



MONASH University

**The Development and Implementation of Research Methods to Examine
Resilience to Major Daily Stressors**

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Abstract

The construct of resilience concerns the achievement of positive outcomes despite adversity. Exposure to adversity imposes risks to mental health and well-being, and can lead to unfavourable psychological outcomes. This can result from even common stressors characterising everyday life. These stressors occur frequently and can sometimes be highly distressing experiences, or ‘major daily stressors’. Understanding the mechanisms through which resilience manifests following these stressors is important for the development of reliable and effective interventions aiming to cultivate resilience. Existing research methods used to develop this understanding, however, are theoretically and methodologically constrained, and can be improved to enhance empirical studies in this field of research. The current thesis presents the development and implementation of a novel, stand-alone research methodology enabling examination of factors facilitating resilience to major daily stressors.

The first step in this endeavour involves demonstrating the utility of a contemporary means of data collection for real-time assessment of psychological responses to daily stressors (Paper #1). In a sample of 48 participants (12 male, 35 female, 1 another gender identity; $M_{age} = 34.5$, $SD = 13.98$), a smartphone-based Experience-Sampling-Application (ESA) was implemented, which successfully monitored daily variations in depressive symptoms and recorded the date, nature, and severity of stressors experienced over time. Importantly, the ESA achieved this while offering valuable advantages to participants (reduced experimental burdens and positive user experiences) and researchers (decreased resource demands and increased accessibility to the ESM).

This method of data collection enabled empirical investigation of prototypical ways individuals respond to major daily stressors (Paper #2). Methodological procedures to process and classify stress responses were developed, and applied to experience-sampling data collected from 122 participants (37 male, 84 female, 1 another gender identity; $M_{age} = 29.64$,

$SD = 11.80$) who downloaded the smartphone ESA. This yielded four distinct trajectories of responding: a vulnerable, delayed, recovery, and stress-resistant group. Each group reflects a collection of responses sharing similar trajectory features (initial reactivity and patterns of recovery). The stress-resistant trajectory was deemed the most favourable outcome and most representative of resilience. It was characterised by minimal initial reactivity on the stressor day, which was maintained after several days.

These findings formed the basis for the modelling of relationships between select person-specific factors (age, self-esteem, and social support) and abovementioned trajectory groups (Paper #3). This was conducted in a sample of 90 participants selected from the previous study (30 male, 60 female; $Mage = 29.82$, $SD = 10.91$). Results demonstrated significant influences of age and social support, but not self-esteem, on odds of participant classification into particular trajectory groups. Specifically, when considered alone, older age and higher levels of perceived social support were associated with delayed trajectory classification (an undesirable pattern of responding). An interaction effect, however, revealed that older age and social support positively influence responses toward stress-resistance when considered together. Study findings highlight the differential effects that age and social support can have on shaping psychological responses to major daily stressors, and emphasise their individual and interactive roles within resilience processes.

Individual papers presented in the current thesis provide meaningful contributions to existing research literature. When considered together, the papers demonstrate the operation of a new research methodology to investigate resilience to major daily stressors. This methodology addresses limitations of previous research methods, and helps advance the study of resilience in the context of daily stressors. Outcomes achieved from implementing such research methods also add new insights to current understandings of resilience processes, and potentially have real world applications in clinical and community settings.

General Declaration

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes three original papers submitted for publication in peer reviewed journals.

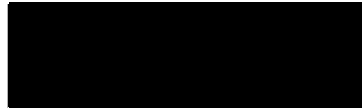
The ideas, development and writing up of all the papers in the thesis were the principal responsibility of myself, the student, working within the School of Psychological Sciences under the supervision of Adjunct Associate Professor Nikki Rickard.

In the case of Chapters 2 – 4 my contribution to the work involved the following:

Thesis Chapter	Publication Title	Status	Nature and % of student contribution	Co-author name(s) Nature and % of Co-author's contribution	Co-author(s), Monash student Y/N*
2	Exploring the utility of a smartphone Experience-Sampling-Application (ESA) for investigating resilience to daily stressors	Manuscript submitted for publication	80% contribution by the student: study design, data collection, data processing, statistical analyses, interpretation, and writing of manuscript	Nikki Rickard, input into manuscript 20%	No
3	The implementation of an Experience-Sampling-Method capturing trajectories of psychological responding following a major daily stressor	Manuscript submitted for publication	80% contribution by the student: study design, data collection, data processing, statistical analyses, interpretation, and writing of manuscript	Nikki Rickard, input into manuscript 20%	No
4	Influences of age, self-esteem, and perceived social support on psychological responses following a major daily stressor	Manuscript submitted for publication	80% contribution by the student: study design, data collection, data processing, statistical analyses, interpretation, and writing of manuscript	Nikki Rickard, input into manuscript 20%	No

Adjunct Associate Professor Nikki Rickard supervised the design and implementation of the entire research project, attained ethics approval (acting as Chief Investigator), assisted conducting statistical analyses, aided interpretation of study findings, and co-authored all submitted manuscripts. Professor Dianne Vella-Brodrick provided consultations throughout development of the research project and provided feedback on the final thesis.

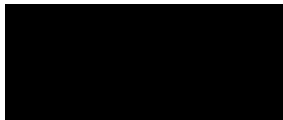
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The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the student's and co-authors' contributions to this work. In instances where I am not the responsible author I have consulted with the responsible author to agree on the respective contributions of the authors.

Main Supervisor signature:



Date: 2/4/2018

List of Publications and Presentations During Candidature

Published Papers:

Rickard, N., Arjmand, H-A., Bakker, D., & Seabrook, E. (2016). Development of a mobile phone app to support self-monitoring of emotional well-being: A mental health digital innovation. *JMIR Mental Health*, 3(4), e49.

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Arjmand, H-A., & Rickard, N. (2018). The implementation of an Experience-Sampling-Method capturing trajectories of psychological responding following a major daily stressor. *International Journal of Stress Management, Manuscript submitted for publication.*

Arjmand, H-A., & Rickard, N. (2018). Influences of age, self-esteem, and perceived social support on psychological responses following a major daily stressor. *Social Indicators Research, Manuscript submitted for publication.*

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Thesis Overview

The experience of adversity is common and relevant to the global population. Adversity is most often unpleasant, and can overcome individual capacities to manage distress. This can lead to unfavourable psychological outcomes including symptoms of depression and anxiety. Such outcomes can arise from even common events like daily stressors, or hassles (Almeida, Wethington, & Kessler, 2002). Psychological responses following adversities, however, are known to vary across individuals, and include manifestations of resilience (Bonanno, 2004, 2005)—the achievement of positive outcomes despite adversity (Fletcher & Sarkar, 2012). Understanding the mechanisms which facilitate resilience or vulnerability to daily stressors has great utility for developing programs and interventions serving to cultivate resilience, and prevent psychological declines toward mental illness.

Daily stressors are typically minor events, and little research has been conducted in the context of major daily stressors. Major daily stressors can be defined as a subset of daily stressors which are appraised with high negativity. These events contrast with daily stressors in general which are typically minor events rated ‘low’ or ‘medium’ in severity (Almeida et al., 2002), and potentially traumatic events (PTEs) which occur outside the experience of everyday life (Bonanno & Mancini, 2008). In order to advance understandings of mechanisms facilitating resilience in this context, empirical research methodologies must be accessible and examine resilience in reliable and valid ways. As such, the broad aim of the current thesis was to provide a working example of a novel research methodology addressing these requirements, which can be used to explore of mechanisms underlying resilience to major daily stressors. This aim was achieved through the fulfilment of two primary objectives:

1. Developing tailored research methods to capture and explore variations in psychological responses following a major daily stressor. This comprised two components:
 - a) Implementing a contemporary and temporally sensitive means of data collection suited to examinations of resilience to daily stressors (Paper #1).
 - b) Executing methodological procedures to convert experience-sampling data into trajectories of psychological responding, with subsequent classification into prototypical response groups (Paper #2).
2. Utilising these methods to investigate mechanisms facilitating resilience to major daily stressors (Paper #3).

The first component of objective 1 concerned the utility of a tailored means of data collection for the study of resilience to daily stressors. An Experience-Sampling-Method (ESM) was employed to a) accommodate the frequent, varied, and unpredictable nature of daily stressors, and b) provide momentary assessment of changes in psychological functioning over time. Notably, the ESM was delivered through a purpose-designed, smartphone-based Experience-Sampling-Application (ESA) named MoodPrism (www.moodprismapp.com). The utility of this innovative method of data collection is presented in Paper #1:

Arjmand, H-A. & Rickard, N. (2018). Exploring the utility of a smartphone Experience-Sampling-Application (ESA) for investigating resilience to daily stressors. *Assessment, Manuscript submitted for publication.*

The second component of objective 1 builds on data collection methods described in Paper #1 to advance the thesis aim. This component concerned the transformation of experience-sampling data into meaningful representations of psychological responding following a major daily stressor experience, and subsequent classification of responses into

broad categories of responding. Notably, Paper #2 adopted a trajectory-based analysis of responses to capture distinct threats posed by major daily stressors (immediate impacts on psychological functioning, and risks of stress-accumulation). Detailed descriptions of procedures to conduct such analyses are outlined in Paper #2:

Arjmand, H-A., & Rickard, N. (2018). The implementation of an Experience-Sampling-Method capturing trajectories of psychological responding following a major daily stressor. *International Journal of Stress Management, Manuscript submitted for publication.*

Isolating groups of individuals exhibiting varied patterns of responding provides a platform from which to explore person-specific factors differentiating favourable and unfavourable response trajectories. Select person-specific variables associated with resilience in previous research literature (age, self-esteem, and social support) were investigated, and their relationships with trajectory groups identified in Paper #2 were examined. Details of analyses conducted and associated findings are presented in Paper #3:

Arjmand, H-A., & Rickard, N. (2018). Influences of age, self-esteem, and perceived social support on psychological responses following a major daily stressor. *Social Indicators Research, Manuscript submitted for publication.*

The presentation of these papers is preceded by a ‘General Introduction’ which introduces the construct of resilience, and reviews empirical research methods used in previous studies to investigate resilience to daily stressors. Strengths and limitations of such methods are critically examined, and research proposals underpinning aims of papers in the current thesis are emphasised. The thesis concludes with a ‘General Discussion’ which draws together principle components of the thesis and discusses theoretical and practical implications of research findings. Strengths and limitations of the thesis are also described,

and several directions for future research are presented. Importantly, this section discusses how each of the three research papers achieve the overarching aim of the thesis and offer novel contributions to the existing body of resilience research literature.

As this thesis is presented in line with Monash University guidelines as a “thesis by publication”, the chapters within consist of individual research papers submitted for publication. Therefore, due to the nature of the format of this thesis and established guidelines of Monash University, there will be some unavoidable repetition throughout the chapters. This is primarily because the same concepts, definitions, and arguments introduced or discussed in the thesis, are also separately relevant in each submitted paper.

Chapter 1: General Introduction

1. An introduction to Resilience and Adversity

Adversity is a consistent feature of life affecting the global population. While adversity can in some circumstances be considered positive, it is generally viewed as hardship linked to difficulty, misfortune, or trauma (see Fletcher & Sarkar, 2012). For decades researchers explored the development of psychopathology in high-risk populations, with studies taking interest in the heterogeneity of outcomes between individuals (Garmezy, 1991; Masten, 1989, 2001, 2007; Rutter, 1979; Werner, 1995; Werner & Smith, 1982). Over time, the scope of such research narrowed, focusing on positive adaptation following adversity, and subsequently developed into the study of resilience (see Masten, 2011; Masten & Narayan, 2012; Rutter, 2006). Masten, Best, and Garmezy (1990) define resilience as “the dynamic process of, capacity for, or outcome of successful adaptation despite challenging or threatening circumstances” (p. 426). Two core principles are captured within this definition and are common to most conceptualisations of resilience; 1) exposure to adversity, and 2) the manifestation of positive adaptation (Fletcher & Sarkar, 2012).

The experience of adversity encompasses exposure to unfavourable circumstances often associated with maladjustment or psychopathology (Luthar & Cicchetti, 2000). Early resilience studies conducted research with juvenile populations exposed to adversities chronic and enduring in nature, including socioeconomic disadvantage (Buckner, Mezzacappa, & Beardslee, 2003; Garmezy, 1991; Werner, 1992; Werner & Smith, 1982), parental mental illness (Masten & Coatsworth, 1998), maltreatment (Beeghly & Cicchetti, 1994; Cicchetti & Rogosch, 1997; Cicchetti, Rogosch, Lynch, & Holt, 1993), or urban poverty and community violence (Luthar, 1999; Martinez & Richters, 1993). Such circumstances pose direct risks to

psychological development and involve a set range of interrelated and dependent stressors linked to the chronic adversity.

Resilience has also been studied in the context of potentially traumatic events (PTEs) (Bonanno, 2004; Bonanno, Kennedy, Galatzer-Levy, Lude, & Elfrstrom, 2012; Bonanno, Field, Kovacevic, & Kaltman, 2002; Bonanno, Mancini, et al., 2012; Dolgin et al., 2007). Such events have been labelled as '*potentially* traumatic' to highlight that psychological responses are measurably heterogeneous and individual perceptions regarding the traumatic nature of events may differ (Bonanno, 2004, 2005; Bonanno & Mancini, 2008). In contrast to chronic adversity, PTEs are highly aversive, single-incident, and isolated events that typically fall outside the range of everyday experiences, causing significant disruption to typical functioning (Bonanno & Mancini, 2012). Examples of PTEs include being fired at work, suffering a major personal injury or illness, getting divorced, getting robbed, or losing a close friend/family member. Epidemiological studies have shown that the majority of people will experience at least one PTE in their lifetime (Kessler, Sonnega, Bromet, Hughes, & Nelson, 1995; Ozer, Best, Lipsey, & Weiss, 2003), and research has demonstrated undesirable outcomes associated with PTE exposure including symptoms of anxiety, post-traumatic stress, and depression (Hapke et al., 2005; Moreno-Peral et al., 2014; Paykel, 2003; Vink et al., 2009).

Inherent in conceptualisations of chronic adversity and PTEs is the notion of trauma and extreme severity. As both of these are highly adverse experiences, the importance of cultivating resilience in such contexts is self-evident. Adversity, however, manifests in a variety of ways and can lead to negative outcomes without being traumatic in nature; a primary example of this is daily stressor experiences (Almeida, 2005; Almeida Piazza, Stawski, & Klein, 2010; Charles, Piazza, Sliwinski, Mogle & Almeida, 2013; Mroczek et al., 2015; Piazza, Charles, Sliwinski, Mogle, & Almeida, 2013; Zautra, 2003). These occur as

part of everyday living, and negative effects resulting from daily stressor experiences uniquely contribute to physical and psychological distress distinct from chronic adversity and PTEs (Pearlin, Liberman, Menaghan, & Mullan, 1981; Serido, Almeida, & Wethington, 2004; Zautra, 2003). As such, although the significance of daily stressors may be less obvious due to their routine, unexceptional, and everyday nature, cultivating resilience in this context is nonetheless worthwhile.

1.1. Resilience to Daily Stressors

Daily stressors, or hassles, have been defined as the “stresses and strains of daily living” (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982, p. 120) or the minor stressors that characterise everyday life (Kanner, Coyne, Schaefer, & Lazarus, 1981). Daily stressors encompass irritants and frustrations occurring during everyday transactions with the environment, such as arguments with spouses or colleagues, overly bureaucratic encounters, or coming down with a cold. Such experiences occur frequently, with people regularly experiencing at least one per day (Almeida et al., 2002).

Daily stressors have been shown to contribute to several unfavourable outcomes. For example, a study conducted by Almeida et al. (2002) examined associations between daily stressor experiences and health outcomes, and found that the experience of daily stressors predicted increases in physical symptoms and negative mood. Such effects have been corroborated across numerous studies finding similar associations with symptoms of depression and anxiety, reductions in positive feelings, and unhealthy behaviours (DeLongis et al., 1982; DeLongis, Folkman, & Lazarus, 1988; Cassidy, 2000; Chang & Sanna, 2003; Johnson & Sherman, 1997; Kanner et al., 1981; Lohaus, Beyer, & Klein-Heßling, 2004; van Eck, Nicolson, & Berkhof, 1998). This is because, in addition to individual, immediate, and direct impacts on health and well-being, daily stressors also have the potential to accrue over a series of days to generate persistent frustrations, irritations, and overloads which can evolve

into more serious psychological disturbances (Lazarus, 1999; Schilling & Diehl, 2014; Zautra, 2003).

Deboeck and Bergeman's (2013) reservoir model provides a useful analogy of the stress-accumulation process. In this model, a reservoir is used to represent a vessel within which stress can accumulate. As stressors are experienced, 'liquid' enters the reservoir, filling it up, representing an accumulation of stress. Rather than allowing stress to accumulate unabated, people generally dissipate stress, with varying degrees of efficacy. Propensities to dissipate stress are represented by an outlet at the bottom of the reservoir from which liquid can drain. Individuals with large outlets can dissipate stress well, consistently reducing any accumulating stress. Individuals with small outlets are less efficient and are at risk of accumulating stress when stressors occur in succession. This is because the rate of stress exposure can easily overcome the rate of dissipation permitted by small outlets, leading to a build-up of unresolved stress or 'emotional residue' (Scott, Ram, Smyth, Almeida, & Sliwinski, 2017). The negative effects of such stress accumulation are indicated across numerous studies. Research suggests that the experience of successive stressors in a short period of time has negative physical and psychological consequences (Bolger & Schilling, 1991; Grzywacz, Almeida, & McDonald, 2002; Schilling & Diehl, 2014). For example, a study conducted by Schilling and Diehl (2014) showed that increases in daily stressor frequency and severity, or 'stressor pile-up', over a one week period resulted in increased reports of negative affect above and beyond effects of concurrent stressors. As illustrated in the reservoir model, this reflects an incremental accumulation of stress from individual stressors experienced in succession which ultimately gives rise to unfavourable health outcomes (Bergeman & Deboeck, 2014; Deboeck & Bergeman, 2013).

1.1.1. Minor versus Major Daily Stressors. Although daily stressors are commonly appraised as minor events, they can also be highly distressing experiences. This is

exemplified in several measures of daily stressor experiences, which accommodate ratings of stressor severity along a continuum. For example, Kanner et al. (1981) developed a daily hassles inventory which presents participants a list of over 100 hassles to be rated as either “somewhat severe”, “moderately severe”, or “extremely severe” if they were experienced in the previous month. Other measures of daily stressor experiences, or hassles, assess the severity of stressors in similar ways (Almeida et al., 2002; Brantley, Waggoner, Jones, & Rappaport, 1987). This highlights that, despite possessing objective severity characteristics that are clearly distinct from chronic adversity and PTEs, ratings of severity may also vary between separate daily stressor experiences. As such, while some daily stressors may be less severe in nature, others may generate higher levels of distress and be considered more major events or ‘major daily stressors’.

Major daily stressors can be defined as a subset of daily stressor experiences with high severity ratings. Although ratings scales of severity differ across measures of daily stressor experiences (Almeida et al., 2002; Brantley et al., 1987; Kanner et al., 1981), ‘high severity ratings’ defining major daily stressors may be considered ratings exceeding moderate levels of severity. This is because, in general, daily stressors are typically minor events rated as ‘low’ or ‘medium’ in severity (Almeida et al., 2002). Consistent with previous research, which considers the ‘potential’ nature of traumatic or distressing events (Bonanno, 2004, 2005; Bonanno & Mancini, 2008), the severity rating of a given daily stressor involves a degree of subjectivity. Like PTEs, individual daily events are likely to be perceived differently from person to person and, as such, categorisation of stressors as ‘minor’ or ‘major’ depends on individual experience. This notion also explains why other means of distinction, such as the type of stressor experienced (e.g., ‘a poor night’s sleep’ versus ‘having to wait in line at the bank’), may be less useful as compared to distinctions based on severity ratings. Specifically, it becomes difficult to classify one type of daily stressor as

minor events, and others as major events, when the subjective experience of daily stressors differs across individuals.

Targeted distinctions between minor and major daily stressors are generally lacking in daily stressor research (Diehl & Hay, 2010, 2013; Neupert, Almeida, & Charles, 2007). Despite using measures that assess the severity of daily stressors, these studies do not examine minor and major daily stressors separately. Given that daily stressors are typically rated as ‘low’ or ‘medium’ in severity (Almeida et al., 2002), the proportion of stressors experienced by participants in previous studies is likely biased towards minor events. Consequently, scant research appears to exist examining resilience with a targeted focus on major daily stressors, and render findings of previous studies less applicable in this context.

Exploring resilience to major daily stressors is important as they are likely to engender greater risks to psychological functioning than posed by minor daily stressors. Although little is understood regarding major daily stressors, it could be reasoned these stressors share stressor-specific characteristics of PTEs and minor daily stressors. For instance, major daily stressors might incur large direct impacts on psychological functioning like PTEs. In addition to this, like minor daily stressors, major daily stressors might also occur frequently, possibly in succession, and engender risks of stress-accumulation. Major daily stressors would therefore be more severe than minor ones (although not as severe as PTEs), and occur more frequently than PTEs (although not as frequent as minor daily stressors). As such, it is important to characterise patterns of resilience to major daily stressors and examine factors which promote favourable responding, as it is not known whether they are identical across all stressor severities. For example, profiles of resilience to major daily stressors may manifest similarly to those in response to PTEs; in such cases, people’s varying capacity to cope after a trauma could be anticipated by their capacity to cope with the more frequent major daily stressors. Another possibility may be that factors

promoting favourable responses to major daily stressors may vary from those identified in previous studies. Cultivating resilience to major daily stressors could therefore require enhancement of a distinct range of personal attributes or coping strategies, separate from those facilitating resilience to other forms of adversity.

