34	0.198	-0.262	0.354	0.279	0.347	0.21	-0.102	-0.212	-0.244	0.107	1	-0.294	-0.255	0.377	0.301
	Sig. (2-tailed)	0.997	0.767	0.502	0.695	0.044	0.104	0.355	0.216	0.082	0.176	0.089	0.313	0.629	0.309	0.24	0.61	.	0.163	0.229	0.069	0.153
	N	25	25	25	25	24	24	24	24	25	25	25	25	25	25	25	25	25	24	24	24	24

rating scale home hyper	Pearson Correlation	-0.255	-0.05	-0.185	0.348	.832(**)	-0.05	-.659(**)	0.064	-0.359	-0.124	-0.242	-0.341	-0.28	-0.197	-0.322	-0.026	-0.294	1	.647(**)	0.084	-0.078
	Sig. (2-tailed)	0.229	0.816	0.386	0.096	0	0.82	0	0.771	0.085	0.565	0.255	0.103	0.184	0.356	0.125	0.905	0.163	.	0.001	0.704	0.723
	N	24	24	24	24	24	23	24	23	24	24	24	24	24	24	24	24	24	24	24	23	23
rating scale home inatt	Pearson Correlation	-0.215	-0.034	-0.256	.429(*)	.830(**)	-0.019	-.441(*)	0.192	-0.136	0.038	-0.21	-0.207	-0.216	-0.128	-0.309	0.175	-0.255	.647(**)	1	0.029	0.062
	Sig. (2-tailed)	0.312	0.875	0.228	0.036	0	0.932	0.031	0.38	0.527	0.86	0.324	0.332	0.31	0.551	0.142	0.413	0.229	0.001	.	0.896	0.779
	N	24	24	24	24	24	23	24	23	24	24	24	24	24	24	24	24	24	24	24	23	23
rating scale school hyper	Pearson Correlation	-0.07	0.152	0.028	0.093	0.085	.895(**)	-0.103	-.873(**)	0.319	0.073	-0.108	-0.099	-0.084	-0.069	0.088	-0.108	0.377	0.084	0.029	1	.689(**)
	Sig. (2-tailed)	0.744	0.478	0.898	0.665	0.701	0	0.641	0	0.128	0.735	0.615	0.644	0.698	0.748	0.681	0.616	0.069	0.704	0.896	.	0
	N	24	24	24	24	23	24	23	24	24	24	24	24	24	24	24	24	24	23	23	24	24
rating scale school inatt	Pearson Correlation	0.092	0.192	-0.224	0.151	0.063	.781(**)	0.099	-.553(**)	.504(*)	0.357	-0.019	0.097	0.196	0.047	0.21	0.267	0.301	-0.078	0.062	.689(**)	1
	Sig. (2-tailed)	0.668	0.369	0.292	0.48	0.775	0	0.655	0.005	0.012	0.087	0.929	0.654	0.358	0.828	0.324	0.207	0.153	0.723	0.779	0	.
	N	24	24	24	24	23	24	23	24	24	24	24	24	24	24	24	24	24	23	23	24	24

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Study 8

J.7 Pearson's r correlations between home and school rating scale (ADDES) scores and scores on 11 items of the self-report scale for normal children.

		RSHPERC	RSSPERC	RSHIMP	RSSIMP	Read	Maths	Write	Lose	No Think	Concen	Sit Still	Direct	Talk	Troub HOM	Troub SCH	rating scale home hyper	rating scale home inattentive	rating scale school hyper	rating scale school inatt	FSIQ	AGE
RSHPERC	Pearson Correlation	1	.318(*)	-.681(**)	-.296(*)	-0.097	-0.118	0.183	0.021	0.024	0.066	.316(*)	0.208	-0.011	0.203	0.044	.868(**)	.844(**)	.296(*)	0.275	0.083	0.052
	Sig.	.	0.024	0	0.037	0.472	0.38	0.172	0.875	0.86	0.626	0.017	0.12	0.937	0.129	0.747	0	0	0.037	0.053	0.541	0.702
	N	57	50	57	50	57	57	57	57	57	57	57	57	57	57	57	57	57	50	50	57	57
RSSPERC	Pearson Correlation	.318(*)	1	-0.278	-.799(**)	0.004	-0.043	0.173	0.049	0.037	.297(*)	0.254	0.077	0.045	-0.065	0.095	.331(*)	.311(*)	.814(**)	.898(**)	0.09	0.067
	Sig.	0.024	.	0.05	0	0.979	0.757	0.21	0.726	0.793	0.029	0.064	0.579	0.749	0.641	0.494	0.019	0.028	0	0	0.52	0.63
	N	50	54	50	54	54	54	54	54	54	54	54	54	54	54	54	50	50	54	54	54	54
RSHIMP	Pearson Correlation	-.681(**)	-0.278	1	.471(**)	-0.097	0.095	-0.207	-0.053	-0.043	0.069	-0.179	-0.257	0.129	-0.166	-0.072	-.802(**)	-.506(**)	-.343(*)	-0.174	-0.017	-0.242
	Sig.	0	0.05	.	0.001	0.475	0.484	0.122	0.696	0.75	0.608	0.183	0.053	0.339	0.218	0.596	0	0	0.015	0.226	0.898	0.07
	N	57	50	57	50	57	57	57	57	57	57	57	57	57	57	57	57	57	50	50	57	57
RSSIMP	Pearson Correlation	-.296(*)	-.799(**)	.471(**)	1	-0.006	0.105	-0.017	0.08	-0.129	-0.252	-0.251	-0.053	0.045	0.049	-0.169	-.374(**)	-0.24	-.888(**)	-.708(**)	-0.052	-0.18
	Sig.	0.037	0	0.001	.	0.968	0.452	0.904	0.567	0.351	0.066	0.067	0.702	0.746	0.723	0.223	0.008	0.094	0	0	0.711	0.193
	N	50	54	50	54	54	54	54	54	54	54	54	54	54	54	54	50	50	54	54	54	54
READING	Pearson Correlation	-0.097	0.004	-0.097	-0.006	1	0.045	.348(**)	0.238	0.033	0.111	0.169	0.167	0.084	0.175	-0.086	0.019	-0.074	0.081	0.025	0.111	-0.027
	Sig.	0.472	0.979	0.475	0.968	.	0.722	0.005	0.056	0.796	0.379	0.178	0.182	0.505	0.184	0.496	0.888	0.582	0.559	0.857	0.379	0.831
	N	57	54	57	54	65	65	65	65	65	65	65	65	65	65	65	57	57	54	54	65	65
MATHS	Pearson Correlation	-0.118	-0.043	0.095	0.105	0.045	1	.289(*)	-0.058	-0.054	0.111	-0.05	0.128	0.147	0.043	-0.022	-0.03	-0.143	-0.009	-0.093	-0.042	-0.194
	Sig.	0.38	0.757	0.484	0.452	0.722	.	0.02	0.648	0.667	0.379	0.69	0.308	0.242	0.736	0.865	0.826	0.288	0.949	0.502	0.74	0.121
	N	57	54	57	54	65	65	65	65	65	65	65	65	65	65	65	57	57	54	54	65	65
WRITING	Pearson Correlation	0.183	0.173	-0.207	-0.017	.348(**)	.289(*)	1	-0.052	-0.169	-0.044	0.151	.371(**)	0.087	0.069	-0.13	0.21	0.165	0.075	0.11	-0.108	-0.157
	Sig.	0.172	0.21	0.122	0.904	0.005	0.02	.	0.68	0.179	0.729	0.23	0.002	0.489	0.584	0.301	0.117	0.22	0.591	0.429	0.391	0.211
	N	57	54	57	54	65	65	65	65	35	65	65	65	65	65	65	57	57	54	54	65	65
LOSE	Pearson Correlation	0.021	0.049	-0.053	0.08	0.238	-0.058	-0.052	1	0.204	.377(**)	.273(*)	0.067	-0.007	.479(**)	0.154	0.083	0.058	-0.046	-0.059	0.048	0.148
	Sig.	0.875	0.726	0.696	0.567	0.056	0.648	0.68	.	0.103	0.002	0.028	0.598	0.958	0	0.221	0.538	0.668	0.743	0.673	0.703	0.241
	N	57	54	57	54	65	65	65	65	65	65	65	65	65	65	65	57	57	54	54	65	65
NOTHINK	Pearson Correlation	0.024	0.037	-0.043	-0.129	0.033	-0.054	-0.169	0.204	1	0.193	0.234	-0.02	.303(*)	0.197	.311(*)	0.033	0.089	-0.008	0.058	0.082	-0.04
	Sig.	0.86	0.793	0.75	0.351	0.796	0.667	0.179	0.103	.	0.123	0.06	0.871	0.014	0.115	0.012	0.81	0.509	0.952	0.677	0.517	0.749
	N	57	54	57	54	65	65	65	65	65	65	65	65	65	65	65	57	57	54	54	65	65
CONCENT	Pearson Correlation	0.066	.297(*)	0.069	-0.252	0.111	0.111	-0.044	.377(**)	0.193	1	0.239	0.101	.270(*)	0.237	.386(**)	0.039	0.182	0.249	0.213	0.233	0.02
	Sig.	0.626	0.029	0.608	0.066	0.379	0.379	0.729	0.002	0.123	.	0.055	0.423	0.029	0.057	0.001	0.772	0.176	0.069	0.123	0.062	0.876

	N	57	54	57	54	65	65	65	65	65	65	65	65	65	65	65	57	57	54	54	65	65
SITSTILL	Pearson Correlation	.316(**)	0.254	-0.179	-0.251	0.169	-0.05	0.151	.273(*)	0.234	0.239	1	0.141	0.079	.293(*)	0.122	0.259	.332(*)	.296(*)	0.255	-0.117	-0.081
	Sig.	0.017	0.064	0.183	0.067	0.178	0.69	0.23	0.028	0.06	0.055	.	0.264	0.531	0.018	0.334	0.052	0.012	0.03	0.063	0.353	0.523
	N	57	54	57	54	65	65	65	65	65	65	65	65	65	65	65	57	57	54	54	65	65
DIRECT	Pearson Correlation	0.208	0.077	-0.257	-0.053	0.167	0.128	.371(**)	0.067	-0.02	0.101	0.141	1	0.099	0.09	0.072	0.246	0.203	0.032	0.061	-0.007	0.004
	Sig.	0.12	0.579	0.053	0.702	0.182	0.308	0.002	0.598	0.871	0.423	0.264	.	0.431	0.473	0.569	0.065	0.13	0.819	0.659	0.959	0.976
	N	57	54	57	54	65	65	65	65	65	65	65	65	65	65	65	57	57	54	54	65	65
TALK	Pearson Correlation	-0.011	0.045	0.129	0.045	0.084	0.147	0.087	-0.007	.303(*)	.270(*)	0.079	0.099	1	-0.189	0.11	0.022	0.113	-0.026	0.134	0.197	-0.003
	Sig.	0.937	0.749	0.339	0.746	0.505	0.242	0.489	0.958	0.014	0.029	0.531	0.431	.	0.131	0.383	0.871	0.404	0.851	0.333	0.116	0.978
	N	57	54	57	54	65	65	65	65	65	65	65	65	65	65	65	57	57	54	54	65	65
TROUBHOM	Pearson Correlation	0.203	-0.065	-0.166	0.049	0.175	0.043	0.069	.479(**)	0.197	0.237	.293(*)	0.09	-0.189	1	.415(**)	0.2	0.054	-0.114	-0.141	-0.084	0.042
	Sig.	0.129	0.641	0.218	0.723	0.164	0.736	0.584	0	0.115	0.057	0.018	0.473	0.131	.	0.001	0.135	0.692	0.411	0.31	0.506	0.738
	N	57	54	57	54	65	65	65	65	65	65	65	65	65	65	65	57	57	54	54	65	65
TROUBSCH	Pearson Correlation	0.044	0.095	-0.072	-0.169	-0.086	-0.022	-0.13	0.154	.311(*)	.386(**)	0.122	0.072	0.11	.415(**)	1	0.046	0.025	-0.012	0.026	-0.028	-0.004
	Sig.	0.747	0.494	0.596	0.223	0.496	0.865	0.301	0.221	0.012	0.001	0.334	0.569	0.383	0.001	.	0.735	0.853	0.931	0.853	0.825	0.975
	N	57	54	57	54	65	65	65	65	65	65	65	65	65	65	65	57	57	54	54	65	65
rating scale home hyper	Pearson Correlation	.868(**)	.331(*)	-.802(**)	-.374(**)	0.019	-0.03	0.21	0.083	0.033	0.039	0.259	0.246	0.022	0.2	0.046	1	.624(**)	.370(**)	0.206	0.006	0.043
	Sig.	0	0.019	0	0.008	0.888	0.826	0.117	0.538	0.81	0.772	0.052	0.065	0.871	0.135	0.735	.	0	0.008	0.15	0.967	0.751
	N	57	50	57	50	57	57	57	57	57	57	57	57	57	57	57	57	57	50	50	57	57
rating scale home inattentive	Pearson Correlation	.844(**)	.311(*)	-.506(**)	-0.24	-0.074	-0.143	0.165	0.058	0.089	0.182	.332(*)	0.203	0.113	0.054	0.025	.624(**)	1	0.231	.339(*)	0.193	-0.021
	Sig.	0	0.028	0	0.094	0.582	0.288	0.22	0.668	0.509	0.176	0.012	0.13	0.404	0.692	0.853	0	.	0.107	0.016	0.15	0.879
	N	57	50	57	50	57	57	57	57	57	57	57	57	57	57	57	57	57	50	50	57	57
rating scale school hyper	Pearson Correlation	.296(*)	.814(**)	-.343(*)	-.888(**)	0.081	-0.009	0.075	-0.046	-0.008	0.249	.296(*)	0.032	-0.026	-0.114	-0.012	.370(**)	0.231	1	.705(**)	0.01	0.097
	Sig.	0.037	0	0.015	0	0.559	0.949	0.591	0.743	0.952	0.069	0.03	0.819	0.851	0.411	0.931	0.008	0.107	.	0	0.942	0.487
	N	50	54	50	54	54	54	54	54	54	54	54	54	54	54	54	50	50	54	54	54	54
rating scale school inatt	Pearson Correlation	0.275	.898(**)	-0.174	-.708(**)	0.025	-0.093	0.11	-0.059	0.058	0.213	0.255	0.061	0.134	-0.141	0.026	0.206	.339(*)	.705(**)	1	0.203	0.004
	Sig.	0.053	0	0.226	0	0.857	0.502	0.429	0.673	0.677	0.123	0.063	0.659	0.333	0.31	0.853	0.15	0.016	0	.	0.142	0.977
	N	50	54	50	54	54	54	54	54	54	54	54	54	54	54	54	50	50	54	54	54	54
FSIQ	Pearson Correlation	0.083	0.09	-0.017	-0.052	0.111	-0.042	-0.108	0.048	0.082	0.233	-0.117	-0.007	0.197	-0.084	-0.028	0.006	0.193	0.01	0.203	1	0.003
	Sig.	0.541	0.52	0.898	0.711	0.379	0.74	0.391	0.703	0.517	0.062	0.353	0.959	0.116	0.506	0.825	0.967	0.15	0.942	0.142	.	0.98
	N	57	54	57	54	65	65	65	65	65	65	65	65	65	65	65	57	57	54	54	65	65
AGE	Pearson Correlation	0.052	0.067	-0.242	-0.18	-0.027	-0.194	-0.157	0.148	-0.04	0.02	-0.081	0.004	-0.003	0.042	-0.004	0.043	-0.021	0.097	0.004	0.003	1
	Sig.	0.702	0.63	0.07	0.193	0.831	0.121	0.211	0.241	0.749	0.876	0.523	0.976	0.978	0.738	0.975	0.751	0.879	0.487	0.977	0.98	.
	N	57	54	57	54	65	65	65	65	65	65	65	65	65	65	65	57	57	54	54	65	65

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Study 9

J.8 Pearson's r correlations for self-report and experimental variables for unmedicated ADHD children.