1.2. A Model of Stress and Resilience

Understanding the mechanisms facilitating resilience to daily stressors is important to curb declines in mental health and development of psychopathological outcomes.

Consequently, a theme of resilience research has been to explore variations in psychological responses following adversity and accurately identify manifestations of positive adaptation (e.g., Bonanno & Mancini, 2012; Noor & Alwi, 2013). This aids differentiation between resilient and non-resilient responders, and is useful for identifying potential factors which may be facilitating individual resilience and vulnerability. This information can be used in a range of settings to combat daily stress and improve mental health and well-being. For example, it can be used to inform the development of resilience programs for clinical and non-clinical populations, support preventative screening of at risk individuals, and create educational material to boost resilience of the general public.

Existing models of stress and resilience are multifaceted and postulate that well-being outcomes following adversity are influenced by numerous interacting factors (Almeida, 2005; Kumpfer, 2002; Lazarus & Folkman, 1984). For example, a framework of resilience developed by Kumpfer (2002) suggests that active coping behaviours and voluntary stress-management strategies are important factors in processes of resilience which may influence adaptation following adversity. For instance, individuals may adopt ‘assimilative’ or ‘accommodative’ coping strategies in order to ameliorate negative effects of stressor experiences (Brandstätter & Rothmund, 2002). The former refers to situations where an individual tries to actively change an adverse situation in order to ameliorate its negative

effects, like walking away from a heated argument, changing jobs, or moving to a better neighbourhood; the latter refers to strategies which aim to change subjective evaluations of the adversity, like downgrading the personal relevance of a stressor or viewing it as a challenge rather than a threat to daily living. Lazarus and Folkman's (1984) transactional model of stress and coping suggest that these depend on primary and secondary cognitive appraisals of stressor experiences. Primary cognitive appraisals determine whether the stressor or adversity is personally threatening to an individual, while the secondary cognitive appraisals refer to an evaluation of the availability of personal resources required to successfully manage the stressor and the stress it produces (Lazarus & Folkman, 1987). Together, these appraisals are thought to predict an individual's choice of coping strategies which influence psychological responses to adversity, and are important antecedents in adaptation processes.

Personal attributes are likely to influence an individual's thoughts and cognitive appraisals of incoming stressors, and are also theorised to have direct influences on psychological responses and well-being outcomes following adversity. Research studies have implicated numerous characteristics within resilience processes throughout psychological research (see Diehl, Hay, & Chui, 2012; Mancini & Bonanno, 2009; Zolkoski & Bullock, 2012). Almeida (2005) provides model of resilience, organising these characteristics into primary factors influencing outcomes following adversity—shown in Figure 1.

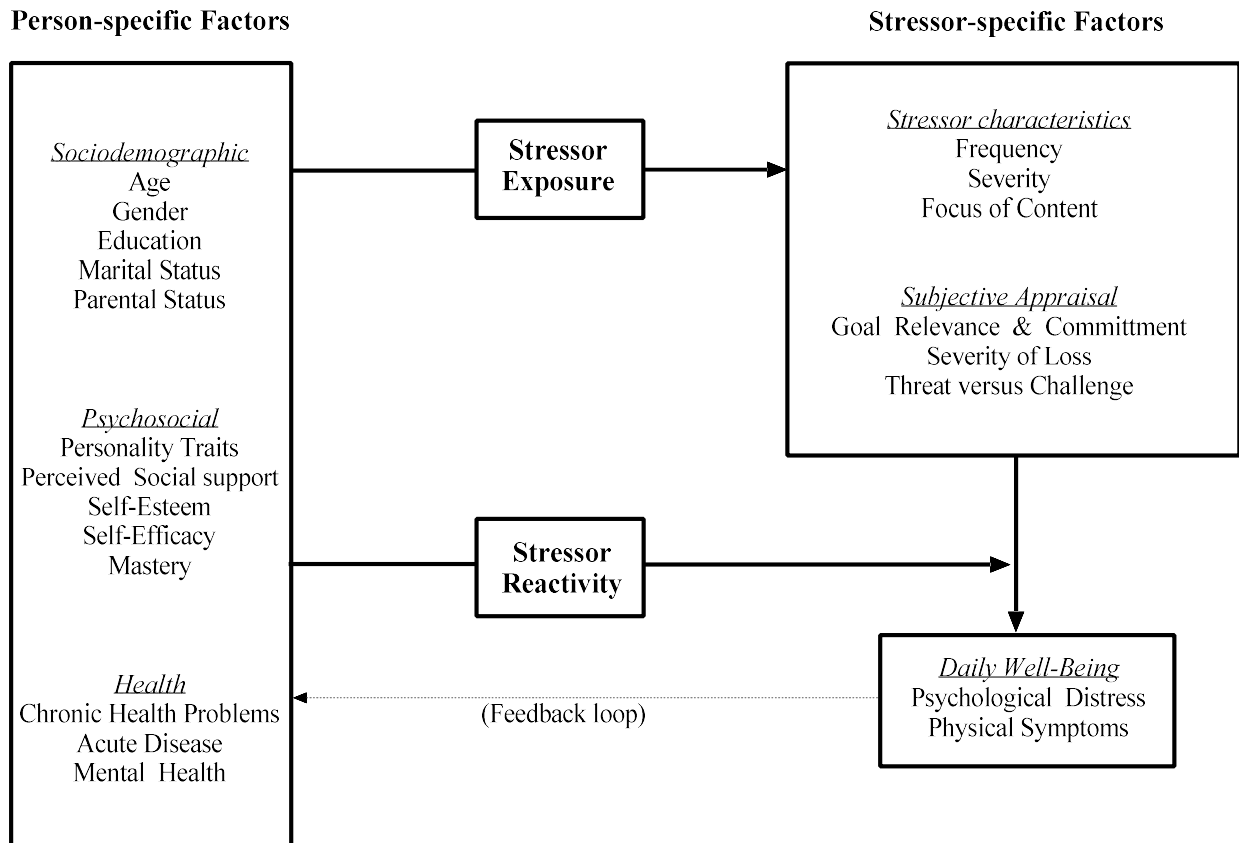


Figure 1. Conceptual model outlining key factors and subcomponents involved in resilience processes (adapted from: Almeida, 2005).

This model is a ‘protective’ type of resilience model—one of three categories of resilience models described by Garmezy, Masten, and Tellegen (1984). Protective models are useful as they highlight ‘protective factors’ (personal assets or resources) which moderate the probability of reaching a negative outcome following adversity. Importantly, such models of resilience accommodate the possibility of factors operating in varied ways to influence outcomes; for example, they may directly reduce or neutralise effects of risk factors, or they may generate “multiplicative interactions or synergistic effects in which one variable potentiate the effect of another” (Rutter, 1987, p. 106). Here, risk is synonymous with the terms ‘adversity’ or ‘stressors’ and are used interchangeably; it serves as an umbrella term

encompassing different forms of risk including chronic adversity, PTEs, and minor or major daily stressors. Protective models of resilience provide a more nuanced understanding of resilience promoting factors, and are in contrast to ‘compensatory’ models of resilience (which focus on resilience promoting factors operating independent of risk factors), or ‘challenge’ models (which focus on the development of resilience following repeated exposure to moderate levels of risk) which give less consideration to potential interactive effects.

In Almeida’s (2005) model, well-being outcomes following stressor experiences are influenced by two primary factors—person-specific and stressor-specific factors. *Person-specific* factors reflect ‘protective factors’ mentioned above (left portion of model in Figure 1) and include sociodemographic, psychosocial, and health variables. The ‘stressor reactivity’ pathway highlights that these factors can have direct influences on modulating psychological responses, attenuating or exacerbating negative outcomes typically associated with stressor experience. For example, several studies have indicated protective effects of older age, higher self-esteem, and greater social support in response to daily stressor experience (Cichy, Stawski, & Almeida, 2014; Dumont & Provost, 1999; Uchino, Berg, Smith, Pearce, & Skinner, 2006). Almeida’s (2005) model also includes a ‘stressor exposure’ pathway which highlights the possibility that person-specific factors can also influence the likelihood of experiencing particular types of stressors. For instance, older populations may be more likely to experience stressors concerning age-related physical declines or significant life events like losing close friends or family; in contrast, younger adults may experience work related difficulties or significant events tied to relationship breakdowns.

The *stressor-specific* component of the model reflects notions of risk encapsulated in the definition of protective models described above, and considers the objective characteristics that describe and differentiate stressors from one another. Importantly, it

considers the range of ways adversity may manifest. The stressor-specific component considers differences between adversities such as frequency of occurrence, severity, or focus of content. For example, daily stressors, which occur frequently and are typically considered relatively minor events (Almeida et al., 2002), can easily be differentiated from PTEs, which occur infrequently and are extremely severe in nature (Bonanno & Mancini, 2008). The stressor-specific component also emphasises that the focus of content of all stressors can vary and relate to a range of different areas of living. For example, they may relate to personal finances, physical health, interpersonal relations, within work or educational settings, or at home (Almeida et al., 2002). This is important to consider when exploring predictors of resilience as several studies have revealed the nuanced nature with which person-specific factors may facilitate resilience. For example, some factors may confer protective effects in response to interpersonal daily stressors (arguments/tensions), while other factors may mitigate effects of network stressors, healthcare stressors, work/school stressors, or home stressors (Almeida et al., 2002; Hay & Diehl, 2010).

Models of stress and resilience are notable products of empirical research literature as they describe multifaceted relationships between various factors (person-specific, stressor-specific, cognitive appraisals, or coping behaviours) and well-being outcomes; this is important as they can be used to guide the development of programs and interventions for cultivating resilience (e.g., Cohn & Pakenam, 2008; Luthans, Avey, & Patera, 2008; Millea, Liossis, Shochet, Biggs, & Donald, 2008; Steinhardt & Dolbier, 2008). For example, Steinhardt and Dolbier (2008) developed a resilience intervention aimed at improving resilience in college students, and targeted salient components of Almeida (2005) and Kumpfer's (2002) models of resilience. Specifically, the intervention aimed to enhance levels of several protective person-specific factors (optimism, positive affect, self-esteem, and self-leadership), and encouraged adaptive use of a number of problem- and emotion-focused

coping behaviour strategies. The program was implemented in a sample of 30 college students over four weeks. As compared to a wait-list group control, the intervention was found to improve dispositional resilience, levels of protective factors, and the use of more effective coping strategies. Importantly, the intervention group exhibited lower scores on psychological and psychosomatic symptoms (depressive symptoms, negative affect, perceived stress, and somatic illness) during a time of increased academic stress.

2. Research Methods Investigating Resilience to Daily Stressors

As models of stress and resilience are rooted in empirical research, it is imperative that research studies examine resilience in valid and reliable ways. The efficacy of resilience programs may be compromised if they are not grounded in studies utilising robust research methodologies. As major daily stressors represent a relatively unexplored form of adversity, research methods tailored to investigate resilience in this context are lacking. Contrastingly, several research methods have been utilised to examine resilience to daily stressors in general. These methods, however, are methodologically and theoretically constrained. Such methods can be updated and contemporised to improve the quality of research findings, aid development in the research field, and contribute towards enhancing efficacy of resilience interventions.

2.1. Investigating Resilience to Daily Stressors via Adjustment Group Classification

Several cross-sectional research studies have explored resilience to daily stressors by forming adjustment groups and exploring between-group differences (DuMont & Provost, 1999; Herman-Stahl & Petersen, 1996; Noor & Alwi, 2013). For example, Dumont and Provost (1999) surveyed 298 adolescents at a single time point, measuring previous stressor exposure (number of stressors experienced over the preceding six months) and current levels of depressive symptoms. By crossing scores of depression and stressor exposure, the authors

formed three adjustment groups: a well-adjusted group (low exposure, low symptoms), a resilient group (high exposure, low symptoms), and a vulnerable group (high exposure, high symptoms). Using discriminant function analyses, findings revealed that the resilient group was associated with higher levels of self-esteem and problem-solving-based coping strategies. Studies using similar methods allude to the involvement of several other variables in resilience processes. When compared with vulnerable group members, resilient individuals have also been found to possess higher optimism, mastery, and active coping (Herman-Stahl & Petersen, 1996), as well as better social resources like social support, mother-child communications, and teacher support (Noor & Alwi, 2013). Investigating resilience in this way permits identification of distinguishing characteristics of resilient individuals and provides researchers insights regarding possible mechanisms facilitating resilience to daily stressors. Despite this utility, forming adjustment groups using a cross-sectional approach is associated with several limitations.

One of the limitations involves biases associated with retrospective reporting. Data collected in studies requiring participants to report experiences of stressors over an extended duration are subject to recall biases (e.g., Dumont & Provost, 1999; Herman-Stahl & Petersen, 1996; Lai & Mak, 2009; Pinquart, 2009; Noor & Alwi, 2013). Recall biases are “systematic error[s] due to differences in accuracy or completeness of recall to memory of past events or experiences” (Porta, 2014, p. 240). Studies vulnerable to recall biases may lead to inaccurate reports of mood and factors surrounding stressful events (Piasecki, Huffor, Solhan, & Trull, 2007; Ptacek, Smith, Espe, & Rafferty, 2006; Stone et al., 1998). For instance, as memories are reconstructive, retrospective reports are subject to mood congruent recall—a bias influencing individuals’ memories whereby current moods affect types of memories recalled (Clark & Teasdale, 1982; Eich, Reeves, Jaeger, & Graff-Radford, 1985). Individuals experiencing positive moods may therefore be less likely to recall negatively

valanced information. ‘Availability heuristics’ may also influence memory recall—particular stressors may be easier to recall as compared to others, perhaps because of being especially memorable, unique, personally relevant, or due to their recent occurrence (Johnson & Sherman, 1997; Sloboda, O’Neill, & Ivaldi, 2001). Therefore, daily stressors may be underreported as they are typically unexceptional and routine events of daily living, unlikely to be readily available for recall when considered over extended durations. Together, these biases generate risks for inaccurate reporting of stressors experienced across time, and cast doubt on the validity of adjustment groups formed as stressor reports represent a key variable underpinning group classifications.

Considerations must also be made with regards to the frequency with which daily stressors occur. Daily stressors occur frequently, and studies examining resilience often limit participants’ expression of the number of times stressors are experienced over a given duration. This is because traditional stress scales measure the number of different stressors experienced, but not the frequency with which specific stressors occur (Sim, 2000). As scales lack provisions for participants to express the frequencies with which individual stressors are experienced, individuals experiencing a recurring stressor (e.g., misplacing car keys) numerous times over six months may receive underrepresented stressor scores. This may similarly lead to potential misclassification of participants and minimise the validity of adjustment groups formed.

2.2. Investigating Resilience to Daily Stressors via Experience-Sampling-Methods

Alternative research methods can be used to overcome the abovementioned limitations. One such method is the Experience-Sampling-Method (ESM) (Almeida, 2005; Diehl et al., 2012). The ESM assesses participants in their natural environment and aims to capture life as it is lived (Bolger, Davis, & Rafaeli, 2003). Participants are prompted regularly to complete brief on-the-spot assessments of variables of interest—such as current mood,

thoughts, or behaviours—in natural environments. The ESM overcomes limitations of retrospective methods by minimising recall biases and permitting reports of recurrent stressor experiences (Schwartz, Neale, Marco, Shiffman, & Stone, 1999; Stone et al., 1998). This is afforded through reduced durations over which participants must recall variables of interest (e.g., in the past day versus the last six months). Additionally, as assessments are conducted frequently, participants are not restricted in reporting stressor events only once; participants can report recurring stressors on separate days, providing data regarding the frequencies of specific stressor experiences over study durations.

The capacity of the ESM to accurately track temporally sensitive phenomena makes its adoption advantageous within research investigating resilience to daily stressors. Indeed, a wide range of research studies have incorporated the ESM into study designs. For example, studies frequently source experience-sampling data from the National Survey of Daily Experiences (NSDE) (Cichy et al., 2014; Koffer, Ram, Conroy, Pincus, & Almeida, 2016; Piazza et al., 2013; Sutin, et al., 2016; Wong & Almeida, 2013). The NSDE was a large scale study conducted from 1996 to 1997 which collected data from over 1200 respondents (Keys & Ryff, 1998; Lachman & Weaver, 1998; Mroczek & Kolarz, 1998). The NSDE utilised an ESM which assessed participants via telephone interviews for eight consecutive days. These studies assess stressor experiences using the Daily Inventory of Stressful Events (DISE; Almeida et al., 2002). The DISE is a semi-structured interview that collects a high level of detail regarding stressor-specific elements involved in resilience processes (Almeida et al., 2002; Almeida, 2005). More recent studies using the DISE have extended experimental durations from 8 days to 30 consecutive days (Diehl & Hay, 2010, 2013; Hay & Diehl, 2010). Using these methods, researchers collected highly detailed data which provided insight into participants' psychological responses to naturally occurring daily stressor experiences.

Daily stressor studies adopting the ESM capitalise on rich details provided by experience-sampling data, and often examine resilience by measuring outcomes of affective reactivity (Almeida et al., 2016; Charles, Piazza, Luong, & Almeida, 2009; Mroczek & Almeida, 2004; Neupert et al., 2007; Stawski, Almeida, Lachman, Tun, & Rosnick, 2010). Affective reactivity is conceptualised as the magnitude of a person's change in affect on days when stressors occur as compared to stressor free days; this difference represents the degree to which a stressor exerts influence on individual well-being (Almeida, 2005; Bolger & Zuckerman, 1995). Mounting evidence using this approach has illustrated associations between affective reactivity and increases in risk of mental disorders, chronic medical conditions, and mortality (Charles et al., 2013; Mroczek et al., 2013; Piazza et al., 2013). In contrast to forming distinct adjustment groups, these studies employ multilevel modelling analyses to capture within-person measures of affective reactivity to reflect a person's trait-like reactivity response to daily stressors, and then examine variables influencing between-person differences in the relationship between daily stress and reactivity (Cohen, Gunthert, Butler, O'Neill, & Tolpin, 2005). For example, Mroczek and Almeida (2004) examined the role of neuroticism and age on affective reactivity to daily stressors in a sample of 1012 participants. In this study, baseline assessments captured levels of neuroticism and age, while daily experience sampling tracked stressor experiences and levels of negative affect over eight consecutive days. A mixed model comprising multiple levels was formulated which captured within-persons affective reactivity at level 1, and introduced between-person variables (age and neuroticism) at level 2. Findings indicated higher reactivity to daily stressors among individuals with higher neuroticism, and individuals older in age. Several studies utilise similar research methodologies and have revealed relationships between affective reactivity and a variety of other variables—see reviews by Diehl et al. (2012) and Schilling and Diehl (2015).

Despite a wide range of research findings achieved through studies utilising this methodology, methodological and theoretical limitations constrain research in this field. Specifically, assessments of affective reactivity alone limit theoretical understandings of psychological responses to stress, and experimental burdens associated with daily assessments may impede adoption of the ESM in future research studies.

2.2.1. Limitation 1 – Partial assessment of psychological responses to stress.

Advantages granted by the ESM may not be fully harnessed through assessment of affective reactions to daily stressors alone. An underutilised strength of the ESM in the previous studies investigating resilience to daily stressors is the opportunity to capture movie-like views of psychological phenomena over time. That is, experience-sampling data can be used to examine temporal changes in psychological functioning beyond initial affective reactions to daily stressors. This is relevant because an important component of emotional responses includes subsequent patterns of recovery following initial reactions (Bonanno, 2004; Bonanno & Diminich, 2013; Scott et al., 2017). This has been demonstrated in trajectories of psychological responding identified in PTE research, and advocated in contemporary daily stress theory (Scott et al., 2017; Smyth et al., 2017).

A line of research has investigated resilience using trajectory-based methods, and examines variations in psychological responses following exposure to a primary stressor of interest; these have primarily been conducted in the context of PTEs. Bonanno and colleagues have utilised methodological designs assessing participants at multiple time points over extended durations and determined the shape and frequency of heterogeneous trajectory profiles (see Bonanno, 2004, 2005; Bonanno & Diminich, 2013; Bonanno, Westphal, & Mancini, 2011)—these are displayed in Figure 2.

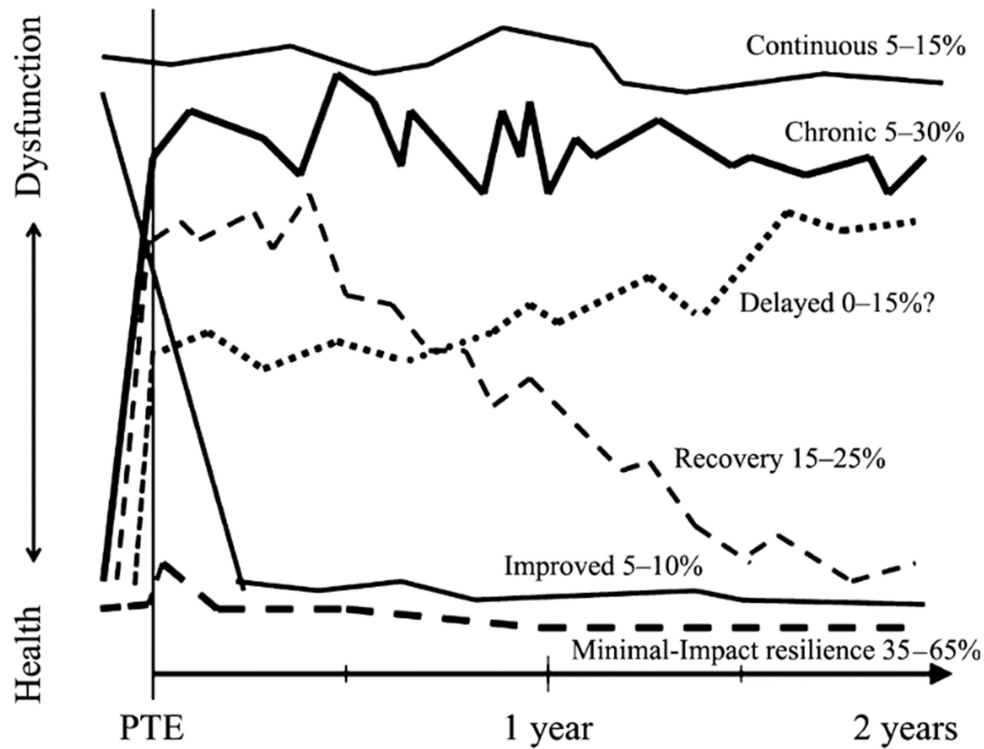


Figure 2. Prototypical trajectories following exposure to a PTE (source: Bonanno & Diminich, 2013)

Across numerous empirical studies, six distinct trajectories have been identified which characterise typical patterns of responding following a PTE. Manifestations of these trajectories have been consistent as they have been observed in response to a range of different PTEs including cancer diagnosis (Hou & Lam, 2014; Hou, Law, Yin, & Fu, 2010), physical injury (Bonanno, Kennedy, et al., 2012; Quale & Schanke, 2010; White, Driver, & Warren), sexual assault (Steenkamp, Dickstein, Salters-Pedneault, Hofmann, & Litz, 2012), spousal bereavement (Bonann, Wortman, & Nesse, 2004), a terrorist attack (Bonanno, Rennie, & Dekel, 2005), and natural disasters (Tang, 2007; Weems & Graham, 2014).

Two notable features distinguish trajectories: 1) the magnitude of initial reactions, and 2) patterns of recovery following initial reactions—for example, both chronic and recovery trajectories share large initial reactions, however diverge as the direction of the recovery trajectory returns toward healthy functioning, while chronic responses maintain high levels of dysfunction. Across research studies, resilience manifests as a stable trajectory of healthy functioning before and soon after PTE exposure which is maintained over time—expressed through the ‘minimal-impact resilience’ trajectory. Resilient individuals do not lack negative psychological response to PTEs, rather they experience transient or short-term dysregulation in emotional and physical well-being immediately after a PTE. Unlike other trajectories, however, these reactions are relatively brief, do not significantly impede functioning, and enable resilient individuals to continue meeting normal demands of daily life (Bonanno, 2004; Folkman & Moskowitz, 2000; Keltner & Bonanno, 1997; Tugade & Fredrickson, 2004).

2.2.1.1. The utility of trajectory-based assessments of psychological responses to daily stress. Trajectory-based assessments of psychological responses provide a holistic assessment of responding, and are yet to be integrated into daily stressor study designs. In addition to assessing initial reactivity alone, trajectory-based assessments also capture patterns of recovery following initial reactions. This is important in the context of investigating resilience to daily stressors as patterns of recovery following initial reactions serve as a good representation of individual capacities to dissipate stress following daily stressor experiences (Bergemann & Deboeck, 2014; Scott et al., 2017). Consequently, it accommodates the stress-accumulation mechanisms of risk associated with daily stressors, through which negative physical and psychological effects are thought to be generated. As differences in capacities to dissipate stress are integral to stress accumulation processes (Bergeman & Deboeck, 2014), examination of individual patterns of recovery are critical.

The ESM fundamentally permits trajectory-based approaches as assessments are conducted on a regular basis, resulting in multiple points of data over time for each participant. These can be sequenced to illustrate the dynamic fluctuations in psychological responses following stressor experiences. Individuals with distinct patterns of responding can be grouped, and group differences can subsequently be examined to identify factors potentially facilitating resilience.

While cross-sectional designs could be used to categorise people as such, a trajectory-based approach superior in this regard. Specifically, trajectory-based assessments enable greater sensitivity to identify resilient individuals. For example, many PTE research studies explore resilience using cross-sectional designs where an assessment is conducted months to years after exposure (e.g., Baran, 2013; Bensimon, 2012; Elad-Strenger, Fajerman, Schiller, Besser, and Shahar, 2013; Fu, Leoutsakos, & Underwood, 2013; Gan, Xie, Wang, Rodriguez, & Tang, 2013; Metzl, 2009; Nishi, Matsuoka, & Kim, 2010; Rucklidge & Blampied, 2011). Elad-Strenger et al. (2013) studied risk-resilience dynamics in the context of forced relocation among Jewish settlers, and measured psychological outcomes at a single time point six years following resettlement. The researchers examined the effects of ideological commitment and national attachment on stress and depression, and found lower levels of stress and depression in participants with lower ideological commitment and participants with higher national attachment. Although such methods could also be used to identify factors associated with individuals exhibiting lower symptoms of stress and depression following a daily stressor—albeit within a smaller time-frame like minutes, hours, or days—such methods reveal little about antecedent pathways of progression toward end outcomes, as measures of functioning are confined to a single end-point. This limits observations of heterogeneity among psychological responses. As Figure 2 shows, several trajectories exhibit similar levels of psychological functioning years after stressor exposure (e.g., minimal-

impact resilience, recovery, and improved). This is also applicable in the context of daily stressor studies examining only initial reactivity portions of psychological responding; that is, stress responses may share similar initial reactivity profiles, however differ in relation to the direction of subsequent patterns of responding (e.g., chronic and recovery patterns). Without multiple assessments over time exposure, individual pathways of progression toward end-points, or beyond initial reactions, are overlooked, and responses with distinct trajectory profiles can appear homogenous. Cross-sectional studies therefore have reduced sensitivity in differentiating resilient individuals who may be grouped with individuals achieving similar end-point levels of adjustment. This reduces the validity of findings purporting associations between predictor variables and resilience; such variables may not truly predict resilience, but rather reflect associations with individuals exhibiting response trajectories with shared features. Consequently, research methods conducting multiple assessments over time are superior to cross-sectional designs as they afford greater sensitivity to heterogeneity among psychological responses.

2.2.1.2. Improving trajectory-based assessments of psychological responses to stress. While trajectory-based assessments of psychological responding would be well-suited to investigate resilience to daily stressors, such methods can be enhanced to improve interpretability of research findings. Previous PTE studies using trajectory-based assessments to investigating resilience often overlook occurrences of additional stressors subsequent to the primary stressor of interest (e.g., Bonanno, Kennedy, et al., 2012; Bonanno, Mancini, et al., 2012; deRoos-Cassini, Mancini, Rusch, & Bonanno, 2010; Hou et al., 2010; Norris, Tracy, & Galea, 2009; Pietrzak et al., 2014; Steenkamp, et al., 2012; Weems & Graham, 2014). Additional stressors can cause further distress and likely affect response trajectories (Bonanno, Galea, Bucciarelli, & Vlahov, 2007; Forbes et al., 2015; Quale & Schanke, 2010).

Without adequate monitoring of these stressors, it is unclear whether response trajectories are contaminated by the effects of additional stressor experiences.

Ongoing temporal assessment of stressors is important to evaluate resilience uniformly across participants. Without continual monitoring of stressor events, judgements of resilient classifications become complicated due to differences in individual stressor experiences across time. For example, separate individuals may experience a common PTE yet have varying stressor experiences outside the PTE of interest. One individual may experience additional PTEs, while another individual may experience only the PTE of interest. As a result, in studies overlooking potential effects of peripheral stressors, it remains unclear whether individual trajectories reflect patterns of adjustment in response to a single PTE or multiple PTEs. It could be argued that individuals displaying chronic trajectories may not be vulnerable or ‘non-resilient’, rather they may have faced additional stressors exceeding capacities for effective coping, as compared to ‘resilient’ individuals who may have experienced fewer or no peripheral stressors.

To reliably address this argument, study designs could incorporate continual assessments of stressor experiences. Including such assessments provides insight for researchers regarding the context in which trajectories manifest, and provides options for managing differential stressor experiences between participants. For example, researchers may select to remove participants who have experienced a complicated sequence of stressors, in order to create a more homogenous sample. Alternatively, researchers may retain participants with varied stressor experiences, and collect useful details regarding peripheral stressor experiences surrounding the stressor of interest (e.g., dates of occurrence and severity)—such data can be useful in post-hoc analyses to gauge associations between specific trajectory profiles and the number of stressors experienced across time and improve interpretability of observed trajectories.

2.2.2. Limitation 2 – Substantial experimental burdens on research participants and resource demands for researchers. Studies investigating resilience to daily stressors are also limited by the substantial burdens associated with the medium through which the ESM is deployed. Conducting semi-structured interviews via daily telephone calls can be burdensome for both participants and researchers. For example, a study conducted by Hay and Diehl (2010) examined reactivity to daily stressors using the DISE in a sample of 239 adults. Participants were required to complete a single baseline interview, daily phone interviews, and daily self-report diaries over 30 consecutive days. The baseline interviews lasted between two to three hours each. The length of each DISE interview ran between 10 to 15 minutes long (on average), with some lasting up to 30 minutes (Almeida et al., 2002; Diehl & Hay, 2013). Finally, each daily diary took roughly 15-20 minutes to complete. Using a conservative estimate, over 30 days, this accumulates to up to 15 hours of participation. As such, other than being invasive and potentially disrupting the natural flow of behaviour, daily interview methods appear time-intensive for participants and may become a source of burden and intrusion into their lives.

Deploying the ESM through daily telephone interviews can also be resource intensive for researchers. For instance, study participation must often be incentivised in order to attract participants and maintain good compliance throughout experimental durations. This is particularly relevant given the time-intensive nature of daily interview methodologies. In the example described above, participants were reimbursed \$20 for the baseline session and \$8 for each completed diary. Given that the study achieved 6715 days of valid data (and presumably 239 successful baseline sessions), this would amount to tens of thousands of dollars in reimbursement costs. In addition to this, the study utilised a large research team of 30 trained interviewers to conduct the baseline sessions and daily phone interviews. These demonstrate the heavy resource demands placed on researchers in order to adopt daily

interview methods of data collection. This is likely to hamper accessibility to the ESM, as such funds and personnel may be beyond the resources possessed by many researchers.

Taken together, the abovementioned factors represent barriers of progression for the study of resilience to daily stressors, as participants may be reluctant to begin or continue participation without substantial incentives, and heavy resource demands limit adoption of the ESM. Although telephone-interview designs are beneficial in facilitating the collection of detailed and relevant data to conduct valid and rigorous research, such high levels of details afforded by interview methods may not be essential, or ideal, for all future research. Research designs capitalising on recent advancements in technology may offer resolution to these challenges and afford a more practical means of data collection.

2.2.2.1. *Electronic implementations of the ESM.* The ESM has developed in recent years with fast paced advancements in personal electronic devices. Early studies adopting the ESM utilised paper-and-pencil diaries that recorded multiple closed-ended entries. In these studies, participants were notified of times when they should complete questionnaires, and were cued by a beeping wrist-watch or pager (Brandstätter, 1983; Larson, Csikszentmihalyi & Graef, 1980; Jacobs et al., 2007; Larson & Csikszentmihalyi, 1983). A major limitation of using paper-and-pencil assessments, however, is the absence of a means to confirm that entries are being made at the scheduled or prompted time (Stone, Shiffman, Schwartz, Broderick, & Hufford, 2003). Stone et al. (2003) used an unobtrusive photo sensor in paper-and-pencil methods to examine whether questions were being completed at appropriate times. They found that on numerous occasions, participants did not adhere to designated protocols and back- or forward-filled diary entries, minimising advantages afforded by the ESM. Consequently, researchers have experimented with mobile and personal electronic devices to improve participant compliance.

A number of studies have used basic mobile phone devices (Wrzus, Luong, Wagner, & Riediger, 2015) to deploy the ESM and collect data regarding a number of different variables. For example Reid and colleagues developed a mental health assessment and management tool—The Mobile Tracking Young People’s Experiences (Mobiletype) program (Kauer, Reid, Sanci, & Patton, 2012; Khor, Melvin, Reid, & Gray, 2014; Reid et al., 2009, 2011, 2012). In these studies, participants are loaned a mobile phone with the *mobiletype* application (app) installed, prompting participants to complete entries on the device regarding mood, coping behaviours, thoughts, sleep, alcohol, exercise, eating, and television/computer use. Researchers have utilised similar approaches with other devices including Personal Digital Assistance (PDAs), PalmPilots (Kane et al., 2007; Kwapil et al., 2009), and laptops (Rook, August, Choi, Franks, & Stephens, 2016). These devices prompt participants through auditory signals emitted from the device and entries can be time coded to track when participants complete surveys. Disadvantages associated with using these devices, however, are that they can be expensive (e.g., to purchase standalone devices, SIM cards, or damage repairs), time consuming to program, and may also require specialist training or support for ongoing participation. Also, for participants, these devices are foreign, possibly leading to poor compliance (e.g., failure to carry the devices at all times), lack of engagement with the tool, reduced ecological validity, or intrusion into daily life (e.g., having to carry an extra device at all times). Furthermore, such devices have become obsolete with more recent advances in technology through the proliferation of smartphone technology which possess superior capabilities and offer device familiarity to participants.

Smartphones are a relatively new and powerful category of mobile devices possessing advanced capabilities beyond traditional mobile phones, with rich-featured operating systems that rival personal computers (Christensson, 2010). Smartphones have become a fixture of everyday life with ownership rates reaching 77% in Australia, 72% in the United States, and

68% in the United Kingdom (Poushter, 2016). The proliferation and permeation of smartphones into daily life provides a unique opportunity to leverage these devices for use in the field of psychology. For example, several mental health applications (or MHapps; Bakker, Kazantzis, Rickwood, & Rickard 2016) have been developed to promote positive mental health outcomes in users (Donker et al., 2013) such as reductions in levels of depression, anxiety, and improvements in well-being (Bakker, Kazantzis, Rickwood, & Rickard, 2018; Birney, Gunn, Russel, & Ary, 2016; Burns et al., 2011; Carpenter et al., 2016; Grassi, Gaggioli, & Riva, 2011; Kauer et al., 2012; Watts et al., 2013; Villani et al., 2012; Villani et al., 2013). Importantly, smartphone technology can be used to improve the study of human behaviour in clinical and non-clinical settings. Experience-sampling approaches are valuable assets in clinical trial research, and the relevance of combining the ESM with mobile technology in such contexts has been emphasised (Trull & Ebner-Priemer, 2009; Verhagen, Hasmi, Drukker, van Os, & Delespaul, 2016; Vilardaga, Bricker, & McDonnell, 2014). Leveraging personal smartphone devices can be useful to study the efficacy of treatments in psychology and psychiatry, and outcomes of clinical trial research can aid optimisation of treatment approaches by customising treatments to personalised needs and aligning them with an individual's strengths.

A number of smartphone-based Experience-Sampling-Applications (ESAs) have been developed and implemented in psychological research studies. These include ESAs such as MoodPrism (Rickard, Arjmand, Bakker, & Seakbrook, 2016), StudentLife (Wang et al., 2014), MuPsych (Randall & Rickard, 2013), and EmotionSense (Rachuri et al., 2010). Research methods using smartphone-based ESAs are an elegant alternative to semi-structured interviews, paper-pen diary methods, and designs using PDAs, PalmPilots, or outdated mobile phones. In addition to advantages granted by traditional implementations of the ESM, ESA adaptations using smartphones technology provide a number of unique benefits:

a) ESAs delivered through smartphones can reduce experimental burden and intrusion into daily life. As smartphones are personal and portable devices, participants can complete assessments within ESAs at their convenience—this relaxes restrictions of reporting at specific times or places. Experimenter demands are substantially reduced as ESAs can be downloaded remotely onto personally owned devices, and survey responses can be completed using the touch-screen interface on all smartphone devices. Participants' responses can be recorded onto smartphones and uploaded wirelessly to an online database for researchers to collate and analyse. Together, these remove any requirements to physically meet researchers or partake in lengthy phone calls at regular time intervals.

b) A high level of flexibility exists in designing ESAs which provides researchers freedom in designing empirical research studies. ESAs can be programmed and tailored specifically for researcher interests. This may relate to inclusion of specific psychometric surveys relevant to research aims, as well as the content included in micro-surveys and the frequency with which participants are prompted to complete them. Moreover, researchers can design user-friendly and self-explanatory ESAs; this further aids reduction of experimental burden by removing requirements to train participants as apps can be designed to guide users toward effective app use.

c) Like traditional mobile phones, smartphones permit the collection of time-coded data indicating the date, time, and duration participants spend completing assessments. This allows useful examination of participant compliance and integrity of collected data.

d) Due to the high ownership rates of modern smartphone devices, smartphone-based ESA utilise participants' personally owned devices which helps to maintain ecological validity and device familiarity; this removes the need to loan foreign devices and is likely to translate into good participant compliance and engagement (e.g., Randall & Rickard, 2013; Reid et al., 2009; Reid et al., 2012).

e) Many of the benefits described above also translate into potential reductions in resource demands for researchers. For example, as requirements for participants to physically meet or communicate with researchers are circumvented, experience-sampling data can be collected from large samples using smaller research teams. Moreover, as ESAs can be made available to download from participants' personally owned smartphone devices, monetary costs associated with loaning foreign devices (i.e., purchasing devices, purchasing SIM cards, sending SMS reminders, or damage repairs) are entirely avoided. Monetary costs may also be reduced by providing inbuilt, non-monetary incentives embedded within ESAs to encourage continued participation. Due to the power and flexibility of modern smartphones, applications can be programmed to provide some personal utility to users and inspire voluntary use of the application (e.g., facilitating mood tracking or tips to manage stress reactions).

3. Summary

The study of resilience is wide ranging and encompasses investigations of positive adaptation in response to a variety of different stressors. Daily stressors represent one form of adversity which, despite seeming inconsequential relative to PTEs or chronic adversity, can generate unfavourable psychological outcomes. With increasing research, understandings of mechanisms underlying resilience processes grow and highlight the roles of person- and stressor-specific factors, as well as cognitive appraisals and coping strategies, in facilitating resilience or vulnerability to daily stressors. Such information has real world utility in the development of resilience interventions and programs in clinical and non-clinical settings to curtail psychological disturbances resulting from daily stressor experiences and improve mental health and well-being. In order to ensure the development of highly effective interventions, empirical research studies informing models of resilience must utilise valid and reliable research methodologies.

Research methods used in studies investigating resilience to daily stressors often utilise multi-level modelling analyses to capture within-person measures of affective reactivity and assess between-person differences to explore variables influencing the relationship between daily stress and reactivity. These studies, however, are theoretically constrained and assess only a limited portion of stress responses, overlooking patterns of recovery following initial reactions to daily stressors. Here, two-dimensional assessments of stress responses encompassing both initial reactions and subsequent patterns of recovery are more appropriate. This is because such assessments afford a comprehensive examination of resilience which considers immediate and direct psychological impacts of daily stressors, as well as potential risks of stress-accumulation engendered by daily stressor experiences.

Previous research often conducts examinations of resilience to daily stressors utilising the ESM, which offers highly detailed data regarding individual experiences of daily stressors and subsequent affective reactions. Such studies adopt a daily-diary-interview methodology which involves conducting frequent semi-structured telephone interviews over 30-day experimental durations. A disadvantage of this method of data collection is that it can be time-intensive for participants, and resource-intensive for researchers. Such methods can be improved by minimising experimental burdens placed on participants, and resource demands placed on researchers. While this has become increasingly feasible through the adoption of personal electronic devices in psychological research (such as PDAs, PalmPilots, mobile phones, and laptops), electronic adaptations of the ESM can be further improved with more contemporary advances in technology.

4. The Current Approach

The current thesis integrates methods outlined in this chapter to examine processes of resilience in a novel way. Specifically, tailored research methods are developed and

implemented (spanning from initial data collection to final explorations of factors facilitating resilience) which avoid limitations of previous research methodologies.

Trajectory-based methods developed in PTE research are customised and applied in the context of major daily stressors. Previous daily stressor research typically explores resilience using a partial assessment of psychological responses following stressor exposure (i.e., initial reactivity). In contrast, trajectory-based methods are adopted in the current research as they introduce a more holistic assessment of stress responses by also considering subsequent patterns of responding following initial reactions. This is important to consider as patterns of recovery capture individual abilities to dissipate stress, and are implicated in stress-accumulation processes. To accommodate this approach, an ESM is utilised. The ESM is well suited to trajectory-based methods of assessment as participant experiences are sampled frequently in real-time. Individual data points can be collated to provide dynamic illustrations of psychological functioning over time, and to demonstrate the ways individuals respond to naturally occurring stressor experiences. Importantly, the ESM offers resolution to limitations of previous implementations of trajectory-based methods (in PTE research), as it can enable continual, ongoing monitoring of stressor experiences.

Consistent with contemporary adaptations of the ESM, which take advantage of the latest innovations in personal electronic devices, the ESM implemented in the current thesis uses a smartphone-based ESA to collect data relevant to the study of resilience. Smartphone technology presents new opportunities to improve the utility of the ESM by collecting experience-sampling data using participants' personally owned devices. Smartphones have become a common fixture of everyday life and can be exploited to capture relevant details about daily experiences required for rigorous study of resilience. Unique advantages granted by these devices offer the potential to minimise participant burdens and increase accessibility to prospective researchers. Smartphone-based ESAs may ultimately provide an efficient,

cost-effective, and ecologically valid means of data collection, and represent a unique approach worthy of integration into contemporary research methods.

The development of this integrated approach is presented incrementally across subsequent chapters, in the order outlined in the thesis overview. Each chapter focusses on a particular component of the methodology, and discusses the fulfilment of objectives forming the structure of the thesis, which ultimately underpin its overarching aim.