		Fsiq	Age	Inatt	Dist	Prem	Reading	Maths	Writing	Lose thin	Troub Hom	Troub Sch	No Think	Concent	Talk	Sit Still	Direct	no reach reaction time	reach movement time	reach reaction time
FSIQ	Pearson Correlation	1	0.016	-0.124	0.16	0.242	-0.022	0.312	0.079	-.769(**)	-.576(*)	-0.314	0.1	0.246	-0.085	-0.265	-0.093	-0.141	-0.038	-0.25
	Sig. (2-tailed)	.	0.954	0.661	0.57	0.384	0.942	0.299	0.797	0.002	0.04	0.297	0.746	0.417	0.782	0.382	0.763	0.615	0.893	0.368
	N	15	15	15	15	15	13	13	13	13	13	13	13	13	13	13	13	15	15	15
AGE	Pearson Correlation	0.016	1	-0.332	-0.402	-0.407	0.444	0.027	0.214	-0.032	0.011	-0.208	-0.09	0.525	0.288	0.044	0.148	-.644(**)	.538(*)	-.587(*)
	Sig. (2-tailed)	0.954	.	0.226	0.137	0.132	0.128	0.93	0.482	0.919	0.971	0.495	0.77	0.065	0.339	0.886	0.63	0.01	0.039	0.021
	N	15	15	15	15	15	13	13	13	13	13	13	13	13	13	13	13	15	15	15
INATT	Pearson Correlation	-0.124	-0.332	1	.685(**)	.753(**)	-0.018	-0.079	0.165	0.078	-0.002	0.305	0.067	-0.514	0.54	-0.026	-0.195	.525(*)	-.543(*)	.572(*)
	Sig. (2-tailed)	0.661	0.226	.	0.005	0.001	0.955	0.796	0.589	0.799	0.994	0.31	0.827	0.073	0.057	0.933	0.523	0.044	0.036	0.026
	N	15	15	15	15	15	13	13	13	13	13	13	13	13	13	13	13	15	15	15
DIST	Pearson Correlation	0.16	-0.402	.685(**)	1	.692(**)	0.025	0.118	.593(*)	-0.333	-0.021	-0.127	0.549	-0.255	0.272	0.233	-0.087	0.374	-0.304	0.203
	Sig. (2-tailed)	0.57	0.137	0.005	.	0.004	0.937	0.701	0.033	0.266	0.947	0.68	0.052	0.401	0.37	0.443	0.777	0.17	0.271	0.469
	N	15	15	15	15	15	13	13	13	13	13	13	13	13	13	13	13	15	15	15
PREM	Pearson Correlation	0.242	-0.407	.753(**)	.692(**)	1	0.168	0.299	0.3	-0.235	-0.215	-0.029	0.268	-0.312	0.28	0.062	-0.203	0.266	-0.452	0.279
	Sig. (2-tailed)	0.384	0.132	0.001	0.004	.	0.583	0.321	0.32	0.439	0.481	0.924	0.377	0.299	0.355	0.841	0.505	0.338	0.091	0.313
	N	15	15	15	15	15	13	13	13	13	13	13	13	13	13	13	13	15	15	15
READING	Pearson Correlation	-0.022	0.444	-0.018	0.025	0.168	1	.582(*)	0.314	0.147	-0.071	-0.129	0.149	-0.014	0.368	-0.123	.584(*)	-0.332	0.139	-0.548
	Sig. (2-tailed)	0.942	0.128	0.955	0.937	0.583	.	0.037	0.297	0.631	0.818	0.674	0.626	0.964	0.216	0.69	0.036	0.268	0.651	0.053
	N	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
MATHS	Pearson Correlation	0.312	0.027	-0.079	0.118	0.299	.582(*)	1	0.484	-0.197	-0.08	-0.165	0.033	0.183	0.261	-0.24	0.424	-0.446	-0.17	-0.499
	Sig. (2-tailed)	0.299	0.93	0.796	0.701	0.321	0.037	.	0.094	0.519	0.795	0.591	0.915	0.55	0.388	0.43	0.149	0.126	0.578	0.082
	N	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
WRITING	Pearson Correlation	0.079	0.214	0.165	.593(*)	0.3	0.314	0.484	1	-0.133	0.308	-0.24	0.436	0.064	0.509	0.1	0.14	-0.182	0.386	-0.333
	Sig. (2-tailed)	0.797	0.482	0.589	0.033	0.32	0.297	0.094	.	0.665	0.306	0.43	0.136	0.835	0.076	0.745	0.649	0.551	0.193	0.267

	N	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
LOSETHIN	Pearson Correlation	-.769(**)	-0.032	0.078	-0.333	-0.235	0.147	-0.197	-0.133	1	.647(*)	0.291	-0.157	-0.496	0.344	-0.111	0.08	0.412	0.218	0.351
	Sig. (2-tailed)	0.002	0.919	0.799	0.266	0.439	0.631	0.519	0.665	.	0.017	0.334	0.607	0.084	0.25	0.718	0.794	0.162	0.473	0.239
	N	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
TROUBHOM	Pearson Correlation	-.576(*)	0.011	-0.002	-0.021	-0.215	-0.071	-0.08	0.308	.647(*)	1	0.077	0.198	-0.223	0.161	-0.02	0.144	0.051	0.417	0.237
	Sig. (2-tailed)	0.04	0.971	0.994	0.947	0.481	0.818	0.795	0.306	0.017	.	0.802	0.516	0.464	0.599	0.948	0.64	0.869	0.157	0.435
	N	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
TROUBSCH	Pearson Correlation	-0.314	-0.208	0.305	-0.127	-0.029	-0.129	-0.165	-0.24	0.291	0.077	1	-.642(*)	-.563(*)	0.1	-0.408	0.41	0.487	-0.182	.768(**)
	Sig. (2-tailed)	0.297	0.495	0.31	0.68	0.924	0.674	0.591	0.43	0.334	0.802	.	0.018	0.045	0.744	0.166	0.164	0.091	0.552	0.002
	N	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
NOTHINK	Pearson Correlation	0.1	-0.09	0.067	0.549	0.268	0.149	0.033	0.436	-0.157	0.198	-.642(*)	1	-0.044	-0.06	0.314	-0.063	-0.103	0.343	-0.346
	Sig. (2-tailed)	0.746	0.77	0.827	0.052	0.377	0.626	0.915	0.136	0.607	0.516	0.018	.	0.887	0.846	0.296	0.839	0.738	0.252	0.247
	N	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
CONCENT	Pearson Correlation	0.246	0.525	-0.514	-0.255	-0.312	-0.014	0.183	0.064	-0.496	-0.223	-.563(*)	-0.044	1	-0.246	0.223	-0.198	-.809(**)	0.104	-.626(*)
	Sig. (2-tailed)	0.417	0.065	0.073	0.401	0.299	0.964	0.55	0.835	0.084	0.464	0.045	0.887	.	0.418	0.463	0.518	0.001	0.736	0.022
	N	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
TALK	Pearson Correlation	-0.085	0.288	0.54	0.272	0.28	0.368	0.261	0.509	0.344	0.161	0.1	-0.06	-0.246	1	-0.327	-0.014	0.205	-0.113	0.052
	Sig. (2-tailed)	0.782	0.339	0.057	0.37	0.355	0.216	0.388	0.076	0.25	0.599	0.744	0.846	0.418	.	0.275	0.963	0.501	0.714	0.867
	N	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
SITSTILL	Pearson Correlation	-0.265	0.044	-0.026	0.233	0.062	-0.123	-0.24	0.1	-0.111	-0.02	-0.408	0.314	0.223	-0.327	1	-0.424	0.019	0.44	-0.29
	Sig. (2-tailed)	0.382	0.886	0.933	0.443	0.841	0.69	0.43	0.745	0.718	0.948	0.166	0.296	0.463	0.275	.	0.149	0.95	0.133	0.337
	N	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
DIRECT	Pearson Correlation	-0.093	0.148	-0.195	-0.087	-0.203	.584(*)	0.424	0.14	0.08	0.144	0.41	-0.063	-0.198	-0.014	-0.424	1	-0.186	0.152	-0.09
	Sig. (2-tailed)	0.763	0.63	0.523	0.777	0.505	0.036	0.149	0.649	0.794	0.64	0.164	0.839	0.518	0.963	0.149	.	0.544	0.621	0.77
	N	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
no reach reaction time	Pearson Correlation	-0.141	-.644(**)	.525(*)	0.374	0.266	-0.332	-0.446	-0.182	0.412	0.051	0.487	-0.103	-.809(**)	0.205	0.019	-0.186	1	-0.258	.741(**)
	Sig. (2-tailed)	0.615	0.01	0.044	0.17	0.338	0.268	0.126	0.551	0.162	0.869	0.091	0.738	0.001	0.501	0.95	0.544	.	0.354	0.002
	N	15	15	15	15	15	13	13	13	13	13	13	13	13	13	13	13	15	15	15

reach movement time	Pearson Correlation	-0.038	.538(*)	-.543(*)	-0.304	-0.452	0.139	-0.17	0.386	0.218	0.417	-0.182	0.343	0.104	-0.113	0.44	0.152	-0.258	1	-0.414
	Sig. (2-tailed)	0.893	0.039	0.036	0.271	0.091	0.651	0.578	0.193	0.473	0.157	0.552	0.252	0.736	0.714	0.133	0.621	0.354	.	0.125
	N	15	15	15	15	15	13	13	13	13	13	13	13	13	13	13	13	15	15	15
reach reaction time	Pearson Correlation	-0.25	-.587(*)	.572(*)	0.203	0.279	-0.548	-0.499	-0.333	0.351	0.237	.768(**)	-0.346	-.626(*)	0.052	-0.29	-0.09	.741(**)	-0.414	1
	Sig. (2-tailed)	0.368	0.021	0.026	0.469	0.313	0.053	0.082	0.267	0.239	0.435	0.002	0.247	0.022	0.867	0.337	0.77	0.002	0.125	.
	N	15	15	15	15	15	13	13	13	13	13	13	13	13	13	13	13	15	15	15

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Study 9

J.8 Pearson's r correlations for self-report and experimental variables for normal children.

		Reading	Maths	Write	Lose	No think	Conc	Sit still	Direct	Talk	Troub hom	Troub sch	Age	Fsiq	Hand	REACHRT	REACHMT	NORCHRT	INATT	DIST	IMP
READING	Pearson Correlation	1	0.14	.475(**)	0.211	-0.006	0.276	0.268	0.259	-0.063	0.291	0.014	-0.068	0.074	0.007	-0.046	0.075	-0.011	0.124	0.082	0.086
	Sig. (2-tailed)	.	0.388	0.002	0.192	0.969	0.084	0.094	0.106	0.7	0.068	0.931	0.676	0.651	0.965	0.778	0.645	0.947	0.448	0.615	0.596
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
MATHS	Pearson Correlation	0.14	1	0.274	-0.089	-0.236	0.162	0.037	0.092	0.245	0.019	0.005	-0.253	-0.039	-0.226	0.131	0.166	0.115	0.169	0.243	0.101
	Sig. (2-tailed)	0.388	.	0.087	0.586	0.142	0.319	0.821	0.573	0.127	0.906	0.974	0.116	0.809	0.161	0.421	0.307	0.48	0.297	0.132	0.534
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
WRITING	Pearson Correlation	.475(**)	0.274	1	-0.048	-0.153	-0.001	.320(*)	.337(*)	0.104	0.118	-0.23	-0.038	-0.202	0.26	0.113	0.204	0.211	.365(*)	.314(*)	0.157
	Sig. (2-tailed)	0.002	0.087	.	0.77	0.347	0.993	0.044	0.033	0.523	0.469	0.154	0.814	0.211	0.105	0.489	0.206	0.191	0.021	0.049	0.334
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
LOSE	Pearson Correlation	0.211	-0.089	-0.048	1	0.116	.325(*)	0.223	0.03	-0.069	.508(**)	-0.044	0.309	-0.011	-0.256	-.367(*)	-0.179	-.451(**)	-.381(*)	-.344(*)	-0.251
	Sig. (2-tailed)	0.192	0.586	0.77	.	0.475	0.041	0.168	0.856	0.672	0.001	0.787	0.052	0.348	0.111	0.02	0.269	0.003	0.015	0.03	0.118
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
NOTHINK	Pearson Correlation	-0.006	-0.236	-0.153	0.116	1	-0.083	0.31	-0.075	0.207	0.17	0.299	-0.089	-0.012	0.023	0.156	-0.071	0.076	0.064	0.069	-0.16
	Sig. (2-tailed)	0.969	0.142	0.347	0.475	.	0.611	0.051	0.644	0.2	0.294	0.061	0.583	0.941	0.886	0.336	0.663	0.641	0.696	0.672	0.324
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
CONCENT	Pearson Correlation	0.276	0.162	-0.001	.325(*)	-0.083	1	0.268	0.185	0.223	0.161	0.213	0.015	0.287	-0.107	-0.275	-.383(*)	-.423(**)	-.377(*)	-.346(*)	-0.095
	Sig. (2-tailed)	0.084	0.319	0.993	0.041	0.611	.	0.094	0.254	0.166	0.321	0.187	0.927	0.072	0.512	0.086	0.015	0.007	0.017	0.029	0.561
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
SITSTILL	Pearson Correlation	0.268	0.037	.320(*)	0.223	0.31	0.268	1	0.223	0.136	.332(*)	0.137	-0.069	-0.118	0.037	0.117	0.146	-0.025	0.152	0.087	0.147
	Sig. (2-tailed)	0.094	0.821	0.044	0.168	0.051	0.094	.	0.166	0.401	0.036	0.4	0.674	0.469	0.821	0.471	0.368	0.879	0.349	0.594	0.365
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40