Chapter 2: Paper #1.

Exploring the utility of a smartphone Experience-Sampling-Application (ESA) for investigating resilience to daily stressors

Assessment, Manuscript submitted for publication.

Restatement of thesis objectives:

1. Developing tailored research methods to capture and explore variations in psychological responses following a major daily stressor. This comprised two components:
 - a) Implementing a contemporary and temporally sensitive means of data collection suited to examinations of resilience to daily stressors.
 - b) Executing methodological procedures to convert experience-sampling data into trajectories of psychological responding, with subsequent classification into prototypical response groups.
 2. Utilising these methods to investigate mechanisms facilitating resilience to major daily stressors.
-

Chapter Introduction:

This chapter addresses component (a) of objective 1, and presents the first of three papers included in the current thesis. In order to appropriately study resilience to daily stressors, a suitable method of data collection is essential. Methods of data collection must gather data relevant to core principles of resilience—the experience of adversity and the achievement of a positive outcome (Fletcher & Sarkar, 2012). Moreover, as daily stressors are temporally unpredictable, data collection methods must be temporally sensitive in order to capture onsets of naturally occurring stressors and resulting psychological responses

(Bonanno, 2012). Existing research methods utilise the Experience-Sampling-Method (ESM: Larson & Csikzentmihalyi, 1983) to accommodate such challenges. Individual experience-sampling reports can be sequenced to provide researchers a window into a person's personal experiences: a continual, data driven representation of stressor events and psychological responses encapsulated within a specified time frame.

As discussed in Chapter 1, previous implementations of the ESM are methodologically constrained. The aim of this paper was to extend the utility of the ESM by capitalising on recent proliferation and advances in smartphone technology. A contemporary smartphone-based Experience-Sampling-Application (ESA), "MoodPrism", was deployed (made freely available for download on GooglePlay and the iOS AppStore) to collect suitable data for investigating resilience to daily stressors. The participants recruited in this chapter were sampled from an initial pool of early users, which subsequently expanded over time and provided a larger pool of users from which samples were selected for studies presented in subsequent chapters. MoodPrism is a recent ESA developed by Rickard, Arjmand, Bakker, and Seabrook (2016) that supports self-monitoring of emotional well-being and allows (with consent) collection of user data for psychological research (see Appendix A). The application has potential value across a wide range of psychological research and, in this chapter, its utility in the context of studying resilience to daily stressors is examined.

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Exploring the utility of a smartphone Experience-Sampling-Application (ESA) for
investigating resilience to daily stressors

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Abstract

Resilience is broadly defined as the maintenance of psychological functioning in response to adversity. The temporal features of resilience can be challenging to measure in valid and reliable ways. The current study explored the utility of a smartphone-based Experience-Sampling-Application (ESA) for gathering data relevant to investigations of resilience to daily stressors. In a sample of 48 participants (12 male, 35 female, 1 another gender identity; $M_{age} = 34.5$ years, $SD = 13.98$), the capacity of this method to meet three key objectives procured from resilience literature was examined: daily sampling of psychological health (objective 1); daily assessment of participants' stressor experiences including details regarding the day, nature, and severity of the event (objective 2); and maintaining a pleasant user experience with high levels of engagement, compliance, ease-of-use, and minimal experimental burden (objective 3). Findings demonstrated that the ESA was successful in meeting all three objectives. Smartphone-based ESAs therefore appear to have good utility for collecting temporally sensitive data pertinent to examinations of resilience to daily stressors, and provide a contemporary, burden-light means through which to engage participants for resilience research.

Daily stressors, or hassles, have been defined as the stresses and strains of daily living (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982; Kanner, Coyne, Schaefer, & Lazarus, 1981). They occur frequently and have unique contributions to physical and psychological distress distinct from significant negative life events or chronic adversity (Almeida, Wethington, & Kessler, 2002; Pearlin, Liberman, Menaghan, & Mullan, 1981; Serido, Almeida, & Wethington, 2004; Zautra, 2003). Research has explored resilience factors facilitating positive outcomes in response to daily stressor experiences, and has demonstrated buffering effects of several variables including family support (Cichy, Stawski, & Almeida, 2014), personality (Mroczek & Almeida, 2004), personal control (Neupert, Almeida, & Charles, 2007), age (Charles, Piazza, Luong, & Almeida, 2009) and cognitive ability (Stawski, Almeida, Lachman, Tun, & Rosnick, 2010). Due to the ubiquitous, unpredictable, and variable nature of daily stressors, capturing relevant data to explore resilience can be challenging and has propelled researchers to deploy innovative methods of data collection.

The Experience-Sampling-Method (ESM)—also referred to as Ecological Momentary Assessment (EMA)—is often employed to tackle challenges associated with studying event-based phenomena (see Schilling & Diehl, 2015; Almeida, 2005). Studies using the ESM assess participants in their natural environment and aim to capture life as it is lived (Bolger, Davis, & Rafaeli, 2003). The ESM involves prompting participants at selected intervals to complete brief, on-the-spot assessments on variables of interest, such as current mood, thoughts, or behaviours (see Larson & Csikszentmihalyi, 1983). This method of data collection has been utilised in numerous studies examining resilience to daily stressors. For example, studies often utilise experience-sampling data sourced from the National Survey of Daily Experiences (NSDE) (Keys & Ryff, 1998; Lachman & Weaver, 1998; Mroczek & Kolarz, 1998) to investigate person-specific factors buffering stress reactivity to daily stressors (Charles et al., 2009; Neupert et al., 2007; Stawski et al., 2010). The NSDE was a

large scale study conducted from 1996 to 1997 which assessed emotional health and everyday stressor experiences through daily telephone interviews conducted across consecutive days. Frequent and repeated assessments like this are a fitting means to study resilience to daily stressors as they accommodate the unpredictable nature of stressor experiences, and enable momentary assessment of resulting psychological responses.

A limitation of applications of the ESM in previous studies, however, concerns high participant burdens. For example, many studies conduct frequent assessments using the Daily Inventory of Stressful Events (DISE; Almeida et al., 2002). The DISE is a semi-structured interview process that collects a high level of detail regarding daily stressor experiences including the date, type (focus of content), and severity of stressors. The inventory consists of a series of stem questions which ask participants whether certain events were experienced in the past 24 hours. Guidelines are provided to interviewers for probing of affirmative responses in order to extract further details regarding daily stressor experiences. In previous studies, interviews conducted through daily telephone calls have been reported to last between 10 to 15 minutes, with some lasting up to 30 minutes (Almeida et al., 2002; Diehl & Hay, 2013). In addition, these studies often required initial baseline assessments with researchers (lasting up to 3 hours) as well as completion of daily self-report diaries (15-20 minutes each). This can accumulate to up to 15 hours of participation in studies which have experimental durations lasting 30 days (e.g., Diehl & Hay, 2010). Deploying ESMs using the DISE can also become resource intensive for researchers. Participants may require substantial monetary incentives for ongoing participation given high levels of participant burden, and conducting daily assessments using the DISE requires large trained research teams (e.g., Hay & Diehl, 2010). Such heavy resource demands may delay progression in this research field as it can limit accessibility to the ESM. Although such designs permit the collection of detailed and relevant data to conduct valid and rigorous research, such levels of detail afforded by

interview methods may not be essential for all future research. Alternative implementations of the ESM may offer resolution to abovementioned challenges.

Experience Sampling Methods Using Portable Electronic Devices

Contemporary research designs utilising the ESM often capitalise on recent advancements in technology to collect experience-sampling data. Psychological research has used a range of devices to deploy the ESM, including Personal Digital Assistants (PDAs) or PalmPilots (Kane et al., 2007; Kwapil et al., 2009), digital wrist watches (Jacobs et al., 2007), mobile phones (Wrzus, Luong, Wagner, & Riediger, 2015), and laptops (Rook, August, Choi, Franks, & Stephens, 2016). These devices are typically loaned and emit audible beeps to prompt participants to complete on-the-spot assessments on the device or in self-assessment booklets. Although these devices have the potential to reduce experimenter demand, they require participants to carry an unfamiliar foreign device throughout the experimental duration. This has the potential to hinder engagement and compliance, create intrusion in the lives of participants, and limit ecological validity. Furthermore, such devices can be expensive, time consuming to setup, and may require training or support for ongoing participation. With more recent advances in technology, new possibilities are afforded through the proliferation of smartphone technology possessing capabilities beyond many of the aforementioned devices while offering device familiarity.

Smartphones are a relatively new and powerful category of mobile devices which have become commonplace today with ownership rates reaching 77% in Australia, 72% in the United States, and 68% in the United Kingdom (Poushter, 2016). This proliferation provides a unique opportunity to leverage these devices to explore human behaviour. Several Experience-Sampling-Applications (ESAs) have been developed and delivered through smartphone devices for psychological research purposes—StudentLife (Wang et al., 2014), MuPsych (Randall & Rickard, 2013), and EmotionSense (Rachuri et al., 2010). Previous

research studies have demonstrated the capacity for smartphone ESAs to collect a wide variety of information such as levels of stress, mood, sleep, social interactions, music listening, and exercise (Rachuri et al., 2010; Randall & Rickard, 2013; Wang et al., 2014). Smartphone ESAs offer an elegant alternative to daily telephone interviews, paper-pen based diary methods, and methods requiring participants to carry foreign devices. ESAs can be developed to collect relevant experience-sampling data to investigate resilience to daily stressors, while also reducing experimental burdens and resource demands associated with previous implementations of the ESM.

Smartphone-based ESAs may confer several advantages over previous implementations of the ESM. For users, ESAs have the potential to reduce experimental burden as requirements to meet or contact researchers can be avoided. This is because ESAs can be downloaded remotely, responses can be input directly into the smartphone devices, and data can be retrieved by researchers wirelessly through the internet. Experimental burdens may also be reduced as devices are portable and users are not restricted to completing assessments at specific locations (e.g., at home or work). Moreover, users can use personally owned devices to complete such assessments; this removes the need to carry and navigate through foreign devices to participate in psychological research, and can help maintain device familiarity and increase comfort. For researchers, ESAs offer flexibility in study designs. ESAs can be programmed specifically to researcher interests and enable customisability in prompt schedules (e.g., hourly, daily, weekly), outcome variables assessed, as well inquiry with regards to relevant details of daily stressor experiences (e.g., date, type, and severity). ESAs may also reduce resource demands for researchers in similar ways through which ESAs reduce experimental burdens for users. For example, removing requirements to meet researchers or manually collecting data from individual users could reduce the size of research teams to implement an ESM study design. Moreover, the

convenience for users using personally owned devices means that researchers are spared the costs of purchasing stand-alone devices and any costs associated with such instruments (e.g., SIM card purchases, SMS reminder texts, or damage repairs). Finally, using familiar and portable devices likely translates into good participant compliance and engagement (e.g., Randall & Rickard, 2013; Reid et al., 2009, 2012), and may also improve the validity of reported experiences as they are unfettered by artificiality of context, or participant fatigue and frustration during participation.

Using smartphone technology for experience-sampling purposes is a relatively novel adaptation in psychological research studies, and its adoption in resilience research examining daily stressors is limited. As such, the aim of the current study was to explore the utility of a purpose-designed smartphone-based ESA for use in studies investigating resilience to daily stressors. This was to be achieved by assessing the app's capacity to fulfil three objectives:

- 1) Daily sampling of psychological health over a 30-day experimental duration.
- 2) Appropriate measurement of participants' stressor experiences including the date, nature, and severity of the event.
- 3) Maintaining a pleasant user experience with high levels of engagement, compliance, ease-of-use, and minimal experimental burden.

Method

Participants

A sample of 48 participants aged between 17 and 61 ($M_{age} = 34.5$ years, $SD = 13.98$) was recruited as part of the promotion of a mental health support application (app), MoodPrism. MoodPrism was promoted to the general public through various means including online promotion (e.g., Facebook and Twitter), presentations for organisations and

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schools, and word of mouth. Participant recruitment was aimed at selecting individuals from a diverse range of backgrounds, education levels, and age (see Table 1).

Table 1.

Sample frequencies and percentages across gender, location, education, study status, and work status.

Variable	N	%
Gender		
Male	12	25.0
Female	35	72.9
Another gender identity	1	2.1
Location		
Inner city	9	18.7
Suburb	36	75.0
Country	1	2.1
International	1	2.1
Don't know/Don't want to answer	1	2.1
Highest level of Education		
Secondary	11	22.9
Tertiary	19	39.6
Post Graduate	17	35.4
Don't know	1	2.1
Studying/Trained		
Full time	17	35.4
Part time	7	14.6
Not at all	24	50.0
Working/volunteering		
Full time	24	50.0
Part time	11	22.9
Not at all, but seeking	4	8.3
Not at all, not seeking	9	18.8

Materials

The application. The MoodPrism app is a purposed-designed ESA (www.moodprismapp.com) which participants downloaded onto personal smartphones. Only details of aspects relevant to achieving objectives of the current study are described in this section. Full details regarding the development of MoodPrism are outlined in a separate paper (see Rickard, Arjmand, Bakker, & Seabrook, 2016).

The app comprises three primary components: ‘on-boarding’ surveys, daily experience-sampling-reports (ESRs) and ‘off-boarding’ surveys. Upon installation, the app prompts participants to complete a battery of full length ‘on-boarding’ surveys in order to unlock full app functionality. These surveys served to assess baseline levels of various person-specific factors. Once surveys are completed, the daily ESR component of the app is made available.

Once a day, within permitted time-frames specified by participants, participants are randomly prompted to complete 15 items comprising a single ESR. After 30 days of completing the first ESR, the app presents several ‘off-boarding’ surveys. ‘Off-boarding’ surveys comprise select surveys included in the ‘on-boarding’ component of the app, while also presenting feedback surveys capturing subjective user experiences of the app. As surveys and ESRs are completed using the touch-screen interface, the app also collects automatic time-stamp data representing the amount of time spent using different components the app; this provides an objective measure of experimental burden and levels of intrusion into daily life.

‘On-boarding’ surveys. The app contains 15 surveys which are completed following app installation. This survey battery includes a demographic survey and a number of other surveys assessing constructs such as social support, personality and mental well-being (see Rickard et al., 2016 for additional details). Of these surveys, only data collected from

participants' responses in the Social Readjustment Rating Scale (Holmes & Rahe, 1967) were used in the current study.

The Social Readjustment Rating Scale (SRRS). The SRRS was used to assess the number of adverse life events experienced by participants. Participants are presented with a list of 43 life events ranked in order of emotional impact, and are asked to select events experienced over the past 12 months. Sample items include the death of a spouse, divorce, being fired at work, minor violations of the law, sexual difficulties, major personal injury or illness, and detention in jail or other institution. In the current study, the reported number of events experienced was summed for each participant to indicate the frequency of adverse life events experienced in the past year. The SRRS has shown good reliability with rank orderings of events consistent in both health adults ($r = 0.96 - 0.89$) and patients ($r = 0.91 - 0.70$) (Gerst, Grant, Yager, & Sweetwood, 1978), and demonstrated good validity with positive correlations with illness scores (Holmes & Rahe, 1967).

Daily experience sampling reports. Relevant items in ESRs included a daily measure of depressive symptoms and an assessment of stressor experiences.

Two-item Patient Health Questionnaire (PHQ-2). Daily symptoms of depression were assessed using the PHQ-2 (Löwe, Kroenke, & Gräfe, 2005). Items in this questionnaire ask participants to rate how much they currently feel “little interest or pleasure in doing things”, and “feeling down, depressed, or hopeless”. Rated on a five-point Likert scale ranging from “not at all” (1) to “extremely” (5), items are summed to given an overall score ranging from 2 to 10 with higher scores indicating higher symptoms of depression. This selection of items has shown good internal consistency (Cronbach's alpha = .83) and correlates highly with established depression measures (Löwe et al., 2005).

Stressor experience report. Daily reports included one item assessing the occurrence and rating of stressor experiences. This question asked participants, “What is the most

negative thing that has happened to you today?” Originally, participants were presented with a list of options from which to select specific events experienced. This list was compiled from various stress events questionnaires and adjusted to relate to both adult and adolescent populations (Cheng, 1997; Coddington, 1972; Newcomb, Huba, & Bentler, 1981; Swearingen & Cohen, 1985; Waaktaar, Borge, Fundingsrud, Christie, & Torgersen, 2004). Following feedback during a beta trial of MoodPrism (Rickard et al., 2016), the items were revised to be broader and briefer, and were subsequently converted into domains of living where negative events may occur. Each domain addressed an area of life common to multiple stressors in the original list; negative social experience, loss of valued material item, negative experience at school/work, negative experience outside of school/work, personal health problems, and health problems of someone close to you. These reflected similar domains included in previous methodologies (Almeida et al., 2002), permitted a broader line of inquiry encompassing the vast range of possible negative events that can occur, and reduced the number of item selections in the list. The list also included a “nothing negative happened” option as well as an “other” option where participants could manually type in any stressor not covered by domains provided on screen. If participants select any option indicating the experience of a negative event, an additional question was presented asking participants to rate the degree of negativity of the event on a four-point Likert scale ranging from “slightly” (1) to “extremely” (4). Although daily stressors are typically considered minor events rated ‘low’ or ‘medium’ in severity, they are not precluded from being rated as highly negative experiences (Almeida, et al., 2002; Kanner et al., 1981) As such, stressors in the current study were separated on a continuum of severity where stressors rated as ‘slightly’ or ‘moderately’ negative were considered ‘minor daily stressors’, and stressors rated as ‘very’ or ‘extremely’ negative were considered ‘major daily stressors’.

‘Off-boarding’ surveys. Data from two ‘off-boarding’ surveys were used in the current study and included a retrospective measure of depressive symptoms, and a survey assessing participants’ subjective user experience of the app.

Patient Health Questionnaire (PHQ-9). The PHQ-9 asks participants to indicate the frequency of various symptoms of depression over the past 2 weeks (Kroenke, Spitzer, Williams, 2001). These are rated on a four-point Likert scale ranging from “not at all” (1) to “nearly every day” (4). The PHQ-9 has shown good construct validity with high correlations with diagnoses by mental health professionals and other depression assessment tools (Diez-Quevedo et al., 2001; Löwe, et al., 2004; Martin, Winfried, Klaiberg, & Braehler, 2006). Items are summed to give an overall score of depressive symptomatology. The PHQ-9 has good internal consistency with a Cronbach’s alpha level of 0.89 (Kroenke et al., 2001).

Mobile Application Rating Scale (MARS). The MARS is a reliable tool for assessing the quality of mobile health applications (Stoyanov et al., 2015). In this study, items from two subscales of the MARS were adapted to assess levels of engagement and functionality of the app. The ‘engagement’ subscale assesses how enjoyable, interesting, customisable, and interactive apps are perceived to be by users, while the ‘functionality’ subscale assesses the functioning, ease of use, navigation, flow logic, and gestural design of apps. On a five-point Likert scale ranging from “strongly disagree” (1) to “strongly agree” (5), participants were asked to rate the degree with which they agreed to statements relating to the app. In the current study, statements adapted from the MARS included “I enjoyed using MoodPrism”, “MoodPrism was interesting”, and “It was easy to use and understand”. The MARS has demonstrated excellent internal consistency ($\alpha = .90$) and inter-rater reliability ($ICC = .79$). Two additional experimenter authored questions were included to assess intrusion into daily life and experimental burden. On the same five-point Likert scale, participants were asked

how much they agreed that “The [daily] alerts every day were a hassle” and “Using [the app] it got in the way of my every day activities”.

Procedure

Ethical approval to conduct the current research study was granted by the Monash University Human Research Ethics Committee (Approval # CF14/968 – 2014000398). MoodPrism was made available for download freely from the AppStore (iOS) and GooglePlay (Android). Participants were invited to download the app as a personal mental health support tool, and were also informed that it doubled as a research tool. Explanatory statements and consent forms were administered electronically through the app. If the reported date of birth reported was less than 18 years, an additional consent form for minors was presented, with checks for parental consent. Participants were informed of incentives built into the research design. This included additional feedback on positive and negative mood functioning (unlocked after one and two weeks, respectively), and entries into a prize draw for two cash vouchers (\$38USD) (offered after completing key milestones: first day, first week, second week, and one month).

Figure 1 below illustrates the app’s data collection schedule. To unlock the full functionality of the app, participants were first required to complete the ‘on-boarding’ survey battery. After completion of these surveys, the first ESR became available and henceforth participants were prompted by the app on a daily basis to complete ESRs. Thirty days after completion of the first ESR, participants were presented with ‘off-boarding’ surveys.