DIRECT	Pearson Correlation	0.259	0.092	.337(*)	0.03	-0.075	0.185	0.223	1	0.043	0.102	-0.03	0.129	0.025	0	0.114	0.094	-0.039	0.135	0.1	0.032
	Sig. (2-tailed)	0.106	0.573	0.033	0.856	0.644	0.254	0.166	.	0.79	0.532	0.852	0.428	0.878	1	0.482	0.564	0.812	0.406	0.539	0.844
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
TALK	Pearson Correlation	-0.063	0.245	0.104	-0.069	0.207	0.223	0.136	0.043	1	-0.122	0.121	-0.038	0.242	0.059	-0.059	-0.132	-0.028	-0.079	-0.11	-0.219
	Sig. (2-tailed)	0.7	0.127	0.523	0.672	0.2	0.166	0.401	0.79	.	0.452	0.456	0.817	0.132	0.716	0.718	0.416	0.864	0.629	0.498	0.174
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
TROUBHOM	Pearson Correlation	0.291	0.019	0.118	.508(**)	0.17	0.161	.332(*)	0.102	-0.122	1	.316(*)	0.109	-0.078	-0.096	-0.03	-0.021	-0.089	0.096	0.032	0.219
	Sig. (2-tailed)	0.068	0.906	0.469	0.001	0.294	0.321	0.036	0.532	0.452	.	0.047	0.504	0.63	0.554	0.854	0.895	0.585	0.556	0.844	0.174
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
TROUBSCH	Pearson Correlation	0.014	0.005	-0.23	-0.044	0.299	0.213	0.137	-0.03	0.121	.316(*)	1	-0.211	0.107	0.251	0.105	0.012	0.078	0.045	-0.022	0.071
	Sig. (2-tailed)	0.931	0.974	0.154	0.787	0.061	0.187	0.4	0.852	0.456	0.047	.	0.192	0.513	0.118	0.517	0.942	0.634	0.782	0.893	0.663
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
AGE	Pearson Correlation	-0.068	-0.253	-0.038	0.309	-0.089	0.015	-0.069	0.129	-0.038	0.109	-0.211	1	-0.062	-0.18	-.675(**)	-.330(*)	-.618(**)	-.634(**)	-.630(**)	-.609(**)
	Sig. (2-tailed)	0.676	0.116	0.814	0.052	0.583	0.927	0.674	0.428	0.817	0.504	0.192	.	0.704	0.266	0	0.038	0	0	0	0
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
FSIQ	Pearson Correlation	0.074	-0.039	-0.202	-0.011	-0.012	0.287	-0.118	0.025	0.242	-0.078	0.107	-0.062	1	0.121	-0.297	-0.207	-0.289	-0.299	-0.309	-0.169
	Sig. (2-tailed)	0.651	0.809	0.211	0.948	0.941	0.072	0.469	0.878	0.132	0.63	0.513	0.704	.	0.458	0.063	0.201	0.07	0.061	0.053	0.297
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
HAND	Pearson Correlation	0.007	-0.226	0.26	-0.256	0.023	-0.107	0.037	0	0.059	-0.096	0.251	-0.18	0.121	1	-0.067	-0.088	0.116	0.109	0.111	-0.032
	Sig. (2-tailed)	0.965	0.161	0.105	0.111	0.886	0.512	0.821	1	0.716	0.554	0.118	0.266	0.458	.	0.68	0.589	0.476	0.505	0.494	0.845
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
INATT	Pearson Correlation	0.124	0.169	.365(*)	-.381(*)	0.064	-.377(*)	0.152	0.135	-0.079	0.096	0.045	-.634(**)	-0.299	0.109	.800(**)	.508(**)	.717(**)	1	.921(**)	.741(**)
	Sig. (2-tailed)	0.448	0.297	0.021	0.015	0.696	0.017	0.349	0.406	0.629	0.556	0.782	0	0.061	0.505	0	0.001	0	.	0	0
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
DIST	Pearson Correlation	0.082	0.243	.314(*)	-.344(*)	0.069	-.346(*)	0.087	0.1	-0.11	0.032	-0.022	-.630(**)	-0.309	0.111	.720(**)	.468(**)	.710(**)	.921(**)	1	.619(**)
	Sig. (2-tailed)	0.615	0.132	0.049	0.03	0.672	0.029	0.594	0.539	0.498	0.844	0.893	0	0.053	0.494	0	0.002	0	0	.	0
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40

IMP	Pearson Correlation	0.086	0.101	0.157	-0.251	-0.16	-0.095	0.147	0.032	-0.219	0.219	0.071	-.609(**)	-0.169	-0.032	.680(**)	.404(**)	.538(**)	.741(**)	.619(**)	1
	Sig. (2-tailed)	0.596	0.534	0.334	0.118	0.324	0.561	0.365	0.844	0.174	0.174	0.663	0	0.297	0.845	0	0.01	0	0	0	.
	N	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

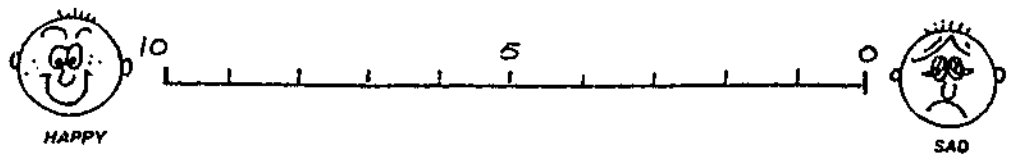
APPENDIX K: STUDENT SELF-EVALUATION SCALE

STUDENT SELF EVALUATION

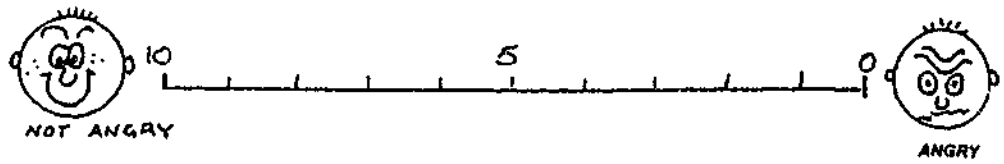
NAME: _____

These are some questions about the kind of person you are and your feelings. Read the question. Put a cross X on the line where you think your answer would go.

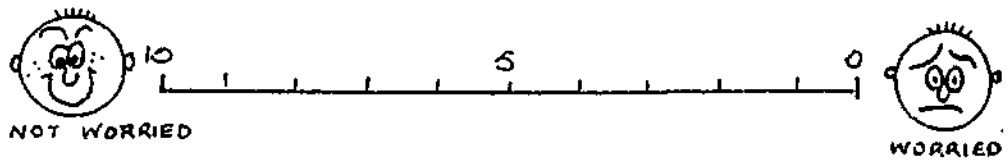
1. How happy are you?



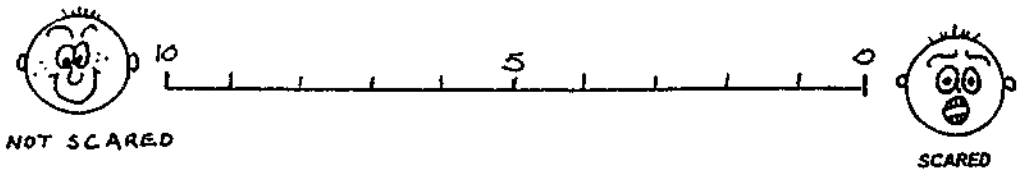
2. Are you an angry person?



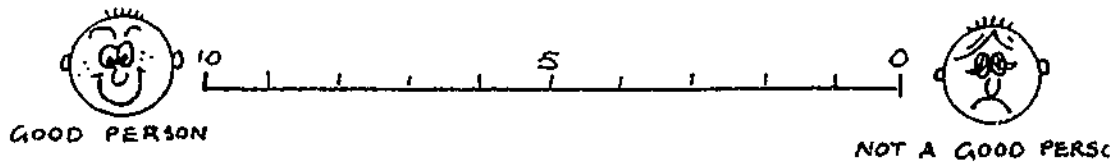
3. Do you get worried?



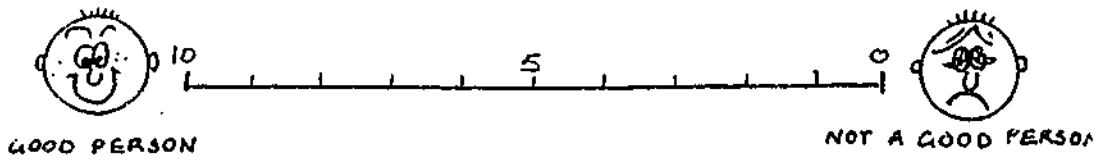
4. Do you feel scared?



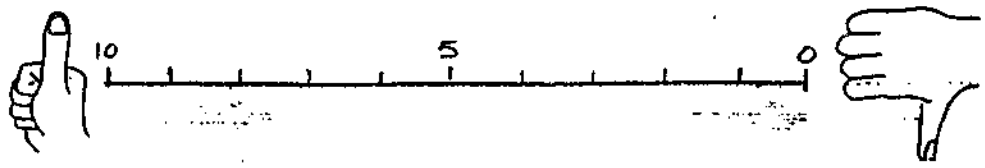
5. What sort of person are you?



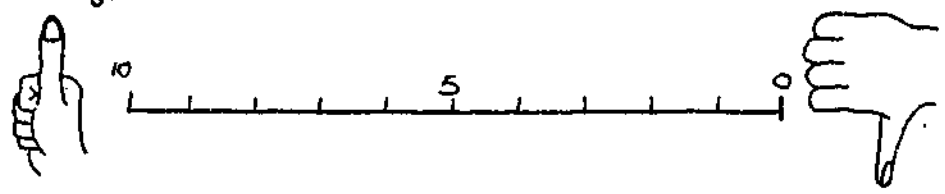
6. What sort of person do other people think you are?



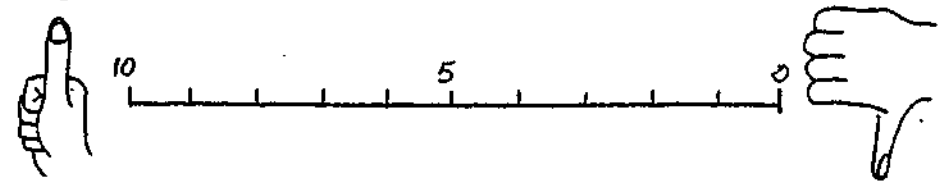
7. Do you like reading?



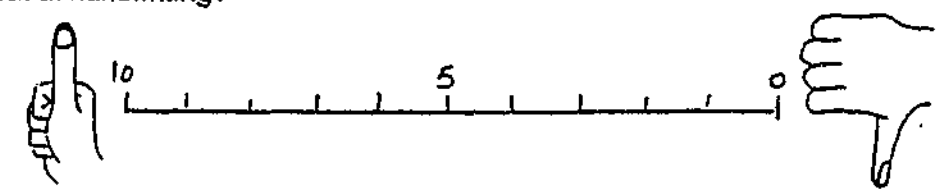
8. Do you like drawing?



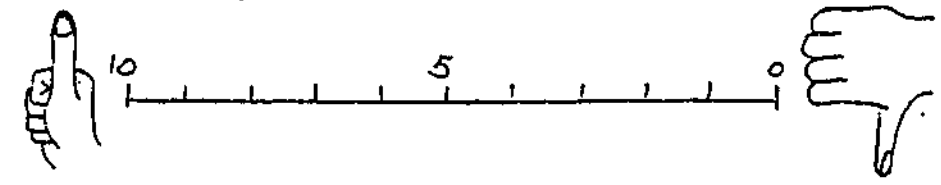
9. Do you like doing maths?



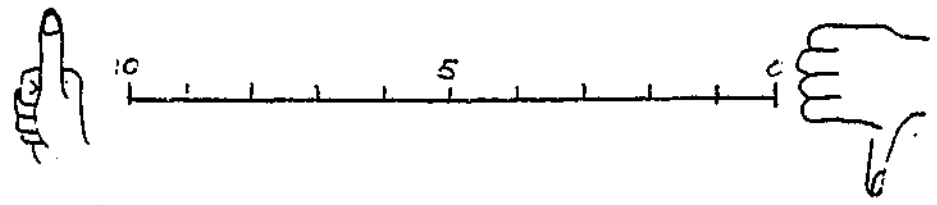
10. Are you neat at handwriting?



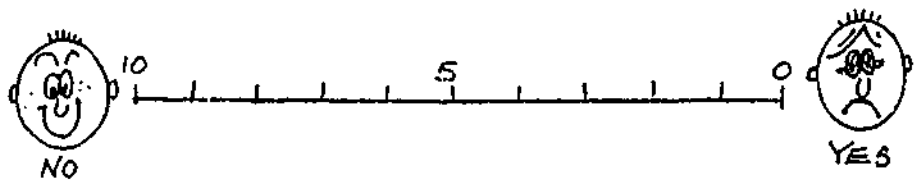
11. Do you keep your bedroom tidy?



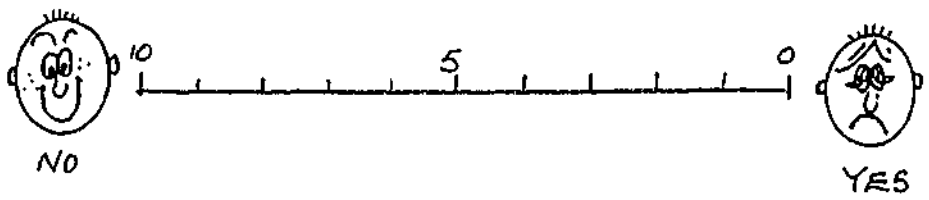
12. Do you have friends?



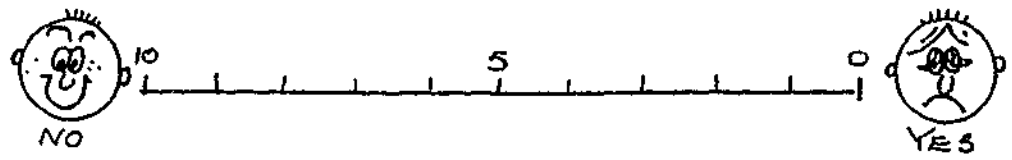
13. Do you lose things?