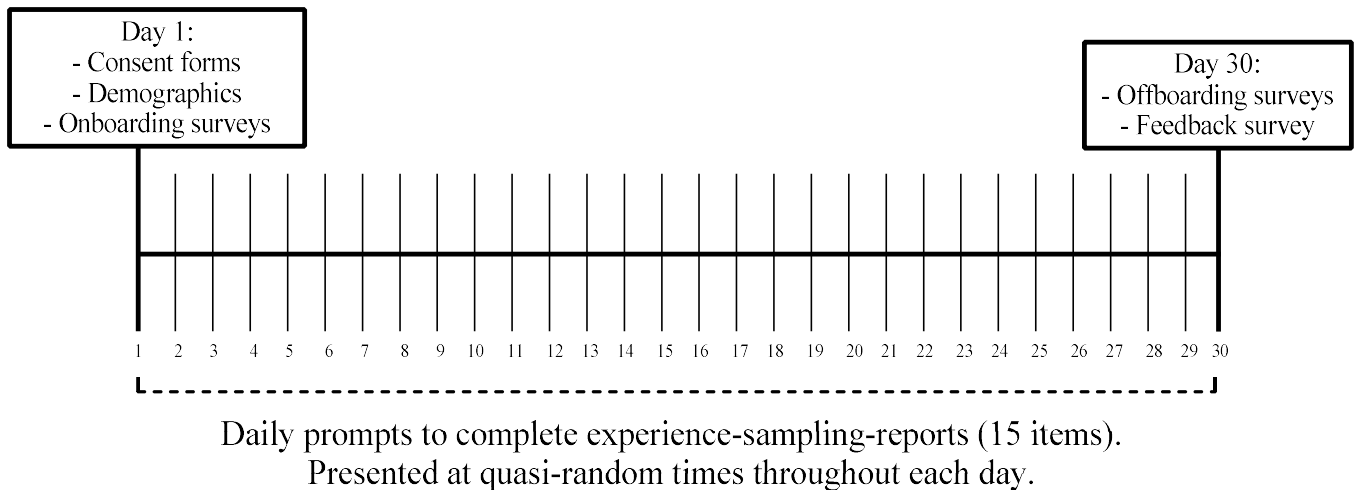


Figure 1. Experience-sampling data collection schedule over 30 days.

Participants' responses to items included in the app were initially stored on participants' smartphone devices. Every 24 hours, this data was then uploaded encrypted into a secure online database. Uploaded data were automatically anonymised with all potential identifiable information removed and only the device ID retained. The database was protected by a firewall and regularly updated security protocols. Responses uploaded to the database were accessible online (via remote download) only by authorised users, which comprised the MoodPrism research team and app developers.

Results

Data were downloaded remotely from the backend database, and participant data were extracted and explored to investigate the app's capacity to achieve objectives of the study. In addition to this, several additional analyses were conducted to further explore and describe data gathered using this method of data collection.

Objective 1: *Daily sampling of psychological health over a 30-day experimental duration.*

Each participant's data was plotted and visually inspected to determine the app's capacity to monitor daily psychological health over the experimental duration. Figure 2 shows a portion (14 days) of data from a single user. Further, experience-sampling data were plotted alongside a datum collected using retrospective methods to compare the level of detail afforded by each approach—this comprised summed scores of the PHQ-2 (from daily ESRs; possible range of scores 2 to 10) and the equivalent two items (#1 & #2) presented in the PHQ-9 (from off-boarding surveys; possible range of scores 2 to 8), respectively.

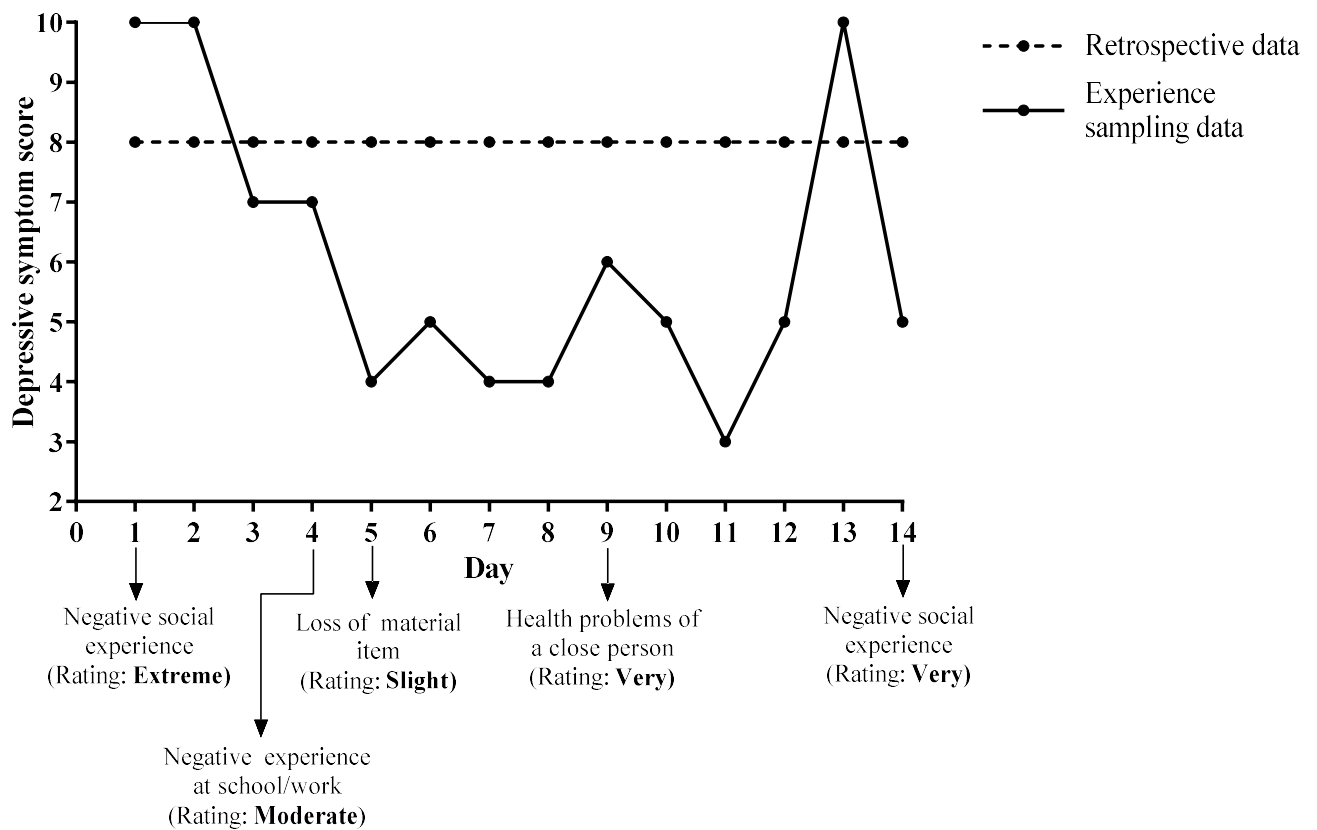


Figure 2. Sample data from a single participant illustrating symptoms of depression—presented through retrospective versus daily experience-sampling data—and stressors experienced over two weeks.

As the rating scales in the PHQ-9 and PHQ-2 differ slightly in the current study, direct comparisons of individual scores obtained from each method of data collection may be untenable. Notwithstanding, general comparisons contrasting data collected using an experience-sampling approach with retrospective methods can illustrate differences in the level of detail afforded by each collection method, and enable comparative examination of their utility within daily resilience research. As shown in Figure 2, the ESA was capable of collecting daily symptoms of depression, which were represented differently using retrospective reports. Using retrospective data, participants' symptoms of depression were observed as a single score reflecting broad psychological health over 14 days. Using daily experience-sampling data, participants' symptoms of depression were observed to vary considerably across days throughout the experimental duration.

Objective 2: *Appropriate measurement of participants' stressor experiences.*

Data collected from ESRs were also used to assess the app's capacity to monitor daily stressors and provide a level of detail comparable to previous (non-ESA) implementations of the ESM (e.g., date, type, and severity of stressor events). As illustrated in Figure 2, the app successfully monitored the occurrence of daily stressor events and recorded details regarding the specific days where events occurred, as well as details regarding the type and severity of the event. Daily reporting of stressor experiences allowed logging of frequencies with which participants experienced specific stressors. Average frequencies of stressors experienced across the sample by *type* are shown in Figure 3A, and average frequencies of stressors experienced by *severity* are shown in Figure 3B.

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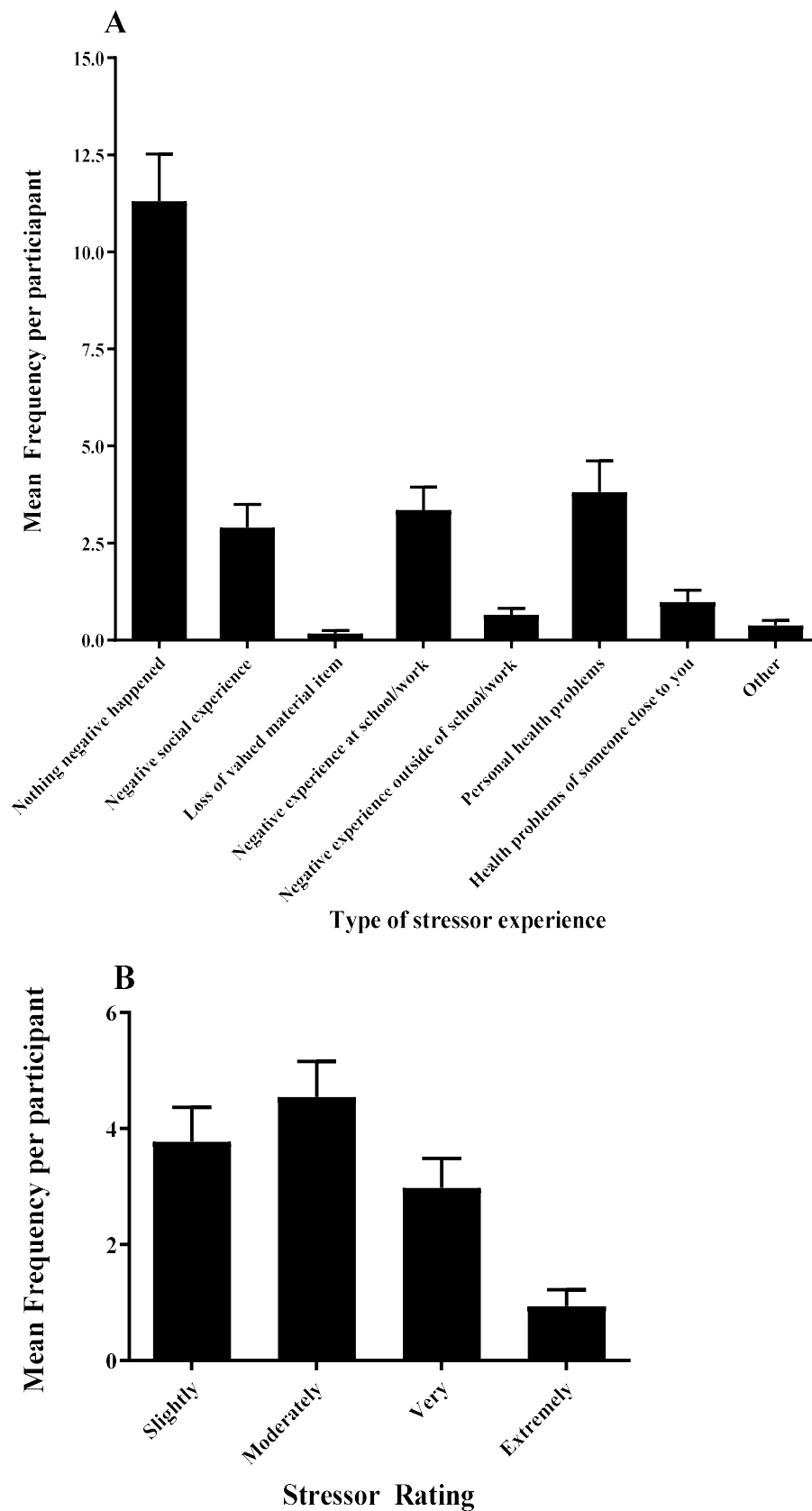


Figure 3. A) Mean frequency of stressor types experienced per participant over 30 days. B) Mean frequency of stressor severities experienced per participant over 30 days (error bars reflect standard error of the mean).

Analyses were conducted to examine differences in the frequency of stressor experiences (dependent variable) across the various stressor types and severities (independent variables). Several outliers were identified and were replaced with standardised scores 3.29 SD above the mean ($N = 11$). Kolmogorov-Smirnov tests indicated that distributions of stressor type and level of severity violated assumptions of normality. As such, non-parametric tests were utilised.

Using Friedman's ANOVA, results showed significant differences in the number of stressors experienced across stressor types, $\chi^2(7) = 133.77, p < .001$. Post-hoc examinations were conducted using Wilcoxon's Signed Ranked Tests. A Bonferroni correction was applied and so all effects are reported at an adjusted criterion alpha level of .006. Significant differences in the frequency of stressors types are shown in Table 2.

Results showed that participants reported experiencing no stressor ($M = 11.31, SD = 8.43, Mdn = 10.50$) significantly more frequently than any specific stressor. No significant differences were observed between participants experiencing a negative social experience ($M = 3.23, SD = 6.00, Mdn = 2.00$), negative experience at work ($M = 3.33, SD = 4.04, Mdn = 2.00$), and personal health problem ($M = 3.67, SD = 5.00, Mdn = 2.00$). Each of these, however, were reported significantly more than losing a valued material item ($M = 0.16, SD = 0.49, Mdn = 0.00$), a negative experience outside of school/work ($M = .65, SD = 1.18, Mdn = 0.00$), personal health problems of someone close ($M = 0.90, SD = 1.80, Mdn = 0.00$), and 'other' events ($M = 0.36, SD = 0.80, Mdn = 0.00$). No significant differences were observed between the latter four stressor types.

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Table 2.

Significance values (p), Z-values (z), and effects sizes (r) of non-parametric comparisons between frequencies of stressor types experienced by participants.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Nothing negative happened		$p < .001$ $z = -4.56$ $r = -.47$	$p < .001$ $z = -5.76$ $r = -.59$	$p < .001$ $z = -4.17$ $r = -.42$	$p < .001$ $z = -5.77$ $r = -.58$	$p < .001$ $z = -3.74$ $r = -.38$	$p < .001$ $z = -5.35$ $r = -.55$	$p < .001$ $z = -5.65$ $r = -.58$
(2) Negative social experience			$p < .001$ $z = -4.46$ $r = -.46$	$p = .336$ $z = -.96$	$p < .001$ $z = -3.77$ $r = -.38$	$p = .359$ $z = -.92$	$p = .003$ $z = -3.01$ $r = -.31$	$p < .001$ $z = -4.24$ $r = -.43$
(3) Loss of valued material item				$p < .001$ $z = -5.00$ $r = -.51$	$p = .016$ $z = -2.40$	$p < .001$ $z = -4.73$ $r = -.48$	$p = .013$ $z = -2.42$	$p = .190$ $z = -1.31$
(4) Negative experience at school/work					$p < .001$ $z = -4.54$ $r = -.46$	$p = .689$ $z = -.40$	$p < .001$ $z = -3.62$ $r = -.40$	$p < .001$ $z = -4.74$ $r = -.48$
(5) Negative experience outside of school/work						$p < .001$ $z = -3.86$ $r = -.39$	$p = .761$ $z = -.30$	$p = .215$ $z = -1.24$
(6) Personal health problem							$p = .001$ $z = -3.24$ $r = -.33$	$p < .001$ $z = -4.37$ $r = -.44$
(7) Health problem of someone close								$p = .143$ $z = -1.47$
(8) Other								

Significant differences were also observed in the number of stressors experienced across stressor severities, $\chi^2(3) = 38.74, p < .001$. Post-hoc examinations were conducted using Wilcoxon's Signed Ranked Tests. A Bonferroni correction was applied with all effects are reported at an adjusted criterion alpha level of .01. Results showed that participants reported experiencing extremely negative stressors ($M = 0.94, SD = 1.92, Mdn = 0.00$) significantly less than stressors rated as slightly ($M = 3.77, SD = 4.09, Mdn = 2.00$), $z = -4.09, p < .001, r = -.42$; moderately ($M = 4.54, SD = 4.25, Mdn = 3.00$), $z = -5.02, p < .001, r = -.51$; and very negative ($M = 2.97, SD = 3.50, Mdn = 2.00$), $z = -4.50, p < .001, r = -.46$. Post-hoc tests also showed that moderately negative stressors were reported significantly more than very negative stressors, $z = -2.64, p < .01, r = -.27$.

To examine whether stressors rated as 'very' or 'extremely' negative reflected highly negative daily stressor experiences (i.e., major daily stressors) as compared to significant life events, frequencies of each variable were contrasted. Participants' reports of significant life events experienced over the past twelve months indicated less than 1 occurrence per month ($M = 0.36, SD = 0.37, Mdn = 0.25$) which is consistent with the infrequency associated with such events. In contrast, over the one month experimental duration in the current study, 'very' and 'extremely' negative events were collectively reported over four times ($M = 4.40, SD = 4.46, Mdn = 2.5$). A Wilcoxon's signed ranked showed that the difference between these frequencies was significant, with 'very' and 'extremely' negative stressors occurring more often over the 1-month study duration as compared to participants' per-month average experience of significant life events, $z = -6.07, p < .001, r = -.61$.

Objective 3: *Maintaining a pleasant user experience with high levels of engagement, compliance, ease-of-use, and minimal experimental burden.*

Subjective feedback data were collated and examined to determine participants' subjective ratings of the app. Participant ratings on relevant items from the MARS scale are shown in Figure 4 and are contrasted with normative data representing ratings of previous health apps.

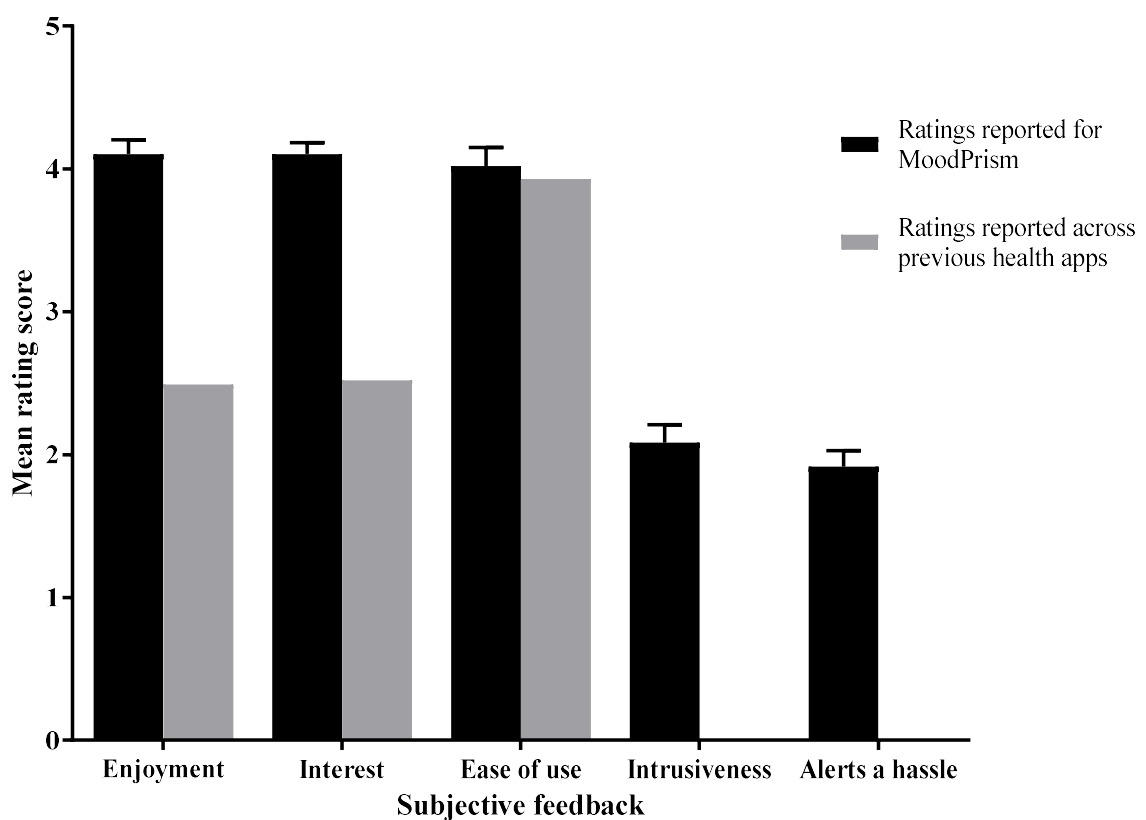


Figure 4. Mean subjective feedback ratings of users' experience of the app with respect to enjoyment, interest, ease of use, and intrusion into daily life ($N = 48$)—1 = 'strongly disagree' and 5 = 'strongly agree' (error bars reflect standard error of the mean). Grey bars represent mean scores observed for other health apps on comparable items researched in previous studies (Stoyanov et al., 2015)—NB, comparative data is not relevant for 'intrusiveness' and 'alerts were a hassle' as they were experimented authored questions.

As can be seen in Figure 4, the app rated highly on levels of enjoyment, interest, and ease-of-use. Overall, participants *agreed* to the statements “I enjoyed using MoodPrism” ($M = 4.10$, $SD = 0.70$), “MoodPrism was interesting” ($M = 4.10$, $SD = 0.56$), and “It was easy to use and understand” ($M = 4.02$, $SD = 0.89$). These ratings are comparable to normative data on ease-of-use ($M = 3.93$, $SD = 0.87$), and higher than ratings of entertainment ($M = 2.49$, $SD = 1.24$) and interest ($M = 2.52$, $SD = 1.24$) (Stoyanov et al., 2015). The app was also rated favourably on levels of experimental burden and intrusion into daily life. Overall, participants *disagreed* to the statements “The alerts every day were a hassle” ($M = 2.08$, $SD = 0.87$) and “Using it got in the way of my every day activities” ($M = 1.92$, $SD = 0.77$).

Objective measures of experimental burden and intrusion into daily life were also calculated. Table 3 shows mean scores of time-stamp data collected from participants’ smartphones, indicating the amount of time spent on different components of the app³.

Table 3.

Itemised and total mean times spent completing components of the ESA, and corresponding percentages of total participation.