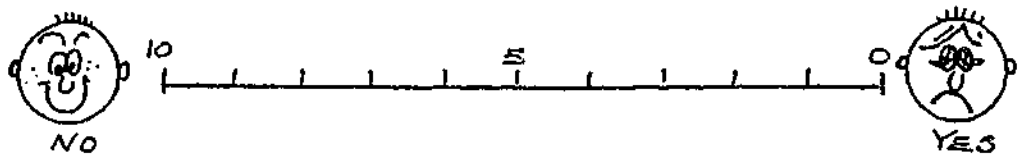
14. Are you bullied by others?



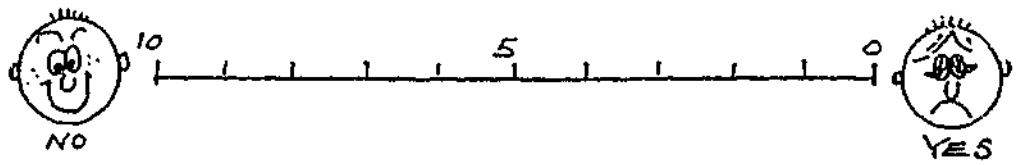
15. Do you get into trouble at home?



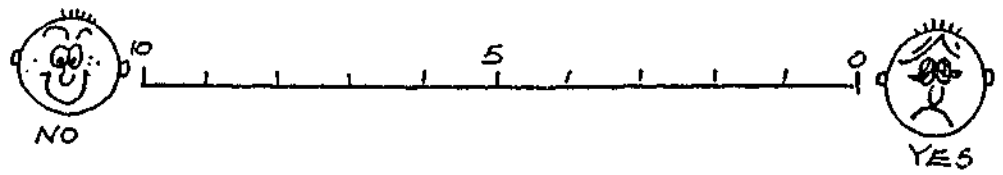
16. Do you get into trouble at school?



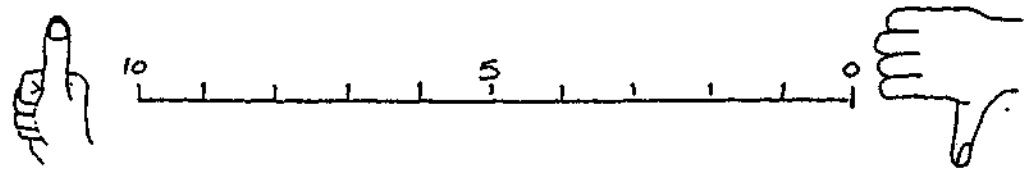
17. Do you do things without thinking?



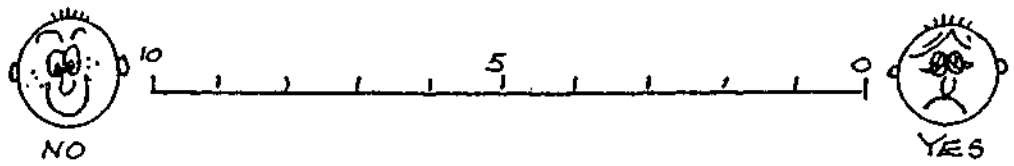
18. Do you find it hard to concentrate?



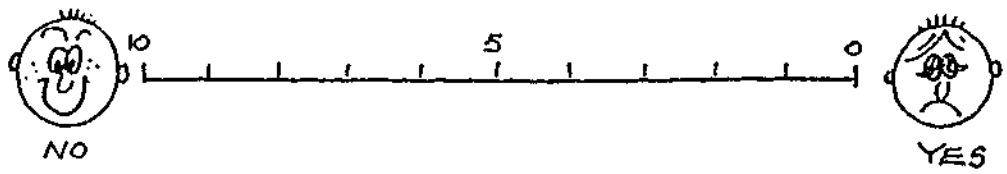
19. Do you talk a lot?



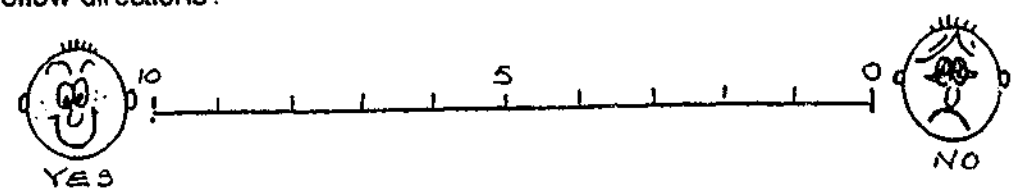
20. Do you find it hard to sit still?



21. Do you get your words mixed up?



22. Can you follow directions?



APPENDIX L: ANALYSES FOR EXPERIMENTS 10 AND 11

Analyses of data for the normal children in Experiment 10

Demographic data

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
FSIQ	7-8yo	17	103.7059	11.3345	2.7490	97.8782	109.5335
	9-10yo	17	111.8824	13.3879	3.2470	104.9989	118.7658
	11-12yo	18	103.8333	12.5663	2.9619	97.5843	110.0824
	Total	52	106.4231	12.8037	1.7756	102.8585	109.9877

One-way ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
FSIQ	Between Groups	752.898	2	376.449	2.425	.099
	Within Groups	7607.794	49	155.261		
	Total	8360.692	51			

L.1 One-way ANOVA for age (7-8, 9-10, 11-12 years) for asymmetry scores on the face-matching task.

Descriptive Statistics

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
7-8yo	17	-.0033	.2008	4.869E-02	-.1065	9.995E-02
9-10yo	17	-.1013	.1669	4.049E-02	-.1871	-1.5476E-02
11-12yo	18	-.0710	.2120	4.997E-02	-.1764	3.445E-02
Total	52	-.0588	.1951	2.705E-02	-.1131	-4.4508E-03

ANOVA table

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.582E-02	2	4.291E-02	1.133	.330
Within Groups	1.855	49	3.786E-02		
Total	1.941	51			

L.2 One-way ANOVA for age (7-8, 9-10, 11-12 years) for asymmetry scores on the chimeric-faces task.

Descriptive statistics

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
7-8yo	17	-.01	.3588	8.703E-02	-.2845	8.449E-02
9-10yo	17	-.3794	.4217	.1023	-.5962	-.1626
11-12yo	18	-.047	.4930	.1162	-.2924	.1980
Total	52	-.1731	.4458	6.183E-02	-.2972	-4.8955E-02

ANOVA table

ANOVA
FACES2

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.100	2	.550	2.981	.060
Within Groups	9.038	49	.184		
Total	10.137	51			

L.3 One-way ANOVA for age (7-8, 9-10, 11-12 years) for asymmetry scores on the grey-scales task.

Descriptive Statistics

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
7-8yo	17	.0368	.2856	6.927E-02	-.1101	.1836
9-10yo	17	-.0588	.3144	7.626E-02	-.2205	.1028
11-12yo	18	-.1458	.3549	8.364E-02	-.3223	3.063E-02
Total	52	-.0577	.3229	4.479E-02	-.1476	3.222E-02

ANOVA table

ANOVA GREY					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.292	2	.146	1.421	.251
Within Groups	5.028	49	.103		
Total	5.319	51			

L.4 Single-sample t-tests: for asymmetry scores of normal children on the face-matching, chimeric-faces, and grey-scales tasks.

Descriptives

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
Face-match	52	-.0588	.1951	2.705E-02
Chimeric	52	-.1731	.4458	6.183E-02
Grey	52	-.0577	.3229	4.479E-02

ANOVAs

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
FACES3	-2.172	51	.035	-5.8761E-02	-.1131	-4.4508E-03
FACES2	-2.799	51	.007	-.1731	-.2972	-4.8955E-02
GREY	-1.288	51	.203	-5.7692E-02	-.1476	3.222E-02

L.5 Chi-squared tests for the frequency of leftward and rightward biases of normal children in the face-matching, chimeric-faces and grey-scales tasks.

	Face-matching task	Chimeric faces task	Grey Scales task
Leftward bias	28 (54%)	35 (67%)	27 (52%)
Rightward bias	16 (31%)	14 (27%)	18 (35%)
No bias	8 (15%)	3 (6%)	7 (13%)
Chi-squared	N=44 Chi DF1 = 3.273	N=49 Chi DF1 = 9.00	N=45 Chi DF1 = 1.8
1 tailed probability	.048	.002	.166
2 tailed probability	.096	.004	.233

Analyses for unmedicated and medicated ADHD children in Experiment 11

Analyses of demographic data

Descriptive Statistics

Descriptive Statistics for unmedicated ADHD children

	N	Minimum	Maximum	Mean	Std. Deviation
AGE	13	7.1666	13.4167	10.243563	1.902578
FSIQ	13	86.00	112.00	99.7692	8.1869
rating scale home hyper	12	.00	7.00	2.5833	2.0207
rating scale home inattentive	12	.00	7.00	2.1667	2.1249
RSHPERC	12	.00	11.00	2.9167	3.7040
rating scale school hyper	10	5.00	12.00	8.2000	2.6583
rating scale school inatt	10	5.00	11.00	7.7000	1.8886
RSSPERC	10	14.00	55.00	29.7000	16.5399
Valid N (listwise)	10				

Descriptive Statistics for medicated ADHD children

	N	Minimum	Maximum	Mean	Std. Deviation
AGE	9	7.2500	14.5833	10.314796	2.519637
FSIQ	9	85.00	115.00	101.4444	11.0805
rating scale home hyper	9	.00	9.00	3.3333	2.8284
rating scale home inattentive	9	.00	8.00	2.3333	2.3979
RSHPERC	9	00	31.00	5.6667	10.0000
rating scale school hyper	9	.00	13.00	8.0000	4.4721
rating scale school inatt	9	1.00	12.00	7.5556	4.1265
RSSPERC	9	1.00	84.00	37.6667	29.9833
Valid N (listwise)	9				

ANOVA table

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
SEX	Between Groups	.128	2	6.391E-02	.244	.785
	Within Groups	12.853	49	.262		
	Total	12.981	51			
FSIQ	Between Groups	752.898	2	376.449	2.425	.099
	Within Groups	7607.794	49	155.261		
	Total	8360.692	51			
rating scale home hyper	Between Groups	9.211E-02	2	4.605E-02	.013	.987
	Within Groups	157.125	43	3.654		
	Total	157.217	45			
rating scale home inattentive	Between Groups	5.463E-02	2	2.732E-02	.007	.993
	Within Groups	171.250	43	3.983		
	Total	171.304	45			
RSHPERC	Between Groups	36.353	2	18.176	.037	.964
	Within Groups	21269.125	43	494.631		
	Total	21305.478	45			
rating scale school hyper	Between Groups	7.643	2	3.822	1.290	.287
	Within Groups	118.543	40	2.964		
	Total	126.186	42			
rating scale school inatt	Between Groups	7.203	2	3.601	1.354	.270
	Within Groups	106.425	40	2.661		
	Total	113.628	42			
RSSPERC	Between Groups	1751.824	2	875.912	1.968	.153
	Within Groups	17800.688	40	445.017		
	Total	19552.512	42			
RSHIMP	Between Groups	81.545	2	40.772	2.070	.139

	Within Groups	846.890	43	19.695		
	Total	928.435	45			
RSSIMP	Between Groups	295.560	2	147.780	1.827	.174
	Within Groups	3235.882	40	80.897		
	Total	3531.442	42			

L.6 Single-sample t-test: for asymmetry scores of all ADHD children on the chimeric-faces, face-matching and grey scales tasks.

Descriptives

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
FACE-MATCH	22	-8.8282E-02	.1440	3.071E-02
CHIMERIC FACES	22	-.1773	.2631	5.609E-02
GREY SCALES	22	-.1051	.3687	7.861E-02

T-tests

One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
FACE- MATCH	-2.875	21	.009	-8.8282E-02	-.1521	-2.4427E-02
CHIMERIC FACES	-3.160	21	.005	-.1773	-.2939	-6.0621E-02
GREY SCALES	-1.337	21	.195	-.1051	-.2686	5.835E-02

L.7 Chi-squared tests for the frequency of leftward and rightward biases in the face-matching, chimeric-faces and grey-scales tasks, for all ADHD children.

	Face-matching task	Chimeric faces task	Grey Scales task
Leftward bias	16 (72.7%)	14 (63.6%)	13 (59.1%)
Rightward bias	5(22.7%)	5 (22.7%)	7 (31.8%)
No bias	1(4.5%)	3 (13.6%)	2 (9.1%)
Chi value	N = 21 Chi DF1 = 5.762	N = 19 Chi DF1 = 4.263	N=20 Chi DF1 = 1.800
One-tail probability	0.013	0.032	0.132
Two-tail probability	0.027	0.064	0.263

L.8 One-way ANOVAs for the asymmetry scores of unmedicated and medicated ADHD children in the face-matching, chimeric faces, and grey scales tasks.

Descriptives

Descriptives

		N	Mean	Std. Deviation	Std. Error
GREY	medicated	9	-.1389	.3574	.1191
	unmedicated	13	-8.1731E-02	.3890	.1079
	Total	22	-.1051	.3687	7.861E-02
FACE-MATCH	medicated	9	-.1420	.1759	5.864E-02
	unmedicated	13	-5.1110E-02	.1096	3.039E-02
	Total	22	-8.8282E-02	.1440	3.071E-02
CHIMERIC FACES	medicated	9	-.2167	.2806	9.354E-02
	unmedicated	13	-.1500	.2582	7.161E-02
	Total	22	-.1773	.2631	5.609E-02

ANOVAs

ANOVA

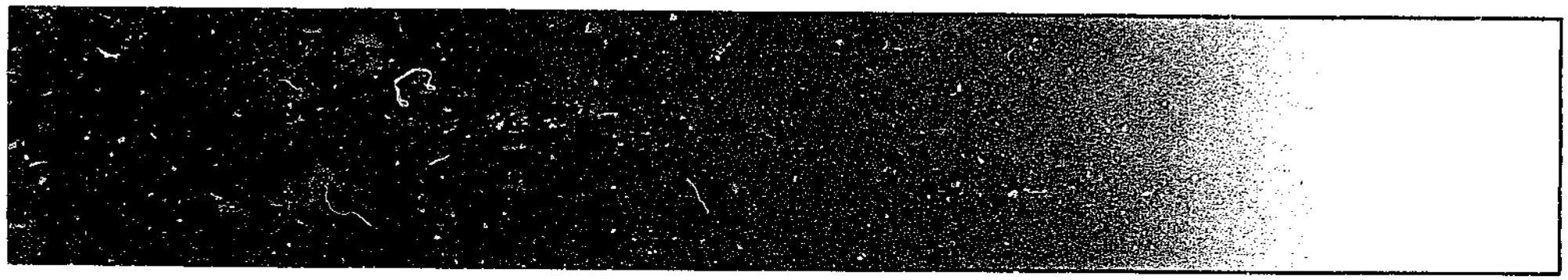
		Sum of Squares	df	Mean Square	F	Sig.
GREY	Between Groups	1.737E-02	1	1.737E-02	.122	.730
	Within Groups	2.837	20	.142		
	Total	2.855	21			
FACE-MATCH	Between Groups	4.391E-02	1	4.391E-02	2.242	.150
	Within Groups	.392	20	1.958E-02		
	Total	.436	21			
CHIMERIC FACES	Between Groups	2.364E-02	1	2.364E-02	.331	.572
	Within Groups	1.430	20	7.150E-02		
	Total	1.454	21			

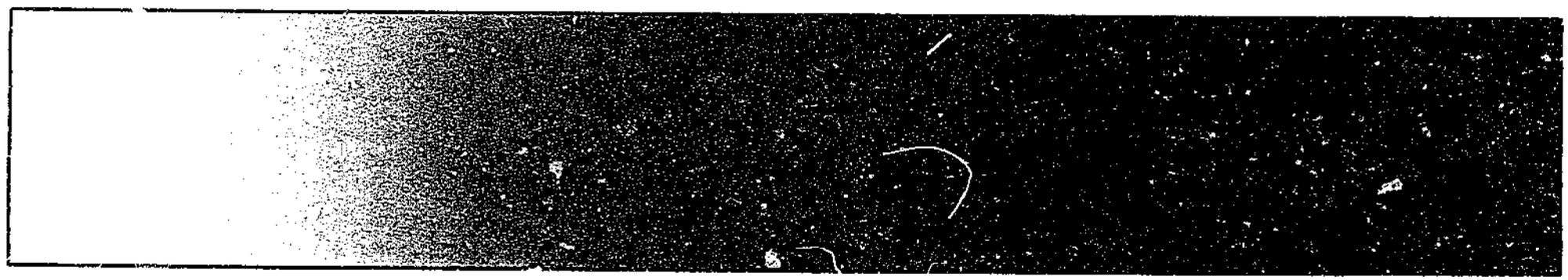
APPENDIX M: SAMPLES OF STIMULI USED IN EXPERIMENTS 10 AND 11

M.1 A sample of face-matching stimuli

M.2 A sample of chimeric-faces stimuli

M.3 A sample of grey-scales stimuli





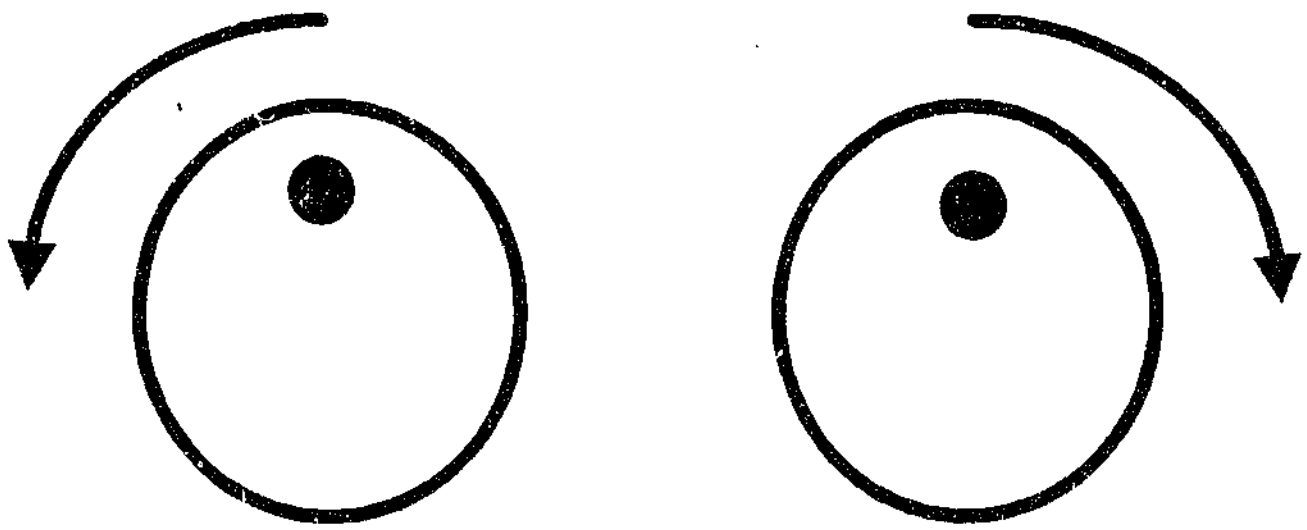
APPENDIX N: COUNTERBALANCING FOR THE BIMANUAL COORDINATION TASK IN EXPERIMENT 12

N.1 Counterbalancing for the 12 clinical and 12 control children:

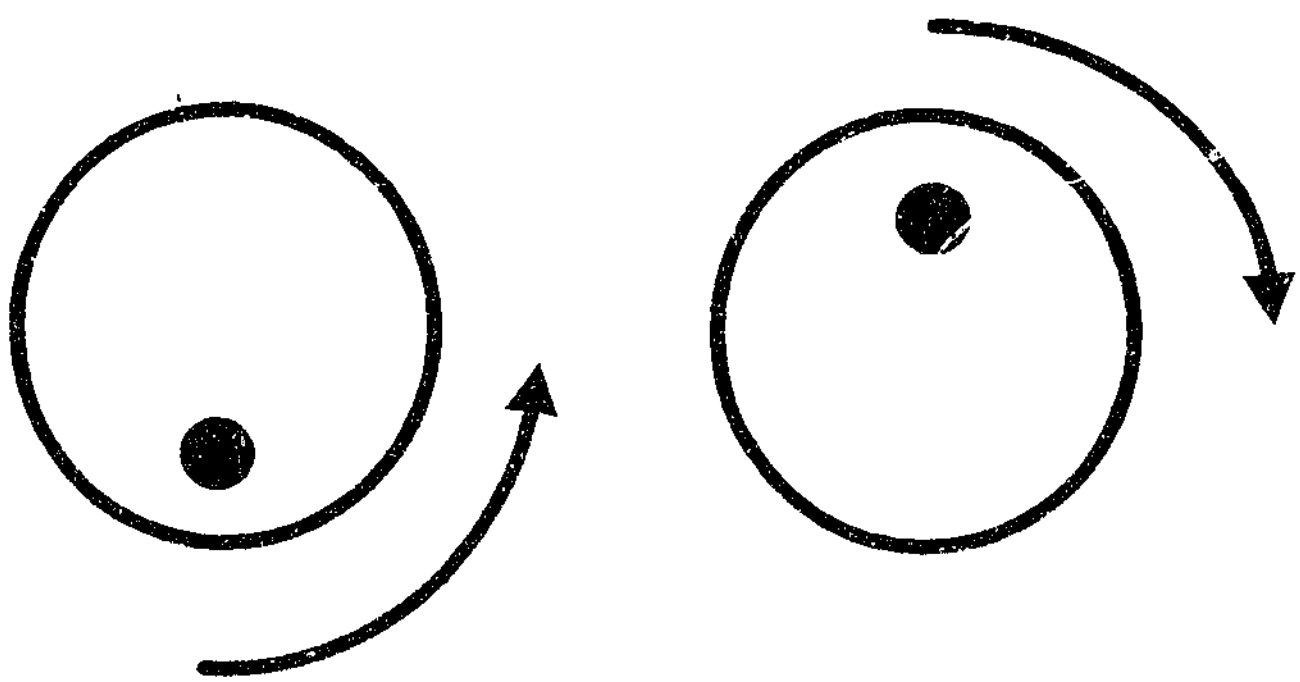
1. in-phase fast in-phase slow out-of-phase slow out-of-phase fast
2. out-of-phase fast out-of-phase slow in-phase slow in-phase fast
3. in-phase slow in-phase fast out-of-phase slow out-of-phase fast
4. out-of-phase slow out-of-phase fast in-phase slow in-phase fast
5. in-phase fast in-phase slow out-of-phase fast out-of-phase slow
6. out-of-phase fast out-of-phase slow in-phase fast in-phase slow
7. in-phase slow in-phase fast out-of-phase fast out-of-phase slow
8. out-of-phase slow out-of-phase fast in-phase fast in-phase slow
9. in-phase fast in-phase slow out-of-phase slow out-of-phase fast
10. out-of-phase fast out-of-phase slow in-phase slow in-phase fast
11. in-phase slow in-phase fast out-of-phase slow out-of-phase fast
12. out-of-phase slow out-of-phase fast in-phase slow in-phase fast

APPENDIX O: IN-PHASE AND OUT-OF-PHASE MOVEMENTS FOR EXPERIMENTS 12 AND 13

In-phase movement



Out-of-phase movement



APPENDIX P: ANALYSES FOR EXPERIMENT 12

Demographic details

Descriptives

		N	Mean	Std. Deviation	Std. Error
IQ	unmed ADHD	12	98.3333	10.2010	2.9448
	controls	12	106.8333	14.3516	4.1430
	Total	24	102.5833	12.9276	2.6388
AGE	unmed ADHD	12	11.0000	1.7071	.4928
	controls	12	11.3541	1.5538	.4485
	Total	24	11.1771	1.6066	.3279
RSHIN	unmed ADHD	11	2.6364	2.1574	.6505
	controls	12	11.5833	1.9287	.5568
	Total	23	7.3043	4.9858	1.0396
RSHHYP	unmed ADHD	11	3.8182	1.4013	.4225
	controls	12	12.2500	1.6583	.4787
	Total	23	8.2174	4.5623	.9513
RSHPERC	unmed ADHD	11	4.6364	3.8019	1.1463
	controls	12	70.7500	20.0641	5.7920
	Total	23	39.1304	36.7167	7.6560
RSSIN	unmed ADHD	9	7.5556	3.5395	1.1798
	controls	8	11.6250	1.8468	.6529
	Total	17	9.4706	3.4842	.8450
RSSHYP	unmed ADHD	9	7.2222	3.6324	1.2108
	controls	8	12.0000	1.6036	.5669
	Total	17	9.4706	3.7101	.8998
RSSPERC	unmed ADHD	9	30.3333	28.5438	9.5146
	controls	8	71.6250	17.1709	6.0708
	Total	17	49.7647	31.4276	7.6223

ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
IQ	Between Groups	433.500	1	433.500	2.797	.109
	Within Groups	3410.333	22	155.015		
	Total	3843.833	23			
AGE	Between Groups	.753	1	.753	.283	.600
	Within Groups	58.611	22	2.664		
	Total	59.364	23			

RSHIN	Between Groups	459.407	1	459.407	110.306	.000
	Within Groups	87.462	21	4.165		
	Total	546.870	22			
RSHHYP	Between Groups	408.027	1	408.027	171.762	.000
	Within Groups	49.886	21	2.376		
	Total	457.913	22			
RSHPERC	Between Groups	25085.813	1	25085.813	115.204	.000
	Within Groups	4572.795	21	217.752		
	Total	29658.609	22			
RSSIN	Between Groups	70.138	1	70.138	8.478	.011
	Within Groups	124.097	15	8.273		
	Total	194.235	16			
RSSHYP	Between Groups	96.680	1	96.680	11.737	.004
	Within Groups	123.556	15	8.237		
	Total	220.235	16			
RSSPERC	Between Groups	7221.184	1	7221.184	12.622	.003
	Within Groups	8581.875	15	572.125		
	Total	15803.059	16			

P.1 Variation in coordination pattern for the in-phase task: Group (unmedicated ADHD, controls) x speed (slow, fast) ANOVA.

Descriptive Statistics

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
variation coordination in-phase slow	unmed ADHD	29 428052	13.911301	12
	controls	16.539667	7.373569	12
	Total	22.983860	12.723642	24
variation in coordination in-phase fast	unmed ADHD	48.968441	18.356835	12
	controls	26.830194	10.976740	12
	Total	37.899317	18.618243	24

ANOVA

Tests of within-subjects effects

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	SPEED	Type III Sum of Squares	df	Mean Square	F	Sig.
SPEED	Linear	2669.651	1	2669.651	22.516	.000
SPEED * GROUP	Linear	256.680	1	256.680	2.165	.155
Error(SPEED)	Linear	2608.513	22	118.569		

Tests of between-subjects effects

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	44481.135	1	44481.135	190.002	.000
GROUP	3680.595	1	3680.595	15.722	.001
Error	5150.404	22	234.109		

P.2 Accuracy of coordination pattern in the in-phase task: Group (unmedicated ADHD, controls) x speed (slow, fast) ANOVA.

Descriptives

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
accuracy coordination in-phase slow	unmed ADHD	21.405139	17.897925	12
	controls	9.617683	6.425474	12
	Total	15.511411	14.463615	24
acuracy coordination in-phase fast	unmed ADHD	34.989386	21.512898	12
	controls	18.686870	15.948329	12
	Total	26.838128	20.305628	24

ANOVA

Tests of within-subject effects

Tests of Within-Subjects Contrasts
Measure: MEASURE_1

Source	SPEED	Type III Sum of Squares	df	Mean Square	F	Sig.
SPEED	Linear	1539.534	1	1539.534	8.531	.008
SPEED * GROUP	Linear	61.157	1	61.157	.339	.566
Error(SPEED)	Linear	3970.284	22	180.467		

Tests of between-subject effects

Tests of Between-Subjects Effects
Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	21521.802	1	21521.802	59.963	.000
GROUP	2367.140	1	2367.140	6.595	.018
Error	7896.256	22	358.921		

P.3 Variation in velocity for in-phase data: Group (unmedicated ADHD, controls) x speed (slow, fast) x hand (left, right) ANOVA.