	Mean Time	% of Total Participation
On-boarding survey battery	37m 14 s ($SD = 11m\ 33s$)	42.43%
A single daily report	1m 37s ($SD = 44s$)	1.89%
30 x daily report	48m 30s	56.57%
Total	85m 44s	100%

³ Mean times are provided only for components of the app deemed relevant for future research. That is, components which collect baseline data regarding individual characteristics (e.g., age, gender, education level, personality, self-esteem, etc.), as well as daily data assessing psychological functioning and the occurrence of stressor experiences. Off-boarding survey times are not included as these served to 1) assess subjective ratings of the app for the current study, or 2) be used in studies conducted by other MoodPrism research team members.

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As can be seen in Table 3, over a 30 day period, using the app did not demand a large amount of time from users. On average, users spent less than 40 minutes completing the on-boarding survey battery, and a less than 2 minutes on individual ESRs totalling less than 1.5 hours of participation. The app achieved good compliance rates with participants completing, on average, 24 ($SD = 5.80$) of the 30 days (78%).

Short completion times can be argued to be a result of non-serious responding. To investigate this possibility all survey responses were analysed for response variability. Assuming non-serious responders select the same answer repeatedly, individuals with no response variance are likely to be non-serious responders. Analyses revealed that out of the 15 on-boarding surveys the majority of participants completed, only four instances (0.76%) of response invariability were identified. Checks were also performed to assess the reliability of surveys administered through a smartphone medium. Reliability estimates were calculated and compared to published reliability data for the standard surveys—these are shown in Table 4.

In the majority of cases, questionnaires presented using the app achieved higher reliability estimates compared to the standard questionnaires. In the few instances where the app's reliability estimates did not exceed that observed in standard questionnaires, Cronbach's alpha scores still reached acceptable scores above .70 (Nunnally, 1978).

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Table 4.

Reliability estimates of psychological questionnaires administered via the ESA compared with published estimates from standard questionnaires.

‘On-boarding’ Survey	Sub-scale	Items	Cronbach’s alpha (reliability)	
			MoodPrism	Standard Questionnaire
Emotional Self-Awareness Scale (Kauer et al., 2012)	Total	33	.89	.83
Warwick-Edinburgh Mental Well-Being Scale (Tennant et al., 2007)	Total	14	.92	.91
Mini-IPIP (Donnellan et al., 2006)	Extraversion	4	.84	.77
	Agreeableness	4	.87	.70
	Conscientiousness	4	.74	.69
	Neuroticism	4	.72	.68
	Intellect/Imagination	4	.77	.65
Patient Health Questionnaire (Kroenke et al., 2001)	Total	9	.89	.89
General Anxiety Disorder Scale (Spitzer et al., 2006)	Total	7	.92	.92
Multi-dimensional Scale of Perceived Social Support (Zimet et al., 1998)	Total	12	.94	.88
Brief Resilience Scale (Smith et al., 2008)	Total	6	.91	.91
Coping Self-Efficacy Scale (Chesney et al., 2005)	Total	26	.78	.95
Music Rewards Scale (Mas-Herrero et al., 2013)	Total	20	.78	.92
Social desirability Scale (Crowne & Marlow, 1960)	Total	12	.79	.89
Rosenberg Self-Esteem Scale (Rosenberg, 1965)	Total	11	.91	.92

Discussion

The aim of the current study was to explore the utility of a smartphone-based ESA for collecting data pertinent to investigating resilience to daily stressors. This was achieved by assessing the capacity of a purpose designed app—MoodPrism—to meet three objectives: (1) collecting daily samples of psychological health over a 30-day experimental duration, (2) appropriate measurement of participants' stressor experiences including the date, type, and severity of stressors, and (3) maintaining a pleasant user experience with high levels of engagement, compliance, ease-of-use, and minimal experimental burden.

Objective 1: Daily Sampling of Psychological Health Over a 30-day Experimental Duration

The first objective concerned the sampling of participants' psychological health over the study duration. Findings indicated that, overall, the smartphone ESA used in the current study was successful in capturing daily assessments of psychological health. Although not achieving 100% response rates, the app was successful in collecting continual and frequent assessment of depressive symptoms. This enabled observation of dynamic variations over time and demonstrated the app's capacity to afford a more nuanced representation of participants' functioning as compared to retrospective reports. Retrospective reports generalised participants' psychological health over the experimental duration and missed variations in symptoms occurring between individual days. Although aggregate data is often preferred for clinical purposes, for research purposes greater detail is generally more informative. A concurrent advantage to frequent experience sampling is the increased likelihood of measuring outcomes near the time of stressor events (as frequencies of assessments increase, the likelihood of measuring participants' functioning near the time of stressors also improves). Sampling participants frequently improves confidence that

measurements accurately reflect participants' level of psychological health at the time of stress (Bonanno, 2012).

Objective 2: Appropriate Measurement of Participants' Stressor Experiences

The second objective of this study concerned the measurement of participants' stressor experiences. The ESA in the current study afforded successful monitoring of participants' stressor experiences in a continual manner over the 30-day study duration. This yielded a high level of detail with regards to individual stressor experiences. This is comparable previous methodologies utilising daily assessments. Previous studies adopted semi-structured interviews (via the DISE) to collect comprehensive data about participants' daily stressor experiences (Almeida et al., 2002; Diehl & Hay, 2010, 2013). These interviews resulted in the collection of short, and fairly open-ended, narratives concerning stressor experiences and included information concerning the date, type, and severity of stressors. In the current study, the ESA collected similar details about participants' stressor experiences in a largely automated fashion, removing requirements for large trained research teams to manually collect daily data. The data collected using the current ESA could therefore be used to replicate analyses conducted in previous studies examining resilience to daily stressors which collect data using the DISE (Charles et al., 2009; Cichy et al., 2014; Mroczek & Almeida, 2004; Neurpert et al., 2007; Stawski et al., 2010). Consequently, the successful measurement of daily psychological functioning, coupled with the effective monitoring of stressor experiences, demonstrated in this study renders the ESA approach a viable alternative to the DISE.

The ESA also provided adequate logging of both type and frequency of stressor experiences. Findings demonstrated the variety of stressors experienced by participants, and the average frequency with which stressors were reported. While the majority of days appear to have been stressor free, participants in the current sample, on average, most often reported

experiencing negative social experiences, negative experiences at school or work, and personal health problems. These findings are consistent with previous research using the DISE citing interpersonal tensions as the most commonly reported daily stressor (Almeida et al., 2002) as well as commonly reported events in various daily stressor inventories such as arguments with family members, getting trouble at school, relationship breakdowns, or given medication by physician (Cheng, 1997; Coddington, 1972; Newcomb et al., 1981; Swearingen & Cohen, 1985; Waaktaar et al., 2004).

The ESA used in the current study also permitted differentiation between the perceived severities of stressors. Findings indicated that stressors rated as ‘slightly’ or ‘moderately’ negative were commonly reported which is consistent with the high frequency with which daily stressors are expected to occur (Almeida et al., 2002). More distressing events rated as ‘very’ or ‘extremely’ negative were observed, on average, several times a month. Although significant negative life events would be rated as such, they were deemed an unlikely source of reports. This is because the prevalence of significant life events was found to be much lower than the frequency of occurrence of ‘very’ and ‘extremely’ negative events observed in the current study. Instead, these events likely reflect a more distressing subset of daily stressors which are perceived as highly negative experiences—‘major daily stressors’. A cursory examination of the types of stressors manually detailed by participants when selecting ‘other’ in daily stressor reports supported this notion, with events such as “[getting a] flat tyre”, “[having the] internet cutting out constantly” being reported as ‘very’ and ‘extremely’ negative experiences.

Objective 3: Maintaining a Pleasant User Experience with High Levels of Engagement, Compliance, Ease-of-use, and Minimising Experimental Burden

The final objective involved assessing participants’ personal experience using the app. This was evaluated through measures of enjoyment, interest, ease-of-use, compliance and

experimental burden. Subjective feedback indicated that the app was rated favourably by users. Participant ratings indicated general agreement that using the app was an enjoyable and interesting experience, and that the app was easy to use and understand. Such findings are comparable to normative data of numerous mental health and well-being apps rated in previous research (Stoyanov et al., 2015). These findings reflect the value of design and architecture of the app in creating an engaging platform from which to participate in psychological research. Apps lacking considerations of aesthetic appeal to users may contribute to low levels of engagement, hindering the utility of smartphone ESAs in psychological research. The app was also rated favourably on levels of experimental burden and intrusion into daily life. Participants disagreed that using the app got in the way of daily activities or that the alerts were a hassle. While these findings also relate to app design, they likely reflect the value of using smartphones as familiar and convenient devices through which to collect data. For participants, using smartphones removed any need to carry a foreign device, partake in lengthy phone calls or specialised training, or physically meet researchers. The helps reduce experimental burden and increases convenience for participants. Taken together, the subjective feedback from participants indicated that users had an overall positive, burden-light, experience with the app.

These findings were corroborated by objective measures of experimental burden and intrusion into daily life. Time-stamp data indicated that participation through the app was not time-intensive. On average, users spent less than 40 minutes completing the on-boarding survey battery, less than 2 minutes on daily ESRs, amounting to less than 1.5 hours of participation over 30-days. This is an improvement on previous research methodologies which have required more time (Diehl & Hay, 2010, 2013; Hay & Diehl, 2010). Importantly, findings of the current study suggest that short completion times were not at the cost of data

quality as little evidence was found of non-serious responding, and surveys administered through the smartphone medium maintained good reliability.

Findings also indicated good participant engagement with the app, with participants completing nearly 80% of all ESRs throughout the full experimental duration. This is comparable to previous studies reporting compliance rates ranging between 69-93%. Studies deploying the ESM using older mobile phones typically report lower compliance rates among participants, e.g., 69% (Kauer et al., 2012), 76% (Reid et al., 2009), 72% (Reid et al., 2012), as compared to the current study. Studies utilising daily telephone interviews typically achieve slightly higher compliance rates reaching 80% (Hay & Diehl, 2010) and 93% (Diehl & Hay, 2013). The slightly lower compliance rate in the current study is likely due to methods used to recruit participants. In contrast to studies achieving higher compliance rates, the current study did not utilise conventional methods of recruitment. While traditional methods recruit participants for the sole purpose of psychological research, the current sample of participants was not overtly recruited for psychological research; rather, participants were invited to download and use the app as a mental health and support tool, and were informed that it also doubled as a research tool. As such, commitment to research participation may have been lacking to a small degree, as the app was downloaded at participants' own volition, without meeting researchers, and without any direct requests to participate. Given this, the compliance rate achieved in the current study was considered a positive outcome. Future research using smartphone ESAs may select more targeted recruitment strategies, involving minor contact with participants, to establish a sense of commitment to participation; this may improve compliance without substantially increasing participant burden.

Strengths and Limitations

A primary strength of utilising smartphone ESAs for research purposes is the reduction of resource demands. While development of the app required specialised skills that were outsourced at a fee (approximately \$31,000USD), this is cheaper compared to previous methods. For example, Hay and Diehl (2010) reimbursed participants \$20 for completing baseline questionnaires, and \$8 for each completed diary day. The final sample included 239 participants with 6715 days of valid data, roughly equating to \$58,500USD. Moreover, aside from outsourced help, the current app was developed and deployed for research purposes by a four person team (including the authors of the current study). This is a notable reduction in resources as previous studies utilise large research teams of 30 to conduct daily telephone interviews (Diehl & Hay, 2010, 2013; Hay & Diehl, 2010). This reduction is important as it provides a more accessible platform from which to implement experience-sampling study designs and collect relevant data for investigating resilience to daily stressors. This accessibility may increase with future development of new ESAs. Such apps may entail customisability to accommodate individual researcher needs. This may remove requirements of developing completely new ESAs, and further minimise costs associated with implementing ESMs.

A challenge experienced in the current study, and a point for consideration in future studies, concerns the way in which stressor data are collected. Capturing all stressors experienced over experimental durations would be ideal, however must be considered with respect to participant burden and intrusion into daily life. While the current study reduced both of these concerns, it did so by sacrificing an even higher level of detail of stressor experiences. While recognising the likely possibility that multiple stressors occur within a single day, this study opted to query participants regarding the most negative experience of the day. This was chosen as it provided a stepped approach in detecting stressors of interest to

the authors. By asking participants about their most negative experience of the day, detection of more distressing events was prioritised. If no such stressor was experienced, participants would then report other, albeit less stressful, experiences permitting detection of stressors of secondary importance. The disadvantage of this approach lies in the mutually exclusive nature with which major or minor stressors can be reported; only one can be reported on a given day, not both. This approach took place of more intrusive and time-intensive potential options involving participants' manual detailing of all major and minor stress experiences on a daily basis.

Conclusion

The current study provides a positive use-case for smartphone ESAs to study resilience to daily stressors. The app's capacity to collect relevant data for such research purposes was demonstrated through the fulfilment of three objectives. This included demonstration of successful data collection encompassing daily sampling of psychological health (objective 1). Such sampling provided greater insights into day-to-day variations in psychological functioning as compared to retrospective methods. Data were collected with continual monitoring of participants' stressor experiences which included the date, nature, and severity of individual stressors comparable to previous research methods (objective 2). Importantly, these objectives were achieved while maintaining a pleasant user experience with high levels of engagement, compliance, ease-of-use, and minimal experimental burden (objective 3).

Accordingly, data collected using a smartphone-based ESA appears near equivalent to data collected using previous implementations of the ESM. The use of an ESA, however, can extend the utility of the ESM further by granting unique advantages to participants and researchers. For participants, ESAs offer a convenient, familiar, and engaging medium from which to participate in psychological research. For prospective researchers, considerable

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value is conferred through ESAs as it offers a means of data collection demanding fewer resources, as compared to previous implementations of the ESM, and improves accessibility to the ESM is increased. Taken together, smartphone-based ESAs offer an alternative means of data collection for the study of resilience to daily stressors. With added utility granted by ESAs, incorporating this implementation of the ESM in future research studies appears well-suited and worthwhile to advance inquiry in this research field.

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Concluding remarks:

In this chapter, the utility of a smartphone-based ESA, MoodPrism, was examined for suitability in the study of resilience to daily stressors. Presented in the form of a research paper submitted for publication, central findings showed that the ESA was an effective means with which to engage participants and collect relevant data for the study of resilience.

Deploying the ESM using an ESA afforded daily sampling of participants psychological functioning, providing ‘movie-like’ views of dynamic changes across time. Importantly, this could be observed concurrently in response to daily stressor experiences, which the app also monitored. Together, these provide data relevant to fundamental principles of resilience, and can be used to conduct empirical research studies in this research field. By implementing a contemporary and temporally sensitive means of data collection suited to examinations of resilience to daily stressors, Paper #1 accomplished component (a) of objective 1 of the thesis.

Chapter 3: Paper #2.

The implementation of an Experience-Sampling-Method capturing trajectories of psychological responding following a major daily stressor

International Journal of Stress Management, Manuscript submitted for publication.

Restatement of thesis objectives:

1. Developing tailored research methods to capture and explore variations in psychological responses following a major daily stressor. This comprised two components:
 - a) Implementing a contemporary and temporally sensitive means of data collection suited to examinations of resilience to daily stressors.
 - b) Executing methodological procedures to convert experience-sampling data into trajectories of psychological responding, with subsequent classification into prototypical response groups.
 2. Utilising these methods to investigate mechanisms facilitating resilience to major daily stressors.
-

Chapter Introduction:

Having demonstrated the utility of the MoodPrism ESA for collecting suitable data for investigations of resilience to daily stressors, a base component of a complete methodology was provided. This enabled progression to component (b) of objective 1, which is addressed in the second paper included in this thesis, and forms the focus of the current chapter. The current chapter presents novel methodological procedures tailored to capture potential variations in psychological responses following a major daily stressor.

Heterogeneity in stress responses has been observed across numerous research studies, and

such explorations are yet to be conducted in the context of major daily stressors. Although established research methods (used to explore resilience to daily stressors in general) could be applied, a more tailored suite of procedures, which overcome limitations of previous methodologies, was implemented to improve analyses of psychological responses.

Note: the paper presented in this chapter is followed by an extended analyses section which includes supplementary analyses which could not be included in the submitted manuscript due to word count limits.

Reprint of Submitted Manuscript

The implementation of an Experience-Sampling-Method capturing trajectories of
psychological responding following a major daily stressor

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Abstract

Contemporary resilience research has revealed heterogeneity in psychological responding following adverse events. Studies primarily explore resilience in the context of either daily stressors, in general, or potentially traumatic events. Little research exists specifically investigating highly distressing daily experiences (major daily stressors), and research methods tailored to examine resilience to such stressors are yet to be developed. The aim of the current study was to implement an experience-sampling based research methodology designed to capture variations in trajectories of psychological responding following a major daily stressor. Experience sampling was conducted through the use of a smartphone Experience-Sampling-Application (ESA) ('Moodprism') which prompts users daily to report symptoms of depression and stressor experiences. Data from a sample of 122 participants (37 male, 84 female, 1 another gender identity; $M_{age} = 29.64$, $SD = 11.80$) were processed according to novel methodological procedures involving: stressor isolation, data quality assessment, response standardisation, group classification, and additional curve-fitting. Four linear trajectory groups were classified—vulnerable, delayed, recovery, and stress-resistant. Deeper insights were achieved through non-linear assessments of individual responses, which highlighted the existence of a variety of non-linear pathways within each group. Study findings demonstrated distinct ways in which individuals may respond to major daily stressors, and highlight differential stress-accumulation risks associated with each response pattern.

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The construct of resilience has been the focus of considerable research for several decades and comprises two core principles: 1) the experience of adversity, and 2) achieving a positive outcome (Fletcher & Sarkar, 2012). Early resilience research explored psychopathological outcomes in children exposed to toxic environments such as poverty, living in an abusive family, or war (Masten, Best, & Garnezy, 1990; Masten & Obradovic, 2006; Masten & Narayan, 2012; Werner, 1992). More recently, studies have investigated resilience in the context of event-based adversities. Unlike chronic adversities, event-based adversities are typically single incident events with definable onsets. These are ubiquitous and vary considerably in frequency, severity, and focus of content (Almeida, Wethington, & Kessler, 2002; Bonanno, 2004).

Studies exploring resilience to event-based adversities generally focus on either daily stressors or potentially traumatic events (PTEs) (e.g., Bonanno & Diminich, 2013; Diehl, Hay, & Chui, 2012). PTEs are considered highly aversive events that typically fall outside the range of normal everyday experience, and are considered ‘potentially’ traumatic because not everyone experiences them as traumatic (Bonanno & Mancini, 2008). PTEs have significant direct impacts on psychological functioning which can persist for months to years (Bonanno, 2004, 2005). In contrast, daily stressors (or hassles) typically encapsulate the minor irritations and frustrations characterising everyday life (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982; Kanner, Coyne, Schaefer, & Lazarus, 1981). While typically appraised as being ‘low’ or ‘medium’ in severity (Almeida et al., 2002), daily stressors occur frequently and resulting stress may accumulate over time to generate exaggerated psychological reactions (Schilling & Diehl, 2014; Zautra, 2003). The experience of both event types is universal, with people typically experiencing daily stressors once a day and at least one PTE during their lifetime (Almeida et al., 2002; Kessler, Sonnega, Bromet, Hughes, & Nelson, 1995; Ozer, Best, Lipsey, & Weiss, 2003).

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Despite generally being considered relatively minor events, daily stressors can often produce highly negative experiences. In a study conducted by Arjmand and Rickard (2018), experience-sampling data collected in a sample of 48 participants over 30 days included numerous reports of ‘very’ and ‘extremely’ negative events —greater than incidence rates typically associated with PTEs. cursory examinations of these events indicated that these stressors were unlikely to be PTEs, and likely occurred within bounds of everyday life. Examples include getting a flat tyre or having the internet cutting out constantly. Experiences like these can be defined as ‘major daily stressors’: a subset of daily stressors appraised with high negativity. Due to high severity ratings and frequencies of occurrence, these stressors share characteristics of minor daily stressors and PTEs. For example, like PTEs, major daily stressors may generate a direct and immediate impact on psychological functioning. This impact is likely to be greater than negative effects generated by minor daily stressors (albeit less than PTEs) and require several days to restore psychological equilibrium. As with minor daily stressors, major daily stressors occur frequently and may similarly engender risks of stress accumulation across days if individuals are unable to recover before subsequent stressors (Deboeck & Bergeman, 2013). As such, major daily stressors may pose combined risks associated with typical daily stressors and PTEs and likely contribute to psychological disturbances.

Research Methods Exploring Psychological Responses to Daily Stressors and Potentially Traumatic Events

Research studies exploring resilience to daily stressors often utilise the Experience-Sampling-Method (ESM) and incorporate daily diary designs to tackle challenges associated with capturing event related phenomena (Almeida, 2005; Schilling & Diehl, 2015). The ESM is advantageous over retrospective methods of data collection as it enables frequent, concurrent sampling of stressor experiences and outcome variables of interest (Arjmand &

Rickard, 2018). Using such methods, previous studies have explored resilience by examining affective reactivity to daily stressor experiences (Stawski, Almeida, Lachman, Tun, & Rosnick, 2010; Charles, Piazza, Luong, & Almeida, 2009; Neupert, Almeida, & Charles, 2007; Mroczek & Almeida, 2004). Affective reactivity is the magnitude of a person's change in affect on days when stressors occur as compared to stressor free days. Studies using this approach conduct multilevel modelling analyses capturing within-person measures of affective reactivity, and explore of between-person differences in variables potentially conferring resilience. These studies have yield insightful associations between several person-specific factors and resilient reactivity profiles, such as higher personal control (Neupert et al., 2007), older age (Uchino, Berg, Smith, Pearce, & Skinner, 2006) and higher fluid cognitive ability (Stawski et al., 2010). Although 'reactivity' encompasses an important aspect of stress responding, many studies demonstrate considerable heterogeneity across individual responses sharing comparable reactivity profiles (Bonanno, 2004, 2005; Bonanno & Mancini, 2008). Studies measuring reactivity alone may provide therefore only limited representations of psychological responses following daily stressor experiences.