Descriptives

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
variation in velocity left in-phase slow	unmed ADHD	.513654	.376396	12
	controls	.185133	5.86285E-02	12
	Total	.349393	.312339	24
variation in velocity right in-phase slow	unmed ADHD	.496972	.428302	12
	controls	.178297	6.53351E-02	12
	Total	.337634	.340980	24
variation in velocity left in-phase fast	unmed ADHD	.558430	.226141	12
	controls	.314108	.181176	12
	Total	.436269	.236070	24
variation in velocity right in-phase fast	unmed ADHD	.441043	.188287	12
	controls	.287477	.190076	12
	Total	.364260	.200963	24

ANOVA

Tests of within-subjects effects

Tests of Within-Subjects Effects
Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SPEED	Sphericity Assumed	7.730E-02	1	7.730E-02	1.111	.303
	Greenhouse-Geisser	7.730E-02	1.000	7.730E-02	1.111	.303
	Huynh-Feldt	7.730E-02	1.000	7.730E-02	1.111	.303
	Lower-bound	7.730E-02	1.000	7.730E-02	1.111	.303
SPEED * GROUP	Sphericity Assumed	9.323E-02	1	9.323E-02	1.340	.260
	Greenhouse-Geisser	9.323E-02	1.000	9.323E-02	1.340	.260
	Huynh-Feldt	9.323E-02	1.000	9.323E-02	1.340	.260
	Lower-bound	9.323E-02	1.000	9.323E-02	1.340	.260
Error(SPEED)	Sphericity Assumed	1.531	22	6.960E-02		
	Greenhouse-Geisser	1.531	22.000	6.960E-02		
	Huynh-Feldt	1.531	22.000	6.960E-02		
	Lower-bound	1.531	22.000	6.960E-02		
HAN	Sphericity Assumed	4.210E-02	1	4.210E-02	17.930	.000
	Greenhouse-Geisser	4.210E-02	1.000	4.210E-02	17.930	.000
	Huynh-Feldt	4.210E-02	1.000	4.210E-02	17.930	.000
	Lower-bound	4.210E-02	1.000	4.210E-02	17.930	.000
HAN * GROUP	Sphericity Assumed	1.518E-02	1	1.518E-02	6.465	.019
	Greenhouse-Geisser	1.518E-02	1.000	1.518E-02	6.465	.019
	Huynh-Feldt	1.518E-02	1.000	1.518E-02	6.465	.019
	Lower-bound	1.518E-02	1.000	1.518E-02	6.465	.019
Error(HAN)	Sphericity Assumed	5.166E-02	22	2.348E-03		
	Greenhouse-Geisser	5.166E-02	22.000	2.348E-03		
	Huynh-Feldt	5.166E-02	22.000	2.348E-03		
	Lower-bound	5.166E-	22.000	2.348E-03		
SPEED * HAN	Sphericity Assumed	2.178E-02	1	2.178E-02	11.418	.003
	Greenhouse-Geisser	2.178E-02	1.000	2.178E-02	11.418	.003
	Huynh-Feldt	2.178E-02	1.000	2.178E-02	11.418	.003
	Lower-bound	2.178E-02	1.000	2.178E-02	11.418	.003

SPEED * HAN * GROUP	Sphericity Assumed	9.820E-03	1	9.820E-03	5.148	.033
	Greenhouse-Geisser	9.820E-03	1.000	9.820E-03	5.148	.033
	Huynh-Feldt	9.820E-03	1.000	9.820E-03	5.148	.033
	Lower-bound	9.820E-03	1.000	9.820E-03	5.148	.033
Error(SPEED*HAN)	Sphericity Assumed	4.197E-02	22	1.908E-03		
	Greenhouse-Geisser	4.197E-02	22.000	1.908E-03		
	Huynh-Feldt	4.197E-02	22.000	1.908E-03		
	Lower-bound	4.197E-02	22.000	1.908E-03		

Tests of between-subjects effects

Tests of Between-Subjects Effects
Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	13.277	1	13.277	77.948	.000
GROUP	1.638	1	1.638	9.618	.005
Error	3.747	22	.170		

Subanalyses of speed x group x hand interaction

P.4 Speed x hand ANOVA for unmedicated ADHD.

Tests of Within-Subjects Effects(a)
Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SPEED	Sphericity Assumed	3.731E-04	1	3.731E-04	.004	.953
	Greenhouse-Geisser	3.731E-04	1.000	3.731E-04	.004	.953
	Huynh-Feldt	3.731E-04	1.000	3.731E-04	.004	.953
	Lower-bound	3.731E-04	1.000	3.731E-04	.004	.953
Error(SPEED)	Sphericity Assumed	1.131	11	.103		
	Greenhouse-Geisser	1.131	11.000	.103		
	Huynh-Feldt	1.131	11.000	.103		
	Lower-bound	1.131	11.000	.103		
HAN	Sphericity Assumed	5.392E-02	1	5.392E-02	15.523	.002
	Greenhouse-Geisser	5.392E-02	1.000	5.392E-02	15.523	.002
	Huynh-Feldt	5.392E-02	1.000	5.392E-02	15.523	.002
	Lower-bound	5.392E-02	1.000	5.392E-02	15.523	.002

	Sphericity Assumed	3.821E-02	11	3.474E-03		
Error(HAN)	Greenhouse-Geisser	3.821E-02	11.000	3.474E-03		
	Huynh-Feldt	3.821E-02	11.000	3.474E-03		
	Lower-bound	3.821E-02	11.000	3.474E-03		
	Sphericity Assumed	3.042E-02	1	3.042E-02	11.146	.007
SPEED * HAN	Greenhouse-Geisser	3.042E-02	1.000	3.042E-02	11.146	.007
	Huynh-Feldt	3.042E-02	1.000	3.042E-02	11.146	.007
	Lower-bound	3.042E-02	1.000	3.042E-02	11.146	.007
	Sphericity Assumed	3.003E-02	11	2.730E-03		
Error(SPEED*HAN)	Greenhouse-Geisser	3.003E-02	11.000	2.730E-03		
	Huynh-Feldt	3.003E-02	11.000	2.730E-03		
	Lower-bound	3.003E-02	11.000	2.730E-03		

a GROUP = unmed ADHD

P.5 Speed x hand ANOVA for controls.

Tests of Within-Subjects Effects(a)
Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
	Sphericity Assumed	.170	1	.170	4.681	.053
SPEED	Greenhouse-Geisser	.170	1.000	.170	4.681	.053
	Huynh-Feldt	.170	1.000	.170	4.681	.053
	Lower-bound	.170	1.000	.170	4.681	.053
	Sphericity Assumed	.400	11	3.635E-02		
Error(SPEED)	Greenhouse-Geisser	.400	11.000	3.635E-02		
	Huynh-Feldt	.400	11.000	3.635E-02		
	Lower-bound	.400	11.000	3.635E-02		
	Sphericity Assumed	3.360E-03	1	3.360E-03	2.749	.126
HAN	Greenhouse-Geisser	3.360E-03	1.000	3.360E-03	2.749	.126
	Huynh-Feldt	3.360E-03	1.000	3.360E-03	2.749	.126
	Lower-bound	3.360E-03	1.000	3.360E-03	2.749	.126
	Sphericity Assumed	1.345E-02	11	1.223E-03		
Error(HAN)	Greenhouse-Geisser	1.345E-02	11.000	1.223E-03		
	Huynh-Feldt	1.345E-02	11.000	1.223E-03		
	Lower-bound	1.345E-02	11.000	1.223E-03		
SPEED * HAN	Sphericity Assumed	1.175E-03	1	1.175E-03	1.083	.320
	Greenhouse-Geisser	1.175E-03	1.000	1.175E-03	1.083	.320

	Huynh-Feldt	1.175E-03	1.000	1.175E-03	1.083	.320
	Lower-bound	1.175E-03	1.000	1.175E-03	1.083	.320
Error(SPEED*HAN)	Sphericity Assumed	1.194E-02	11	1.086E-03		
	Greenhouse-Geisser	1.194E-02	11.000	1.086E-03		
	Huynh-Feldt	1.194E-02	11.000	1.086E-03		
	Lower-bound	1.194E-02	11.000	1.086E-03		

a GROUP = controls

Subanalyses of speed x hand interaction for the unmedicated ADHD children

P.6 ANOVA for hand at slow speed.

Tests of Within-Subjects Effects(a)
Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
HAN	Sphericity Assumed	1.670E-03	1	1.670E-03	.583	.461
	Greenhouse-Geisser	1.670E-03	1.000	1.670E-03	.583	.461
	Huynh-Feldt	1.670E-03	1.000	1.670E-03	.583	.461
	Lower-bound	1.670E-03	1.000	1.670E-03	.583	.461
Error(HAN)	Sphericity Assumed	3.150E-02	11	2.864E-03		
	Greenhouse-Geisser	3.150E-02	11.000	2.864E-03		
	Huynh-Feldt	3.150E-02	11.000	2.864E-03		
	Lower-bound	3.150E-02	11.000	2.864E-03		

a GROUP = unmed ADHD

P.7 ANOVA for hand at fast speed.

Tests of Within-Subjects Effects(a)
Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
HAN	Sphericity Assumed	8.268E-02	1	8.268E-02	24.758	.000
	Greenhouse-Geisser	8.268E-02	1.000	8.268E-02	24.758	.000
	Huynh-Feldt	8.268E-02	1.000	8.268E-02	24.758	.000
	Lower-bound	8.268E-02	1.000	8.268E-02	24.758	.000
Error(HAN)	Sphericity Assumed	3.673E-02	11	3.339E-03		
	Greenhouse-Geisser	3.673E-02	11.000	3.339E-03		
	Huynh-Feldt	3.673E-02	11.000	3.339E-03		
	Lower-bound	3.673E-02	11.000	3.339E-03		

a GROUP = unmed ADHD

P.8 Accuracy of velocity for the in-phase task: Group (unmedicated ADHD, controls) x speed (slow, fast) x hand (left, right) ANOVA.

Descriptives

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
accuracy in velocity left in-phase slow	unmed ADHD	-.100452	.388618	12
	controls	4.81806E-02	.209725	12
	Total	-2.613558E-02	.314687	24
accuracy in velocity right in-phase slow	unmed ADHD	-.108564	.408642	12
	controls	4.75042E-02	.208729	12
	Total	-3.053006E-02	.327192	24
accuracy in velocity left in-phase fast	unmed ADHD	.108911	.643926	12
	controls	.258542	.462258	12
	Total	.183726	.553483	24
accuracy in velocity right in-phase fast	unmed ADHD	1.87039E-02	.775314	12
	controls	.232637	.441244	12
	Total	.125671	.626533	24

Tests of within-subjects effects

Tests of Within-Subjects Effects
Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SPEED	Sphericity Assumed	.804	1	.804	4.215	.052
	Greenhouse-Geisser	.804	1.000	.804	4.215	.052
	Huynh-Feldt	.804	1.000	.804	4.215	.052
	Lower-bound	.804	1.000	.804	4.215	.052
SPEED * GROUP	Sphericity Assumed	5.197E-03	1	5.197E-03	.027	.870
	Greenhouse-Geisser	5.197E-03	1.000	5.197E-03	.027	.870
	Huynh-Feldt	5.197E-03	1.000	5.197E-03	.027	.870
	Lower-bound	5.197E-03	1.000	5.197E-03	.027	.870
Error(SPEED)	Sphericity Assumed	4.197	22	.191		
	Greenhouse-Geisser	4.197	22.000	.191		
	Huynh-Feldt	4.197	22.000	.191		

	Lower-bound	4.197	22.000	.191		
HND	Sphericity Assumed	2.340E-02	1	2.340E-02	3.807	.064
	Greenhouse-Geisser	2.340E-02	1.000	2.340E-02	3.807	.064
	Huynh-Feldt	2.340E-02	1.000	2.340E-02	3.807	.064
	Lower-bound	2.340E-02	1.000	2.340E-02	3.807	.064
HND * GROUP	Sphericity Assumed	7.720E-03	1	7.720E-03	1.256	.275
	Greenhouse-Geisser	7.720E-03	1.000	7.720E-03	1.256	.275
	Huynh-Feldt	7.720E-03	1.000	7.720E-03	1.256	.275
	Lower-bound	7.720E-03	1.000	7.720E-03	1.256	.275
Error(HND)	Sphericity Assumed	.135	22	6.147E-03		
	Greenhouse-Geisser	.135	22.000	6.147E-03		
	Huynh-Feldt	.135	22.000	6.147E-03		
	Lower-bound	.135	22.000	6.147E-03		
SPEED * HND	Sphericity Assumed	1.728E-02	1	1.728E-02	2.960	.099
	Greenhouse-Geisser	1.728E-02	1.000	1.728E-02	2.960	.099
	Huynh-Feldt	1.728E-02	1.000	1.728E-02	2.960	.099
	Lower-bound	1.728E-02	1.000	1.728E-02	2.960	.099
SPEED * HND * GROUP	Sphericity Assumed	4.851E-03	1	4.851E-03	.831	.372
	Greenhouse-Geisser	4.851E-03	1.000	4.851E-03	.831	.372
	Huynh-Feldt	4.851E-03	1.000	4.851E-03	.831	.372
	Lower-bound	4.851E-03	1.000	4.851E-03	.831	.372
Error(SPEED*HND)	Sphericity Assumed	.128	22	5.837E-03		
	Greenhouse-Geisser	.128	22.000	5.837E-03		
	Huynh-Feldt	.128	22.000	5.837E-03		
	Lower-bound	.128	22.000	5.837E-03		

Tests of between-subjects effects

Tests of Between-Subjects Effects Measure: MEASURE_1 Transformed Variable: Average					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	.383	1	.383	.538	.471
GROUP	.670	1	.670	.941	.343
Error	15.666	22	.712		

Analyses for the Out-of-phase task

P.9 Variation in coordination pattern for the out-of-phase task: Group (unmedicated ADHD, controls) x speed (slow, fast) ANOVA.

Descriptives

Descriptive Statistics				
	GROUP	Mean	Std. Deviation	N
variation in coordination out-phase slow	unmed ADHD	54.512746	18.568919	12
	controls	32.946773	13.606334	12
	Total	43.729760	19.426744	24
variation in coordination out-phase fast	unmed ADHD	70.825988	15.793717	12
	controls	54.536312	23.732908	12
	Total	62.681150	21.398637	24

Tests of within-subjects effects

Tests of Within-Subjects Effects Measure: MEASURE_1						
Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SPEED	Sphericity Assumed	4309.862	1	4309.862	22.257	.000
	Greenhouse-Geisser	4309.862	1.000	4309.862	22.257	.000
	Huynh-Feldt	4309.862	1.000	4309.862	22.257	.000
	Lower-bound	4309.862	1.000	4309.862	22.257	.000
SPEED * GROUP	Sphericity Assumed	83.518	1	83.518	.431	.518
	Greenhouse-Geisser	83.518	1.000	83.518	.431	.518
	Huynh-Feldt	83.518	1.000	83.518	.431	.518
	Lower-bound	83.518	1.000	83.518	.431	.518

	Sphericity Assumed	4260.191	22	193.645
Error(SPEED)	Greenhouse-Geisser	4260.191	22.000	193.645
	Huynh-Feldt	4260.191	22.000	193.645
	Lower-bound	4260.191	22.000	193.645

Tests of between-subjects effects

Tests of Between-Subjects Effects
Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	135879.380	1	135879.380	282.840	.000
GROUP	4299.151	1	4299.151	8.949	.007
Error	10569.042	22	480.411		

P.10 Accuracy of coordination pattern in the out-of-phase task: Group (unmedicated ADHD, controls) x speed (slow, fast) ANOVA.