Several studies highlight the importance of considering patterns of responding following initial reaction to stressors. For example, research examining resilience to PTEs show that individuals with similar initial reactivity profiles can exhibit differences in longer term patterns of adjustment (Bonanno et al., 2008; Bonanno, Field, Kovacevic, & Kaltman, 2002; Bonanno, Moskowitz, Papa, & Folkman, 2005; Bonanno, Rennieke, & Dekel, 2005; Bonanno, Wortman, & Nesse, 2004). These studies utilise methods which assess participants' psychological functioning several times over an extended duration following the experience of a PTE (see Bonanno, 2004, 2005; Bonanno & Diminich, 2013). Individual data points were plotted for each participant and individual *trajectories* of responding were captured. Across a number of studies, six prototypical trajectories have been identified, which are

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differentiated by two key features: 1) the magnitude of initial reactions, and 2) patterns of recovery following initial reactions (Bonanno & Mancini, 2008). For example, several trajectories share large initial reactions following stressor onset, which subsequently differentiate as the direction of some responses return towards healthy levels of functioning (recovery trajectory), while other responses maintain high levels of dysfunction (chronic dysfunction trajectory). Considering both initial reactivity and patterns of recovery responding following stressors therefore provides more nuanced differentiation between individual stress responses.

Examining patterns of recovery following stressor exposure has been advocated by contemporary daily stress theory (Scott, Ram, Smyth, Almeida, & Sliwinski, 2017; Smyth et al., 2017), and is important to consider in the context of daily stressors. This is because the high frequencies with which daily stressors occur engender risks of stress-accumulation—a central means through which these events can lead to unfavourable outcomes (DuBois, Felner, Brand, & Evans, 1992; Lazarus, 1999; Schilling & Diehl, 2014; Zautra, 2003). Consequently, monitoring patterns of recovery is vital as it reflects the dissipation of negative effects evoked by daily stressors, and ultimately influences stress-accumulation processes (Bergeman & Deboeck, 2014; Deboeck & Bergeman, 2013). For example, a stressor experience may result in a large initial stress reaction followed by a slow, or absence of, recovery over several days; responding in this way generates an amount of ‘emotional residue’ (Scott et al., 2017), or unresolved stress, which can accumulate if additional stressors occur before psychological equilibrium is re-established (Deboeck & Bergeman, 2013). In contrast, responses to stressor experiences may involve a rapid recovery toward typical levels of functioning after large initial reactions; responding in this way reflects an efficient dissipation of generated stress, produces less emotional residue, and minimises likelihoods of stress accumulation. This positions individuals favourably to face upcoming stressors. Taken

together, trajectory-based assessments can extend existing research methods by enabling a more holistic examination of psychological responses, as compared to previous studies examining only initial reactions, and advance current understandings of the ways in which individuals respond to daily stressors.

A paucity of research specifically examines resilience to major daily stressors, and holistic methods to capture psychological responses to these events are yet to be developed. As conducted in studies examining resilience to PTEs, exploring variations in prototypical trajectories of responding following major daily stressors would be useful to determine whether there are also resilient and non-resilient patterns of responding to such events. The aim of the current study was therefore to implement a research methodology designed to capture and explore variations in trajectory-based patterns of psychological responding following a major daily stressor. Such methods were developed around the classification of four primary patterns of responding, resembling trajectories observed in PTE research, which exhibit different patterns of initial reactivity and subsequent recovery after stressor exposure. Due to the novelty of this methodology in daily stressor research, and exploratory nature of the current study, more specific predictions were not made regarding the prevalence of each response pattern.

Method

Participants

A sample of 122 participants ($M_{age} = 29.64$, $SD = 11.80$) was recruited as part of the promotion of a mental health support smartphone application (app). The app was promoted to the general public through various means including online promotion (e.g., Facebook and Twitter), presentations for organisations and schools, and word of mouth. Participant recruitment was aimed at selecting individuals from a diverse range of backgrounds, education levels, age, and with varying levels of psychological well-being (see Table 1).

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Table 1.

Sample frequencies and percentages across gender and education levels, as well as means and standard deviations of several auxiliary outcome variables.

Variable	N	%		
Gender				
Male	37	30.3		
Female	84	68.9		
Another gender identity	1	0.8		
Highest level of Education				
Primary	26	21.3		
Secondary	50	41.0		
Tertiary	16	13.1		
Post Graduate				
	M	SD	Min	Max
Patient Health Questionnaire (Kroenke et al., 2001)				
	20.4	5.9	10	35
General Anxiety Disorder Scale (Spitzer et al., 2006)				
	16.2	5.2	8	27
Warwick-Edinburgh Mental Well-Being Scale (Tennant et al., 2007)				
	40.0	8.6	18	60
Social desirability Scale (Crowne & Marlow, 1960)				
	5.5	2.7	0	10

Materials

The application. Experience sampling was achieved through daily assessments enabled by a previously validated smartphone Experience-Sampling-Application (ESA) ('MoodPrism'; www.moodprismapp.com) which participants downloaded onto personal smartphone devices (Arjmand & Rickard, 2018; Rickard, Arjmand, Bakker, & Seabrook,

2016). Participants input responses in three components of the app: ‘on-boarding’ surveys, daily experience sampling reports (ESRs), and ‘off-boarding’ surveys. Additional details regarding these components and development of the app are outlined elsewhere (see Arjmand & Rickard, 2018; Rickard et al., 2016). The ESRs are the primary measure reported in this paper.

ESRs were presented randomly on a daily basis within permitted time-frames specified by the user, and completed within the app using the touch-screen interface. The brief questionnaire included 15 items assessing symptoms of anxiety and depression, positive and negative emotional states, well-being, context (where and who they were with), and stressors experienced over the past 24 hours. Materials relevant to the current study included the two items assessing symptoms of depression, and the stressor experience item.

Two-item Patient health questionnaire. Daily symptoms of depression were assessed using the two-item Patient Health Questionnaire (PHQ-2) (Löwe, Kroenke, & Gräfe, 2005). The PHQ-2 asks participants to rate how much they currently feel “little interest or pleasure in doing things”, and “feeling down, depressed, or hopeless”. Rated on a five-point Likert scale ranging from “not at all” (1) to “extremely” (5), items are summed to given an overall score ranging from 2 to 10 with higher scores indicating higher symptoms of depression. This selection of items has shown good internal consistency (Cronbach’s $\alpha = .83$) and correlates highly with established measures of depression (Löwe et al., 2005).

Stressor experience report. Stressor experiences were monitored using a single-item question. Participants were asked “What is the most negative thing that has happened to you today?” Originally, participants were presented with a list of options from which to select experienced events. This list was compiled from various stress event questionnaires and adjusted to relate to both adult and adolescent populations (Cheng, 1997; Coddington, 1972; Newcomb, Huba, & Bentler, 1981; Swearingen & Cohen, 1985; Waaktaar, Borge,

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Fundingsrud, Christie, & Torgersen, 2004). Following feedback during a beta trial of MoodPrism (Rickard et al., 2016) the items were revised to be broader and briefer, and were subsequently converted into domains of living where stressors may occur. Each domain addressed an area of life common to multiple stressors in the original list; negative social experience, loss of valued material item, negative experience at school/work, negative experience outside of school/work, personal health problems, and health problems of someone close to you. These reflected similar domains included in previous methodologies (Almeida et al., 2002), permitted a broader line of inquiry encompassing the vast range of possible stressors that can occur, and reduced the number of item selections in the list. The list also included a “nothing negative happened” option, as well as an “other” option where participants could manually type stressors not covered by domains provided on screen. If participants select any option indicating the experience of a stressor, an additional question was presented asking participants to rate the degree of negativity of the event on a four-point Likert scale ranging from “slightly” to “extremely”. As minor stressors are generally rated as low or medium in severity, (Almeida et al., 2002), stressors rated as ‘slightly’ or ‘moderately’ negative were considered minor daily stressors, while stressors rated as ‘very’ or ‘extremely’ negative were considered major daily stressors.

Experimental Procedure

Ethical approval to conduct the current research study was approved by the Monash University Human Research Ethics Committee (Approval # CF14/968 – 2014000398). MoodPrism was made available for download freely from the AppStore (iOS) and GooglePlay (Android). The app was promoted as an emotional awareness and well-being tool which provides users towards useful and relevant mental health tools and resources. Participants were invited to download the app as a personal mental health support tool, and were informed that data collected from the app would be used for research purposes.

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Explanatory statements and consent forms were administered electronically through the app. Participants below 18 years of age were provided an additional consent form for minors, with checks for parental consent. Participants were informed of a number of incentives built into the research design: additional feedback on positive and negative mood functioning (unlocked after one and two weeks, respectively), and entries to a prize draw for two cash vouchers (\$AU50) (offered after completing key milestones: first day, first week, second week, and one month).

Figure 1 below illustrates the data collection schedule used for each participant. In order to unlock the full functionality of the app, participants were required to complete a battery of ‘on-boarding’ surveys. After this, the first ESR becomes available and henceforth participants are prompted by the app on a daily basis to complete ESRs. After the 30-day experimental duration, participants were presented with a selection of ‘off-boarding’ surveys which included several surveys included in the ‘on-boarding’ survey battery, a feedback survey, and subjective ratings of the app. All data collected using the app were stored in a backend data repository constructed to continuously record user responses.

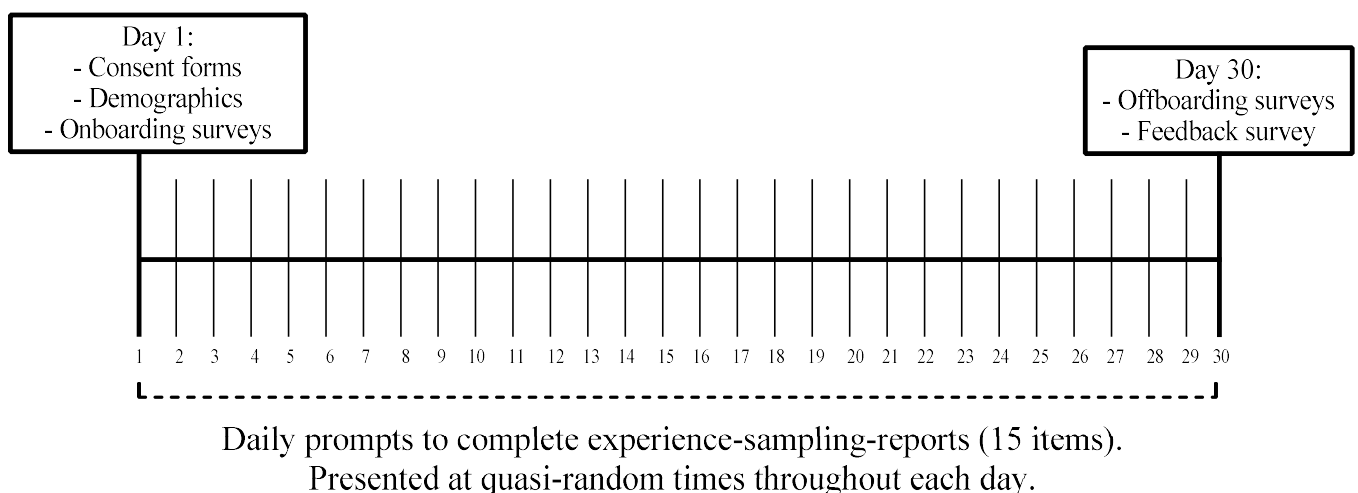


Figure 1. Experience-sampling data collection schedule over 30 days.

Data Processing Procedure

Methods implemented in the current study comprised several data processing steps. In brief, participants' data were first screened to identify and isolate a section of data surrounding a major daily stressor. The quality of isolated data sections was assessed and allocated into one of six grades of data quality. Depressive symptom scores on days within isolated sections were standardised to reflect psychological responses relative to participants' regular mood. Standardised data sections were then used to extract data points reflecting individual initial reactivity and patterns of recovery, which formed the basis of participant classification into separate trajectory groups.

Stressor isolation. Relevant sections of each participant's data set comprised a 7-day span of ESRs including a major daily stressor on the 4th day (see Figure 2)—referred to as 'stress response data'. A single section of this data was extracted for each participant. If multiple major daily stressors were reported throughout a full data set, the stress response data section with the highest data quality rating was selected for extraction.

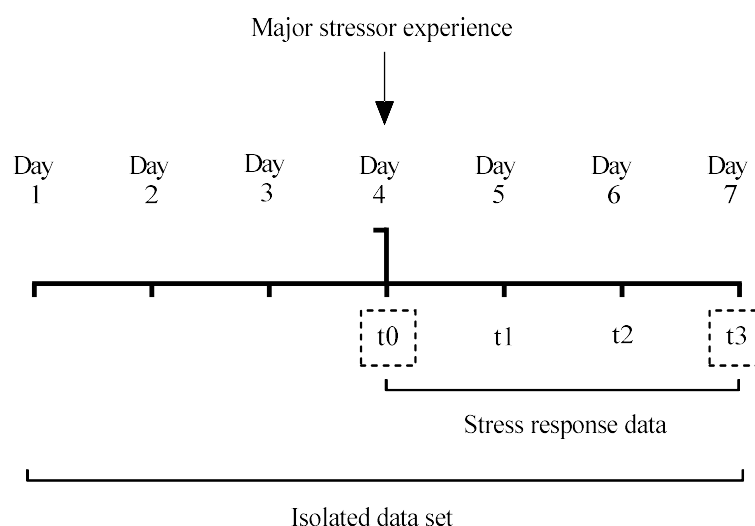


Figure 2. A visual representation of targeted sections of participant data—t0 and t3 reflect the stressor day and the third after, respectively, which were used to operationalise initial reactivity and subsequent recovery.

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Experience-sampling data for each day included depressive symptom scores and reports of stressor experiences. Reports of stressor experiences across these days provided the context in which the major daily stressor occurred. This affords insight regarding the presence or absence of prior or subsequent stressors surrounding the major daily stressor of interest.

Participants possessing poor data sets (due to inconsistent use of MoodPrism) were excluded from analyses—specifically, this comprised participants who did not complete on-boarding surveys following download of the app, participants who used the app sporadically (e.g., 1-3 days) over the 30-day duration, or participants who stopped using the app completely after a few days. Participants who used MoodPrism consistently, but reported no major daily stressors, and therefore possessed no relevant, isolatable data sections, were also excluded. Finally, participants were excluded if they possessed relevant data sections with an isolatable major daily stressor, but had missing data within the section.

Assessment of data quality. Stressors experienced throughout participants' isolated data sets were examined and it was clear that many data sets comprised multiple successive stressors. The most straightforward data sets to interpret were those comprising a major stressor (the target stressor) with no surrounding stressors. In such cases, trajectories are least likely to be contaminated by peripheral stressors and yield the most informative representations of psychological responding. Limiting analyses to only these data sections however would have reduced the available data for analysis due to the high frequency with which daily stressors occur. As stressors are unpredictable and often occur in close proximity, a range of different contexts with varying degrees of potential influence on trajectories likely exist. To capture these differences, the current study classified participants' isolated data sections into 'grades' of data quality. The most 'artefact-free' data sections (with no surrounding stressors) were labelled 'grade 1' data. The next most interpretable data were those in which peripheral stressors were only minor events. While minor events can have

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small direct impacts on psychological health, this was presumed unlikely to create substantial influence on response patterns if they occurred prior or subsequent the stressor of interest (grade 2). The next grade of data (grade 3) comprised situations where minor stressors occurred before *and* after, which would make them less interpretable compared to grade 2. The least interpretable data sets involved contexts where major daily stressors occurred in succession. ‘Grade 4’ comprised data sets containing minor and major daily stressors occurring prior to the major daily stressor of interest—these are likely to negatively influence preparedness to face a stressor. ‘Grade 5’ data also comprised data sets containing minor and major daily stressors prior to the stressor of interest, but also included additional minor stressors after the stressor of interest. Here, prior major daily stressors negatively influence psychological readiness to manage a stressor, and subsequent minor stressor may further exacerbate distress generated from the major daily stressor of interest.

Although inclusion of less interpretable data sets for analyses is not desirable, the benefits of enhancing the sample size were deemed to outweigh the limitations of interpretability for the purposes of the current study. To accommodate the inclusion such data sets, analyses were conducted to examine the potential confounding influences generated by peripheral stressors experiences on patterns of responding. Specifically, associations between grades of data quality (reflecting specific sequences of peripheral stressor experiences) and patterns of responding following the major daily stressor of interest were examined. This shows the extent to which similarities in response patterns within a given group are due to particular sequences of stressors experienced outside the primary major daily stressor. For example, it may be the case that unfavourable responses are associated with grade 5 data, while favourable responses are associated with grade 1 data. Here, differences in stressor experiences confound interpretation of research findings. Individuals exhibiting unfavourable responses may not necessarily be less resilient than individuals exhibiting favourable

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responses; had they experienced no peripheral stressors (grade 1 data), they may too have exhibited a favourable response pattern. Examining associations between patterns of responding and peripheral stressor experiences is important to anticipate these issues and reliably address such possibilities.

Standardisation. As daily mood naturally fluctuates irrespective of stressor experiences, stress response data were standardised according to participants' regular mood. Depressive symptoms from ESRs recorded outside the bounds of any major daily stressor (the stressor day plus three subsequent days) throughout participants' full data sets were considered representative of regular mood. Individual stress response data were standardised (z-scores) using means and standard deviations (SD) calculated from each participant's respective regular mood data. As such, standardised symptom scores on each day ($t_0 - t_3$) represent the number of SDs from regular (mean) symptoms. This accounts for individual mood variability and reflect psychological responses relative to participants' typical functioning.

Defining change from typical psychological functioning. Two change scores were determined for each participant (refer to Figure 2). Participants' *initial reactivity to stressors* was determined using the standardised depressive symptom score on the day of the major daily stressor (t_0 , or 'reactivity point')—this indicates how much change occurred in symptoms of depression relative to typical levels, and provides a measure of the direct impact resulting from stressor exposure. Participants' *pattern of recovery* was determined using the standardised depressive symptoms score on the 3rd day following the major daily stressor (t_3 , or 'recovery point'). This provides a measure of the extent to which participants recovered from immediate reactions.

Meaningful changes in symptoms were defined using ± 1 SD boundaries (Bonanno et al., 2002). Initial reactivity and recovery point scores were subsequently classified as follows.

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A *stress reaction* was assigned when symptom scores increased relative to typical levels of functioning by 1 standard deviation. *No change* was assigned when depression scores remained constant, increased, or decreased by less than 1 standard deviation. *Improved functioning* was assigned when depressive symptoms decreased by greater than 1 standard deviation relative to typical levels⁴.

Defining group classifications. Boundaries defined in the previous step enabled classification into different response groups, which are differentiated by variations in reactivity and recovery point combinations. A vulnerable pattern was assigned to participants exhibiting stress responses at both t0 and t3. A delayed pattern was assigned when participants showed no change or improved responses at t0 but manifested a stress response at t3. Recovery patterns were assigned to participants exhibiting stress responses at t0 and either ‘no change’ (that is, a return to baseline) or improved responses at t3. Finally, a stress-resistant pattern was assigned to participants exhibiting no change or improved responses at both t0 and t3.

Stress response curve fitting. Capitalising on the detailed data provided by the ESM, deeper explorations of stress responses were conducted. Specifically, non-linear assessments⁵ of standardised stress response data were performed to examine further details regarding curves of individual trajectories. To assess curves and rates of change characterising individual stress responses, linear, quadratic, cubic, and exponential functions were fitted to participants’ standardised scores on the stressor day (t0), and the subsequent 3 days (t1, t2, and t3). This permits assessment of potential heterogeneity within linear

⁴ The current study utilised ± 1 SD limits, similarly conducted in previous research (Bonanno et al., 2002), and avoided using larger limits (e.g., ± 1.5 SD or ± 2 SD) as this would decrease sensitivity of identifying stress-resistant/resilient individuals.

⁵ Although such assessments included linear models, these explorations were collectively labelled as ‘non-linear assessments’ to differentiate explorations of stress responses using two (t0 and t3) data points—which can only exhibit linearity—versus four data points (t0, t1, t2, and t3) which may involve non-linearity.

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trajectory groups, and observation of varied non-linear pathways psychological responses could follow while reaching similar outcomes—examples of these are illustrated in Figure 3.