Descriptives

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
accuracy coordination out-phase slow	unmed ADHD	99.048407	57.157518	12
	controls	63.996081	53.838469	12
	Total	81.522244	57.177520	24
accuracy coordination out-phase fast	unmed ADHD	98.032157	45.753817	12
	controls	66.010338	36.054659	12
	Total	82.021247	43.478747	24

Tests of within-subjects effects

Tests of Within-Subjects Effects
Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SPEED	Sphericity Assumed	2.988	1	2.988	.003	.956
	Greenhouse-Geisser	2.988	1.000	2.988	.003	.956
	Huynh-Feldt	2.988	1.000	2.988	.003	.956
	Lower-bound	2.988	1.000	2.988	.003	.956

SPEED * GROUP	Sphericity Assumed	27.552	1	27.552	.029	.865
	Greenhouse-Geisser	27.552	1.000	27.552	.029	.865
	Huynh-Feldt	27.552	1.000	27.552	.029	.865
	Lower-bound	27.552	1.000	27.552	.029	.865
Error(SPEED)	Sphericity Assumed	20636.260	22	938.012		
	Greenhouse-Geisser	20636.260	22.000	938.012		
	Huynh-Feldt	20636.260	22.000	938.012		
	Lower-bound	20636.260	22.000	938.012		

Tests of between-subjects effects

Tests of Between-Subjects Effects
Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	320957.683	1	320957.683	83.551	.000
GROUP	13496.823	1	13496.823	3.513	.074
Error	84511.781	22	3841.445		

P.11 Variation in velocity for the out-of-phase task: Group (unmedicated ADHD, controls) x speed (slow, fast) x hand (left, right) ANOVA.

Descriptives

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
variation in velocity left out-phase slow	unmed ADHD	.553015	.291038	12
	controls	.218107	5.72622E-02	12
	Total	.385561	.267092	24
variation in velocity right out-phase slow	unmed ADHD	.520725	.300244	12
	controls	.200827	7.03465E-02	12
	Total	.360776	.268657	24
variation in velocity left out-phase fast	unmed ADHD	.631621	.230060	12
	controls	.312626	5.90604E-02	12
	Total	.472123	.231359	24
variation in velocity right out-phase fast	unmed ADHD	.525037	.333791	12
	controls	.255745	5.63824E-02	12
	Total	.390391	.271522	24

Tests of within-subjects effects

Tests of Within-Subjects Effects
Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SPEED	Sphericity Assumed	8.098E-02	1	8.098E-02	3.756	.066
	Greenhouse-Geisser	8.098E-02	1.000	8.098E-02	3.756	.066
	Huynh-Feldt	8.098E-02	1.000	8.098E-02	3.756	.066
	Lower-bound	8.098E-02	1.000	8.098E-02	3.756	.066
SPEED * GROUP	Sphericity Assumed	6.637E-03	1	6.637E-03	.308	.585
	Greenhouse-Geisser	6.637E-03	1.000	6.637E-03	.308	.585
	Huynh-Feldt	6.637E-03	1.000	6.637E-03	.308	.585
	Lower-bound	6.637E-03	1.000	6.637E-03	.308	.585
Error(SPEED)	Sphericity Assumed	.474	22	2.156E-02		
	Greenhouse-Geisser	.474	22.000	2.156E-02		
	Huynh-Feldt	.474	22.000	2.156E-02		
	Lower-bound	.474	22.000	2.156E-02		
HND	Sphericity Assumed	6.808E-02	1	6.808E-02	18.197	.000
	Greenhouse-Geisser	6.808E-02	1.000	6.808E-02	18.197	.000
	Huynh-Feldt	6.808E-02	1.000	6.808E-02	18.197	.000
	Lower-bound	6.808E-02	1.000	6.808E-02	18.197	.000
HND * GROUP	Sphericity Assumed	6.281E-03	1	6.281E-03	1.679	.208
	Greenhouse-Geisser	6.281E-03	1.000	6.281E-03	1.679	.208
	Huynh-Feldt	6.281E-03	1.000	6.281E-03	1.679	.208
	Lower-bound	6.281E-03	1.000	6.281E-03	1.679	.208
Error(HND)	Sphericity Assumed	8.230E-02	22	3.741E-03		
	Greenhouse-Geisser	8.230E-02	22.000	3.741E-03		
	Huynh-Feldt	8.230E-02	22.000	3.741E-03		
	Lower-bound	8.230E-02	22.000	3.741E-03		
SPEED * HND	Sphericity Assumed	1.946E-02	1	1.946E-02	2.653	.118
	Greenhouse-Geisser	1.946E-02	1.000	1.946E-02	2.653	.118
	Huynh-Feldt	1.946E-02	1.000	1.946E-02	2.653	.118
	Lower-bound	1.946E-02	1.000	1.946E-02	2.653	.118

	Sphericity Assumed	1.806E-03	1	1.806E-03	.246	.625
SPEED * HND * GROUP	Greenhouse-Geisser	1.806E-03	1.000	1.806E-03	.246	.625
	Huynh-Feldt	1.806E-03	1.000	1.806E-03	.246	.625
	Lower-bound	1.806E-03	1.000	1.806E-03	.246	.625
	Sphericity Assumed	.161	22	7.334E-03		
Error(SPEED*HND)	Greenhouse-Geisser	.161	22.000	7.334E-03		
	Huynh-Feldt	.161	22.000	7.334E-03		
	Lower-bound	.161	22.000	7.334E-03		

Tests of between-subjects effects

Tests of Between-Subjects Effects
Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	15.530	1	15.530	107.547	.000
GROUP	2.318	1	2.318	16.051	.001
Error	3.177	22	.144		

P.12 Accuracy of velocity in the out-of-phase task: Group (unmedicated ADHD, controls) x speed (slow, fast) x hand (left, right) ANOVA.

Descriptives

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
accuracy in velocity left out-phase slow	unmed ADHD	5.08176E-02	.486814	12
	controls	7.22156E-02	.258930	12
	Total	6.15166E-02	.381479	24
accuracy in velocity right out-phase slow	unmed ADHD	-6.042389E-03	.554199	12
	controls	5.31100E-02	.268481	12
	Total	2.35338E-02	.426941	24
accuracy in velocity left out-phase fast	unmed ADHD	.209283	.799913	12
	controls	.498907	.475307	12
	Total	.354095	.660265	24
accuracy in velocity right out-phase fast	unmed ADHD	.135970	.905533	12
	controls	.406756	.491953	12
	Total	.271363	.726575	24

Tests of within-subjects effects

Tests of Within-Subjects Effects
Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SPEED	Sphericity Assumed	1.752	1	1.752	8.041	.010
	Greenhouse-Geisser	1.752	1.000	1.752	8.041	.010
	Huynh-Feldt	1.752	1.000	1.752	8.041	.010
	Lower-bound	1.752	1.000	1.752	8.041	.010
SPEED * GROUP	Sphericity Assumed	.345	1	.345	1.585	.221
	Greenhouse-Geisser	.345	1.000	.345	1.585	.221
	Huynh-Feldt	.345	1.000	.345	1.585	.221
	Lower-bound	.345	1.000	.345	1.585	.221
Error(SPEED)	Sphericity Assumed	4.794	22	.218		
	Greenhouse-Geisser	4.794	22.000	.218		
	Huynh-Feldt	4.794	22.000	.218		
	Lower-bound	4.794	22.000	.218		
HND	Sphericity Assumed	8.743E-02	1	8.743E-02	12.588	.002
	Greenhouse-Geisser	8.743E-02	1.000	8.743E-02	12.588	.002
	Huynh-Feldt	8.743E-02	1.000	8.743E-02	12.588	.002
	Lower-bound	8.743E-02	1.000	8.743E-02	12.588	.002
HND * GROUP	Sphericity Assumed	5.367E-04	1	5.367E-04	.077	.784
	Greenhouse-Geisser	5.367E-04	1.000	5.367E-04	.077	.784
	Huynh-Feldt	5.367E-04	1.000	5.367E-04	.077	.784
	Lower-bound	5.367E-04	1.000	5.367E-04	.077	.784
Error(HND)	Sphericity Assumed	.153	22	6.945E-03		
	Greenhouse-Geisser	.153	22.000	6.945E-03		
	Huynh-Feldt	.153	22.000	6.945E-03		
	Lower-bound	.153	22.000	6.945E-03		
SPEED * HND	Sphericity Assumed	1.201E-02	1	1.201E-02	1.345	.259
	Greenhouse-Geisser	1.201E-02	1.000	1.201E-02	1.345	.259
	Huynh-Feldt	1.201E-02	1.000	1.201E-02	1.345	.259
	Lower-bound	1.201E-02	1.000	1.201E-02	1.345	.259
SPEED * HND * GROUP	Sphericity Assumed	4.804E-03	1	4.804E-03	.538	.471

	Greenhouse-Geisser	4.804E-03	1.000	4.804E-03	.538	.471
	Huynh-Feldt	4.804E-03	1.000	4.804E-03	.538	.471
	Lower-bound	4.804E-03	1.000	4.804E-03	.538	.471
Error(SPEED*HND)	Sphericity Assumed	.197	22	8.935E-03		
	Greenhouse-Geisser	.197	22.000	8.935E-03		
	Huynh-Feldt	.197	22.000	8.935E-03		
	Lower-bound	.197	22.000	8.935E-03		

Tests of between-subjects effects

Tests of Between-Subjects Effects
Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	3.029	1	3.029	2.824	.107
GROUP	.616	1	.616	.575	.457
Error	23.598	22	1.073		

P.13 Correlations of in-phase task variables with ADDES rating scale scores for unmedicated ADHD children.

		IQ	AGE	RSHIN	RSHHYP	RSHPERC	RSSIN	RSSHYP	RSSPERC
accuracy coordination in-phase slow	Pearson Correlation	-.359	-.330	-.112	.293	.135	-.428	-.187	-.365
	Sig. (2-tailed)	.252	.296	.744	.381	.693	.251	.629	.335
	N	12	12	11	11	11	9	9	9
accuracy in velocity left in-phase fast	Pearson Correlation	-.366	.233	-.060	.062	-.010	.304	.580	.637
	Sig. (2-tailed)	.241	.465	.861	.857	.978	.426	.102	.065
	N	12	12	11	11	11	9	9	9
accuracy in velocity left in-phase slow	Pearson Correlation	.087	.364	-.214	-.472	-.417	.443	.288	.534
	Sig. (2-tailed)	.788	.245	.528	.143	.202	.232	.452	.138
	N	12	12	11	11	11	9	9	9
accuracy in velocity right in-phase fast	Pearson Correlation	-.247	.302	-.205	-.039	-.179	.283	.530	.619
	Sig. (2-tailed)	.438	.339	.545	.909	.596	.460	.142	.076
	N	12	12	11	11	11	9	9	9
accuracy in velocity right in-phase slow	Pearson Correlation	.083	.347	-.195	-.469	-.401	.447	.272	.520
	Sig. (2-tailed)	.798	.269	.565	.145	.222	.228	.479	.151
	N	12	12	11	11	11	[illegible]	9	9

acuracy coordination in-phase fast	Pearson Correlation	-.048	-.154	-.212	-.174	-.131	.248	.354	.311
	Sig. (2-tailed)	.883	.634	.530	.609	.701	.521	.350	.416
	N	12	12	11	11	11	9	9	9
variation coordination in-phase slow	Pearson Correlation	-.455	-.443	-.145	.181	-.011	-.214	-.056	-.238
	Sig. (2-tailed)	.138	.149	.671	.594	.974	.580	.887	.537
	N	12	12	11	11	11	9	9	9
variation in coordination in-phase fast	Pearson Correlation	-.614(*)	-.525	.179	.077	.254	.286	.274	.235
	Sig. (2-tailed)	.034	.080	.598	.821	.451	.456	.475	.543
	N	12	12	11	11	11	9	9	9
variation in velocity left in-phase fast	Pearson Correlation	-.211	-.584(*)	.264	.177	.460	.542	.483	.351
	Sig. (2-tailed)	.511	.046	.432	.602	.154	.132	.187	.355
	N	12	12	11	11	11	9	9	9
variation in velocity left in-phase slow	Pearson Correlation	.021	-.514	-.189	-.277	-.225	.379	.065	.098
	Sig. (2-tailed)	.949	.087	.578	.410	.506	.315	.869	.802
	N	12	12	11	11	11	9	9	9
variation in velocity right in-phase fast	Pearson Correlation	-.088	-.486	.066	.024	.230	.510	.446	.343
	Sig. (2-tailed)	.785	.109	.847	.944	.495	.161	.229	.366
	N	12	12	11	11	11	9	9	9

variation in velocity right in-phase slow	Pearson Correlation	-.003	-.466	-.160	-.363	-.255	.385	.046	.114
	Sig. (2-tailed)	.992	.127	.639	.272	.448	.306	.907	.770
	N	12	12	11	11	11	9	9	9

P.14 Correlations of in-phase task variables with ADDES rating scale scores for normal children.

		IQ	AGE	RSHIN	RSHHYP	RSHPERC	RSSIN	RSSHYP	RSSPERC
accuracy coordination in-phase slow	Pearson Correlation	-.226	-.663(*)	-.713(**)	-.003	-.327	-.352	.347	-.014
	Sig. (2-tailed)	.479	.019	.009	.993	.299	.393	.400	.973
	N	12	12	12	12	12	8	8	8
accuracy in velocity left in-phase fast	Pearson Correlation	-.146	.130	-.093	.374	-.135	.186	.498	.334
	Sig. (2-tailed)	.650	.688	.775	.231	.677	.660	.210	.419
	N	12	12	12	12	12	8	8	8
accuracy in velocity left in-phase slow	Pearson Correlation	-.133	-.477	-.372	.550	.062	-.093	.323	.111
	Sig. (2-tailed)	.681	.117	.234	.064	.849	.827	.435	.794
	N	12	12	12	12	12	8	8	8
accuracy in velocity right in-phase fast	Pearson Correlation	-.151	.092	-.136	.401	-.099	.168	.477	.311
	Sig. (2-tailed)	.639	.776	.674	.196	.759	.691	.232	.454

	N	12	12	12	12	12	8	8	8
accuracy in velocity right in-phase slow	Pearson Correlation	-.126	-.471	-.368	.550	.063	-.090	.320	.109
	Sig. (2-tailed)	.697	.122	.240	.064	.846	.832	.440	.796
	N	12	12	12	12	12	8	8	8
acuracy coordination in-phase fast	Pearson Correlation	-.179	-.445	-.412	-.415	-.681(*)	-.637	-.002	-.315
	Sig. (2-tailed)	.577	.147	.184	.180	.015	.089	.996	.448
	N	12	12	12	12	12	8	8	8
variation coordination in-phase slow	Pearson Correlation	-.017	-.289	-.011	.320	.276	-.053	-.160	-.283
	Sig. (2-tailed)	.959	.362	.972	.310	.384	.902	.706	.498
	N	12	12	12	12	12	8	8	8
variation in coordination in-phase fast	Pearson Correlation	-.010	.170	.283	.040	-.066	-.130	-.118	-.219
	Sig. (2-tailed)	.976	.598	.373	.902	.839	.758	.781	.602
	N	12	12	12	12	12	8	8	8
variation in velocity left in-phase fast	Pearson Correlation	.132	.191	.240	-.202	-.388	-.488	-.684	-.663
	Sig. (2-tailed)	.682	.552	.452	.529	.213	.220	.061	.073
	N	12	12	12	12	12	8	8	8
variation in velocity left in-phase slow	Pearson Correlation	.074	-.495	-.065	-.192	-.090	-.043	-.326	-.348
	Sig. (2-tailed)	.818	.102	.840	.550	.781	.920	.431	.399
	N	12	12	12	12	12	8	8	8
variation in velocity right in-phase fast	Pearson Correlation	.066	.051	.080	-.176	-.517	-.846(**)	-.661	-.809(*)
	Sig. (2-tailed)	.840	.875	.805	.583	.086	.008	.074	.015
	N	12	12	12	12	12	8	8	8

variation in velocity right in-phase slow	Pearson Correlation	-.228	-.559	-.301	-.110	-.045	.028	-.008	-.125
	Sig. (2-tailed)	.476	.059	.341	.733	.889	.947	.985	.768
	N	12	12	12	12	12	8	8	8

P.15 Correlations between out-of-phase task variables and ADDES rating scale scores for unmedicated ADHD children.

		IQ	AGE	RSHIN	RSHHYP	RSHPERC	RSSIN	RSSHYP	RSSPERC
accuracy coordination out-phase fast	Pearson Correlation	-.201	-.013	-.096	-.030	-.182	.188	.358	.269
	Sig. (2-tailed)	.530	.967	.780	.929	.593	.628	.344	.483
	N	12	12	11	11	11	9	9	9
accuracy coordination out-phase slow	Pearson Correlation	-.132	-.077	-.426	-.050	-.327	.170	.312	.211
	Sig. (2-tailed)	.683	.812	.192	.885	.327	.662	.414	.586
	N	12	12	11	11	11	9	9	9
accuracy in velocity left out-phase fast	Pearson Correlation	-.097	.449	-.179	.051	-.120	.173	.513	.591
	Sig. (2-tailed)	.765	.143	.599	.881	.726	.655	.158	.094
	N	12	12	11	11	11	9	9	9
accuracy in velocity left out-phase slow	Pearson Correlation	-.236	.427	.035	-.276	-.218	.250	.256	.476
	Sig. (2-tailed)	.460	.167	.919	.412	.520	.517	.506	.195

	N	12	12	11	11	11	9	9	9
accuracy in velocity right out-phase fast	Pearson Correlation	-.177	.436	-.196	.065	-.122	.142	.516	.582
	Sig. (2-tailed)	.582	.156	.563	.850	.721	.715	.155	.100
	N	12	12	11	11	11	9	9	9
accuracy in velocity right out-phase slow	Pearson Correlation	-.157	.410	-.040	-.384	-.330	.267	.162	.423
	Sig. (2-tailed)	.626	.186	.907	.244	.321	.488	.678	.257
	N	12	12	11	11	11	9	9	9
variation in coordination out-phase fast	Pearson Correlation	-.225	-.461	.455	.092	.579	.143	.125	-.081
	Sig. (2-tailed)	.481	.132	.159	.787	.062	.715	.749	.836
	N	12	12	11	11	11	9	9	9
variation in coordination out-phase slow	Pearson Correlation	-.410	-.388	.540	.513	.650(*)	.240	.299	.030
	Sig. (2-tailed)	.185	.213	.087	.107	.030	.534	.434	.939
	N	12	12	11	11	11	9	9	9
variation in velocity left out-phase fast	Pearson Correlation	-.388	-.591(*)	.190	.184	.317	-.035	-.027	-.217
	Sig. (2-tailed)	.213	.043	.577	.587	.342	.928	.945	.574
	N	12	12	11	11	11	9	9	9
variation in velocity left out-phase slow	Pearson Correlation	-.436	-.679(*)	.331	.232	.425	-.104	-.192	-.364
	Sig. (2-tailed)	.157	.015	.319	.492	.192	.790	.621	.335

	N	12	12	11	11	11	9	9	9
variation in velocity right out-phase fast	Pearson Correlation	-.438	-.508	.209	.577	.519	-.130	.121	-.211
	Sig. (2-tailed)	.154	.092	.538	.063	.102	.738	.756	.586
	N	12	12	11	11	11	9	9	9
variation in velocity right out-phase slow	Pearson Correlation	-.416	-.725(**)	.199	.010	.202	-.087	-.384	-.459
	Sig. (2-tailed)	.178	.008	.557	.976	.552	.823	.308	.214
	N	12	12	11	11	11	9	9	9

P.16 Correlations between out-of-phase task variables and ADDES rating scale scores for normal children.

		IQ	AGE	RSHIN	RSHHYP	RSHPERC	RSSIN	RSSHYP	RSSPERC
accuracy coordination out-phase fast	Pearson Correlation	-.296	-.730(**)	-.412	-.007	-.188	-.063	.593	.326
	Sig. (2-tailed)	.350	.007	.183	.983	.559	.883	.122	.431
	N	12	12	12	12	12	8	8	8
accuracy coordination out-phase slow	Pearson Correlation	-.139	-.656(*)	-.227	-.149	-.048	-.716(*)	-.031	-.309
	Sig. (2-tailed)	.667	.021	.478	.643	.882	.046	.942	.457
	N	12	12	12	12	12	8	8	8

accuracy in velocity left out-phase fast	Pearson Correlation	.259	.354	.010	.183	.003	.081	-.105	-.015
	Sig. (2-tailed)	.416	.259	.975	.570	.992	.848	.805	.971
	N	12	12	12	12	12	8	8	8
accuracy in velocity left out-phase slow	Pearson Correlation	.324	.379	.130	.125	.154	.018	-.477	-.276
	Sig. (2-tailed)	.304	.225	.687	.700	.634	.966	.232	.508
	N	12	12	12	12	12	8	8	8
accuracy in velocity right out-phase fast	Pearson Correlation	.275	.398	.094	.120	.074	.191	-.185	-.014
	Sig. (2-tailed)	.387	.200	.770	.711	.820	.651	.661	.973
	N	12	12	12	12	12	8	8	8
accuracy in velocity right out-phase slow	Pearson Correlation	.305	.410	.138	.055	.118	.021	-.510	-.281
	Sig. (2-tailed)	.335	.186	.668	.865	.715	.961	.196	.500
	N	12	12	12	12	12	8	8	8
variation in coordination out-phase fast	Pearson Correlation	.068	.124	.123	.294	-.018	-.406	.182	-.033
	Sig. (2-tailed)	.833	.701	.704	.353	.955	.318	.667	.938
	N	12	12	12	12	12	8	8	8
variation in coordination out-phase slow	Pearson Correlation	.053	-.101	-.074	.403	.274	-.134	.301	.062
	Sig. (2-tailed)	.870	.755	.819	.195	.389	.752	.468	.883
	N	12	12	12	12	12	8	8	8
variation in velocity left out-phase fast	Pearson Correlation	.135	-.259	-.027	-.150	.009	-.513	-.215	-.338
	Sig. (2-tailed)	.675	.417	.933	.642	.977	.193	.610	.413
	N	12	12	12	12	12	8	8	8

variation in velocity left out-phase slow	Pearson Correlation	.088	-.436	-.071	.018	.182	-.354	-.051	-.207
	Sig. (2-tailed)	.785	.156	.82[illegible]	.957	.570	.389	.905	.623
	N	12	12	12	12	12	8	8	8
variation in velocity right out-phase fast	Pearson Correlation	.289	-.544	-.326	-.235	-.115	-.714(*)	-.297	-.458
	Sig. (2-tailed)	.363	.068	.302	.463	.722	.047	.475	.253
	N	12	12	12	12	12	8	8	8
variation in velocity right out-phase slow	Pearson Correlation	-.282	-.316	-.091	-.196	-.039	.112	.343	.304
	Sig. (2-tailed)	.374	.316	.778	.541	.905	.792	.406	.464
	N	12	12	12	12	12	8	8	8

APPENDIX Q: COUNTERBALANCING FOR THE BIMANUAL COORDINATION TASK IN EXPERIMENT 13

OFF MEDICATION

In-phase movement at slow speed

In-phase movement at fast speed

Out-of-phase movement at slow speed

ON MEDICATION

In-phase movement at fast speed

In-phase movement at slow speed

Out-of-phase movement at slow speed

ON MEDICATION

Out-of-phase movement at slow speed

In-phase movement at slow speed

In-phase movement at fast speed

OFF MEDICATION

Out-of-phase movement at slow speed

In-phase movement at fast speed

In-phase movement at slow speed

APPENDIX R: ANALYSES FOR EXPERIMENT 13

R.1 Variation in coordination pattern.

Descriptives

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	on med variation coordination inphase slow	18.483058	6	5.558025	2.269422
	off med variation coordination inphase slow	39.837067	6	13.645527	5.570763
Pair 2	on med variation coordination inphase fast	22.459878	6	5.735372	2.341456
	off med variation coordination inphase fast	33.928982	6	12.656364	5.166939
Pair 3	on med variation coordination outphase slow	61.862465	6	13.626840	5.563134
	off med variation coordination outphase slow	73.406575	6	18.969915	7.744435

Paired t-tests

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	on med variation coordination inphase slow - off med variation coordination inphase slow	-21.354008	9.511913	3.883222	-5.499	5	.003
Pair 2	on med variation coordination inphase fast - off med variation coordination inphase fast	-11.469103	16.557640	6.759628	-1.697	5	.151
Pair 3	on med variation coordination outphase slow - off med variation coordination outphase slow	-11.544110	13.422843	5.479853	-2.107	5	.089

R.2 Accuracy of coordination pattern.

Descriptives

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	on med accuracy coord inphase slow	10.962375	6	5.726527	2.337845
	off med accuracy coordination inphase slow	11.494843	6	5.040916	2.057945
Pair 2	on med accuracy coordination inphase fast	20.397350	6	9.124539	3.725077
	off med accuracy coordination inphase fast	26.730550	6	10.725380	4.378618
Pair 3	on med accuracy coordination outphase slow	62.629758	6	28.466438	11.621375
	off med accurcay coordination outphase slow	48.526070	6	39.748037	16.227068

Paired t-tests

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	on med accuracy coord inphase slow - off med accuracy coordination inphase slow	-.532468	6.502827	2.654768	-.201	5	.849
Pair 2	on med accuracy coordination inphase fast - off med accuracy coordination inphase fast	-6.333200	19.126121	7.808206	-.811	5	.454
Pair 3	on med accuracy coordination outphase slow - off med accurcay coordination outphase slow	14.103688	41.256246	16.842792	.837	5	.441

R.3 Variation in velocity.

Descriptives

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	ONVVLIS	.203750	6	3.79153E-02	1.54788E-02
	OFFVVLIS	.335655	6	.182572	7.45347E-02
Pair 2	ONVVRIS	.209365	6	5.46040E-02	2.23737E-02
	OFFVVRIS	.330992	6	.174821	7.13703E-02
Pair 3	ONVVLIF	.198335	6	1.16659E-02	4.76260E-03
	OFFVVLIF	.353703	6	.106123	4.33245E-02
Pair 4	ONVVRIF	.217552	6	4.23254E-02	1.72793E-02
	OFFVVRIF	.348802	6	.140864	5.75074E-02
Pair 5	ONVVLOS	.305772	6	5.88248E-02	2.40151E-02
	OFFVVLOS	.254902	6	3.89388E-02	1.58967E-02
Pair 6	ONVVROS	.248712	6	5.91731E-02	2.41573E-02
	OFFVVROS	.248952	6	3.31704E-02	1.35417E-02

Paired t-tests

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	ONVVLIS - OFFVVLIS	-.131905	.163417	6.67146E-02	-1.977	5	.105
Pair 2	ONVVRIS - OFFVVRIS	-.121627	.139684	5.70257E-02	-2.133	5	.086
Pair 3	ONVVLIF - OFFVVLIF	-.155368	.107637	4.39426E-02	-3.536	5	.017
Pair 4	ONVVRIF - OFFVVRIF	-.131250	.143209	5.84646E-02	-2.245	5	.075
Pair	ONVVLOS -	5.08700E-02	8.10260E-02	3.30787E-02	1.538	5	.185

5	OFFVVLOS						
Pair 6	ONVVROS - OFFVVROS	-2.400000E-04	4.41080E-02	1.80070E-02	-.013	5	.990

R.4 Accuracy of velocity.

Descriptives

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	ONAVLIS	-.120705	6	.129965	5.30578E-02
	OFFAVLIS	2.63300E-02	6	8.38815E-02	3.42445E-02
Pair 2	ONAVRIS	-.114520	6	.130110	5.31174E-02
	OFFAVRIS	-1.243833E-02	6	9.91482E-02	4.04771E-02
Pair 3	ONAVLIF	.351607	6	.374461	.152873
	OFFAVLIF	5.30550E-02	6	.298005	.121660
Pair 4	ONAVRIF	.350472	6	.369764	.150955
	OFFAVRIF	2.24950E-02	6	.294739	.120327
Pair 5	ONAVLOS	.249017	6	.204575	8.35175E-02
	OFFAVLOS	.283630	6	.157408	6.42616E-02
Pair 6	ONAVROS	.156498	6	.155778	6.35962E-02
	OFFAVROS	.200865	6	9.51404E-02	3.88409E-02

Paired t-tests

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	ONAVLIS - OFFAVLIS	-.147035	.153473	6.26553E-02	-2.347	5	.066
Pair 2	ONAVRIS - OFFAVRIS	-.102082	.128872	5.26117E-02	-1.940	5	.110

Pair 3	ONAVLIF - OFFAVLIF	.298552	.335412	.136931	2.180	5	.081
Pair 4	ONAVRIF - OFFAVRIF	.327977	.361809	.147708	2.220	5	.077
Pair 5	ONAVLOS - OFFAVLOS	-3.461333E-02	9.23373E-02	3.76965E-02	-.918	5	.401
Pair 6	ONAVROS - OFFAVROS	-4.436667E-02	.117762	4.80761E-02	-.923	5	.398

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