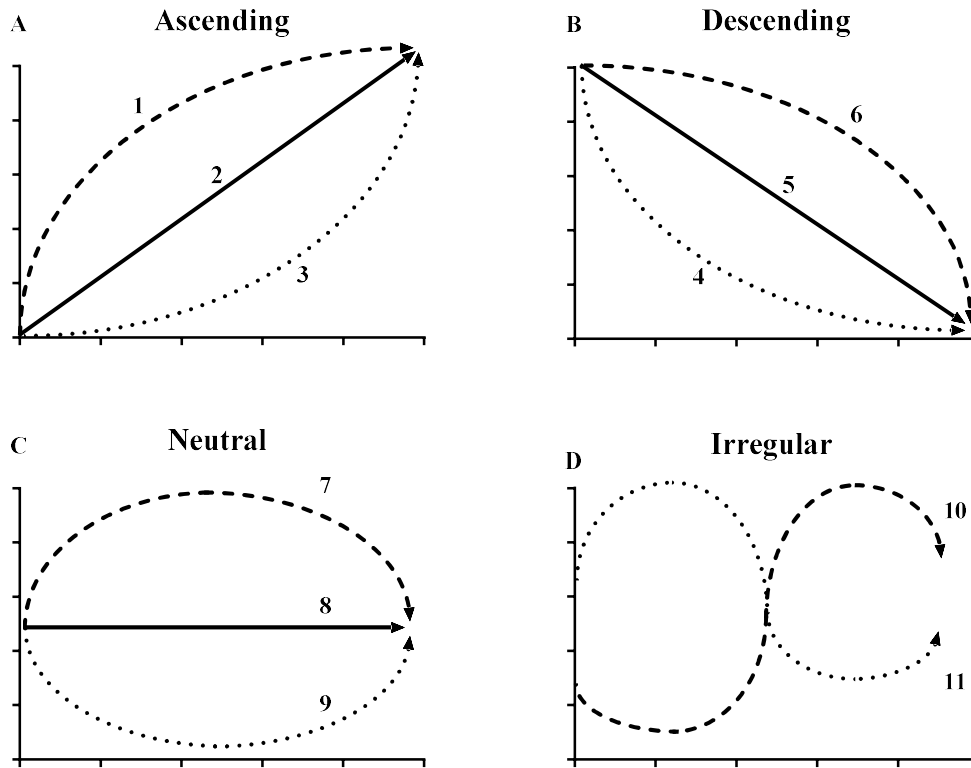


Figure 3. Examples of potential alternative non-linear pathways (dotted lines) reaching similar outcomes across linear trajectories with a) ascending, b) descending, and c) neutral trends, as well as d) possible irregular pathways.

Using MATLAB R2016a, linear, quadratic and cubic functions were fitted to each participant standardised stress response data using the ‘poly1’, ‘poly2’, and ‘poly3’ commands respectively. Exponential functions were fitted using two equations to capture variations in growth and decay patterns (pathways 1, 3, 4, and 6):

$$a * \exp(x) + c \quad (1)$$

$$a * \exp(-x) + c \quad (2)$$

R^2 values were calculated for all functions fitted to participants’ stress response data. Functions achieving the highest R^2 value were selected as most representative of individual stress responses. Using established criteria (Moore, Notz, & Fligner, 2013), only R^2 values

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above 0.7 were considered adequately representative, and in cases where all R^2 values fell below 0.7, the cubic function was selected ($R^2 = 1$) to capture irregularly shaped stress responses.

Results

Data were downloaded remotely and relevant data were extracted and processed according to methods described. The number of participants, data selection process, and breakdown of data quality in the final sample is illustrated in Figure 4.

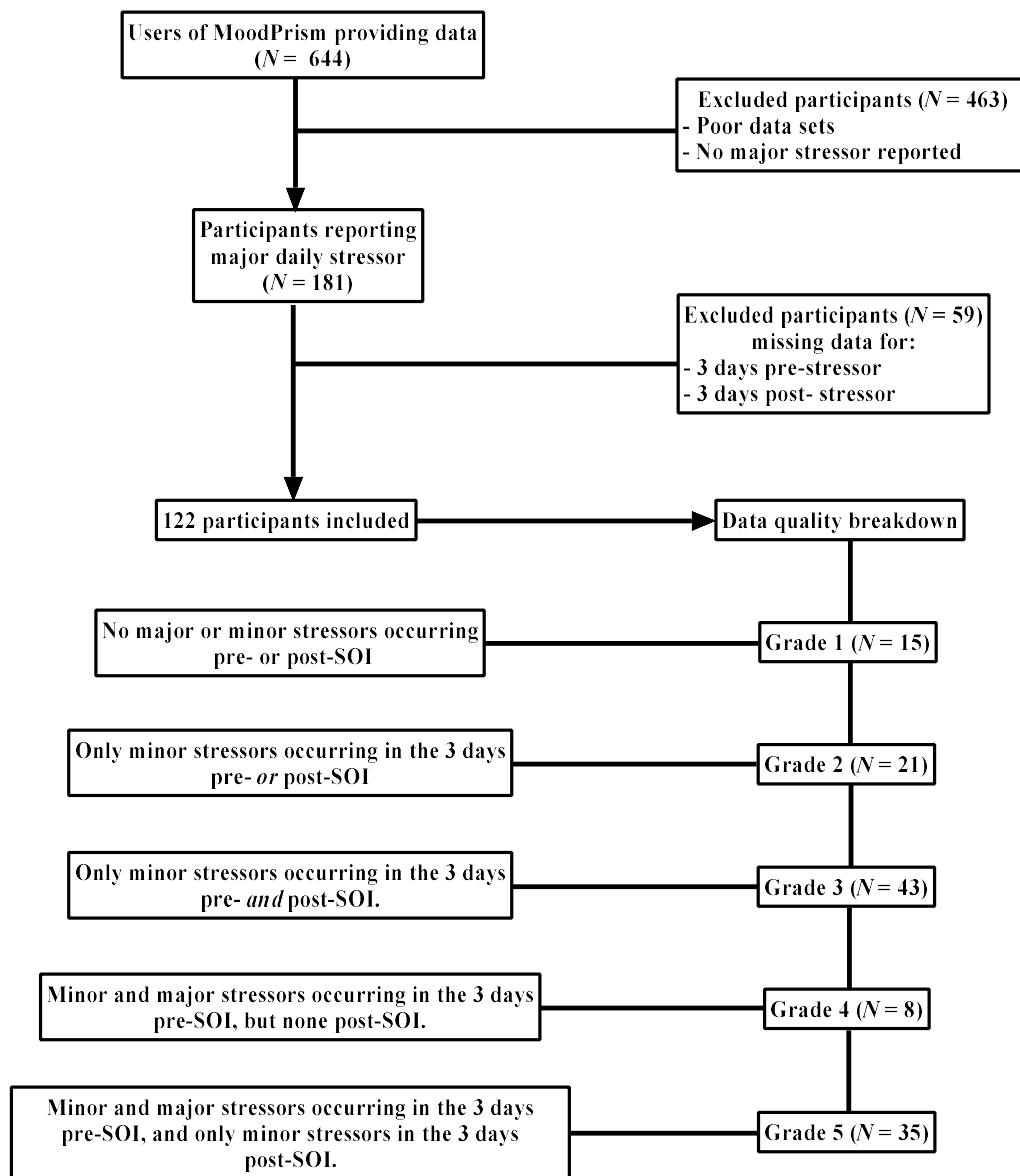


Figure 4. A flowchart illustrating the data selection process and breakdown of data quality. SOI = major daily stressor of interest.

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Figure 4 shows that a considerable number of participants were excluded from the original sample due to inconsistent and ineffective use of the app, or the absence of major stressor experiences. Among participants with appropriate use of the app who reported a major daily stressor, many had missing data surrounding stressors of interest rendering data unusable. A final sample of 122 participants was used in the current study with various classifications of data quality. In 12% of cases, the context in which major stressors occurred was ideal with no surrounding major or minor stressors (grade 1). Grade 2 and grade 3 data, comprising only minor peripheral stressors, occurred more commonly, together representing roughly 52% of cases. Finally, the least straightforward data, involving additional major peripheral stressors, occurred in roughly 36% of cases.

Linear Group Classifications

Based on standardised reactivity (t_0) and recovery point (t_3) combinations, participants were classified into primary groups representing linear trajectories of responding following a major daily stressor. The majority of participants were successfully classified into assigned groups ($n = 115$; 94%), with only a small portion exhibiting unassigned response patterns ($n = 7$; 6%). Specifically, participants most often exhibited the recovery response pattern of responding ($n = 42$; 34%), followed by the stress-resistant ($n = 41$; 34%), vulnerable ($n = 19$; 16%), and delayed ($n = 13$; 11%) patterns. Unassigned responses comprised instances where participants exhibited no change at t_0 and an improved response at t_3 ($n = 3$; 2%), or improved responses at t_0 and no change at t_3 ($n = 4$; 3%). While these groups may be of interest in future studies (for example, to examine post-stressor growth), due to the low frequencies of occurrence they were not investigated further. Average reactivity and recovery point scores for each group are provided in Table 2, and corresponding profile plots of linear trajectories are illustrated in Figure 5.

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Table 2.

Means (and standard deviations) of reactivity and recovery point scores for vulnerable, delayed, recovery, and stress-resistance linear trajectory groups.

Assigned group	Initial reactivity score (t0)	Recovery point score (t3)
1. Vulnerable	3.13 (2.44)	2.59 (1.61)
2. Delayed	-0.06 (0.54)	1.80 (0.76)
3. Recovery	2.79 (2.22)	-0.35 (0.66)
4. Stress-resistant	-0.13 (0.51)	-0.28 (0.59)

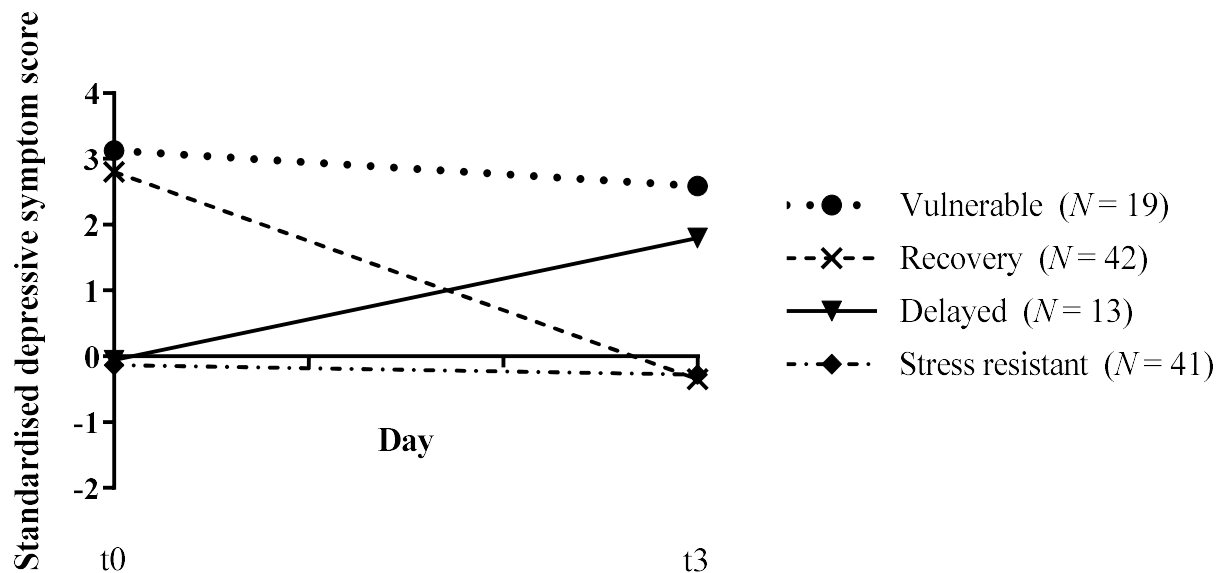


Figure 5. Profile plots of individual trajectory groups. Data points represent mean symptom scores for t0 (reactivity) and t3 (recovery point) across participants comprising each group.

As shown in Figure 5, trajectories are differentiated by reactivity and recovery point combinations, where averaged reactivity scores represent direct impacts sustained following stressor exposure and recovery points represent subsequent patterns of responding. Averaged reactivity and recovery point scores for vulnerable and stress-resistant groups resulted in

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trajectories with neutral (horizontal) trends, while the recovery and delayed groups exhibited descending and ascending trends respectively.

To examine influences of peripheral stressor experiences on group classification, a Pearson's chi-square test was conducted to explore differences in data quality across trajectory groups. As 62.5% of expected counts were less than five, Fisher's exact test (FET) is reported which showed no significant association between group classification and the frequency of specific grades of data quality, $FET = 13.19, p = .537$.

Non-linear Classifications

Non-linear assessment of participants' psychological responses revealed considerable heterogeneity in curves within primary (linear) trajectory groups. Frequencies of non-linear pathways are shown in Table 3.

A Pearson's chi-square test was conducted to examine associations between the linear trajectory groups and the frequency of specific non-linear pathways. As 81.8% of expected counts were less than five, FET is reported which revealed a significant association, $FET = 86.95, p < .001$, with Cramer's V indicating a large effect size ($\phi_c = .60, p < .001$).

Specifically, several non-linear pathways occurred more frequently than expected counts within trajectory groups: pathway #11 occurred more often than expected in the vulnerable group; pathway #4 pathway occurred more often than expected in the recovery group; pathways #1, #2, and #3 occurred more often than expected in the delayed group; pathway #8 occurred more often, and pathway #4 less often, than expected in the stress-resistant group.

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Table 3.

Frequencies (and expected counts) of non-linear pathways within vulnerable, recovery, delayed, and stress-resistant groups.

	Non-linear pathway										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	∩	/	J	∪	\	∩	∩	—	U	~	~
Vulnerable	0 (0.5)	0 (0.8)	0 (0.8)	3 (4.5)	1 (0.5)	0 (0.3)	0 (0.5)	0 (1.7)	5 (2.8)	3 (3.6)	7* (3.0)
Recovery	0 (1.1)	0 (1.8)	0 (1.8)	22*** (9.9)	2 (1.1)	2 (0.7)	1 (1.1)	0 (3.7)	5 (6.2)	8 (8.0)	2 (6.6)
Delayed	2** (0.3)	4*** (0.6)	4*** (0.6)	0 (3.1)	0 (0.3)	0 (0.2)	0 (0.3)	0 (1.1)	1 (1.9)	0 (2.5)	2 (2.0)
Stress-resistant	1 (1.1)	1 (1.8)	1 (1.8)	2* (9.6)	0 (1.1)	0 (0.7)	2 (1.1)	10*** (3.6)	6 (6.1)	11 (7.8)	7 (6.4)

$p < .05^*$

$p < .01^{**}$

$p < .001^{***}$

These results show that individuals classified into the recovery group often exhibit non-linear pathways characterised by early decay of depressive symptoms following large reactions following stressor exposure (pathway #4). In contrast, individuals classified into the delayed group were shown to often exhibit pathways with ascending trends exhibiting multiple growth patterns (early[#1], steady[#2], and late[#3]). Finally, results showed an association between individuals classified into the stress-resistant group with presentations of horizontal pathways with consistent, minor deviations from typical psychological functioning at all time points (pathway #8).

Results also showed numerous unexpected non-linear pathways within specific linear trajectory groups. For example, pathways #9, #10, and #11 were commonly observed in all groups irrespective of directions (ascending, descending, or neutral) associated with the

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group. Similarly, the vulnerable trajectory group comprised several descending (#4 and #5), as opposed to neutral, pathways. Other than these, overall, ascending, descending, and neutral non-linear pathways occurred within linear trajectory groups with concordant trends.

The average R^2 value of non-linear curves fitted to standardised stress response data was 0.9 ($SD = .09$). This means that, overall, non-linear curves fitted to participant stress response data accounted for majority of the variance between data points, and closely represented the shapes of individual standardised stress responses.

Discussion

The aim of the current study was to implement an experience-sampling based research methodology to capture and explore variations in trajectories of psychological responding following a major daily stressor. Using methods outlined in the current study, the majority of participants were successfully classified into four linear trajectories of psychological responding. An additional layer of heterogeneity was observed within these categories through non-linear assessment of responses, demonstrating various secondary pathways through which individuals achieve similar outcomes. Implications of findings as well as strengths and limitations of study methods are discussed below.

Linear Trajectories of Responding Following a Major Daily Stressor

Using methods implemented in the current study, variations in psychological responding were successfully captured through classification of four linear trajectories. Trajectories exhibited distinct patterns of responding along key features of stress responses (Bonanno, 2004, 2005; Scott et al., 2017; Smyth et al., 2018): 1) initial reactivity to the stressor, and 2) patterns of recovery following initial reactions.

The *vulnerable* trajectories comprised large initial increases in symptoms of depressions which were maintained after several days. Individuals exhibiting such responses appear challenged in withstanding and recovering effectively from negative effects generated

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by major daily stressors. Stress dissipation is poor in vulnerable trajectories responses, and after several days, an amount of emotional residue remains available for accumulation with effects of successive stressor experiences. Without adequate recovery following stressors, individuals are positioned poorly to confront future stressors and susceptibility to exaggerated affective disruptions is increased (Schilling & Diehl, 2014).

Individuals exhibiting *delayed* trajectories displayed minimal initial reactions following stressor exposure. After several days, however, symptoms of depression increased above typical levels. These individuals appear to withstand direct effects of the stressor, and subsequently manifest a delayed increase in psychological distress. Despite exhibiting favourable initial reactions, stress-accumulation risks also exist for individuals displaying this pattern of responding. No signs of stress dissipation are exhibited in delayed trajectories and, instead, emotional residue appears to increase over time. Such outcomes similarly render individuals susceptible to stress-accumulation across successive daily stressor experiences, rendering this pattern of responding undesirable.

Recovery trajectories appear less subjected to such outcomes as emotional residue is reduced over time. Individuals exhibiting this pattern of responding manifest a reduction in depressive symptoms after large initial reactions. Such individuals appear able to dissipate negative effects evoked by the stressor and return toward typical levels of psychological functioning. Here, opportunities for stress-accumulation are minimised as less emotional residue remains open for accumulation with effects of additional stressor experiences. While it can be argued that moderate stress-accumulation may occur where stressors are encountered in very close succession, this appears unlikely as findings indicate that recovery responders generally re-establish psychological equilibrium quickly through a rapid decay of symptoms (pathway #4).

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Stress accumulation appears least likely to occur for individuals exhibiting *stress-resistant* trajectories. These individuals exhibit minimal reactivity following stressor exposure and maintain typical levels of functioning several days later. Such individuals appear able to effectively withstand direct effects of major daily stressors, showing no immediate, or delayed, increases in depressive symptoms. Across several days, little or no emotional residue is generated, and substantial risks of stress accumulation are evaded. The stress-resistant trajectory resembles trajectories of minimal-impact resilience observed in previous research (Bonanno, 2004; Bonanno & Mancini, 2008) and represents the most favourable pattern of responding.

While groups identified in the current study resemble several trajectories of responding in PTE research (Bonanno, 2005; Bonanno & Diminich, 2013), they are novel in being identified in the context of major daily stressors. This identification is useful as it provides a platform from which to explore person-specific factors differentiating groups. Profiling individuals exhibiting favourable responses (e.g., stress-resistant) and exploring differentiating factors with individuals exhibiting unfavourable responses (e.g., vulnerable or delayed) can highlight possible mechanisms facilitating resilience to major daily stressors. Benefits of such investigations include corollary profiling of individuals exhibiting unfavourable responses, potentially revealing mechanisms underlying vulnerability. Delineation of such characteristics can help contribute new knowledge to existing bodies of resilience literature and bolster understandings concerning development of individual resilience and vulnerability to major daily stressors. Creating resilience programmes rooted in empirical research can serve to cultivate protective/resilience factors in individuals (e.g., personality characteristics, coping strategies, cognitive styles) to combat stressor generated distress. Preventative screening tools may also be developed for detecting at risk individuals; individual characteristics associated with unfavourable responses to daily stress may serve as

markers of vulnerability to psychopathological development. This can aid identification of vulnerable persons early where intervention may be most effective, curbing development of mental illnesses, and consequently reducing burdens on mental health services and facilities.

Non-linear Assessments of Psychological Responses within Linear Trajectory Groups

Non-linear curve fitting procedures permitted deeper investigation of psychological responses following major daily stressors. Findings revealed several notable outcomes including a) considerable heterogeneity within linear trajectory groups, b) a high frequency of irregular pathways, and c) mismatches between directional trends of non-linear pathways and the trajectory group to which they belong.

a) Heterogeneity observed within linear trajectory groups. A variety of alternative non-linear pathways were observed within trajectory groups. This illustrates heterogeneity in the ways in which participants achieve similar outcomes. As such, in addition to between-group variations, susceptibility to stress accumulation may also vary within linear groups. For example, individuals exhibiting pathway #6 and #4 both exhibit recovery trajectories, however differ in rates of recovery following initial reactivity. The latter involves an early decay of psychological distress which occurs soon after initial reactions, while the former exhibits a relatively delayed decay of distress beginning closer to the third day after initial reactions. Although both pathways share similar outcomes, a prolonged recovery response (#6) entails a delayed dissipation of emotional residue as compared to an early recovery (#4). If major stressors occur in succession, early recoveries appear desirable as the bulk of emotional residue is dispelled soon after stressor exposure, leaving little unresolved stress for accumulation. In contrast, prolonged recoveries restore psychological equilibrium later and therefore pose higher risks of stress-accumulation as stress is unresolved for a longer time period and available for accumulation with effects of additional stressors.

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Heterogeneity within linear groups is important to consider in future research aiming to explore characteristics which influence responses to stress. While specific characteristics (e.g., physical, psychosocial, sociodemographic) may effectively explain variability between groups classified at gross levels (linear trajectories), other characteristics may be more sensitive to differences between responses classified at finer levels (non-linear pathways). Individual characteristics influencing patterns of responding following a major daily stressor may therefore operate at different levels of response classification. As such, future studies (comprising only a single level of classification) achieving null results may benefit from exploring other levels of classification where predictor variables may be more relevant. This advocates adoption of layered approaches in future research where analyses delineating individual characteristics between different response groups are conducted at several levels of classification.

A notable finding concerns heterogeneity in pathways observed specifically within the stress-resistant group. A pathway uniquely exhibited by stress-resistant individuals comprises consistent deviations away from typical psychological functioning at each day following stressor exposure (pathway #8). Findings also indicated that stress-resistant individuals often exhibit other pathways involving inconsistent deviations across days, which could present as large peaks and/or troughs exceeding parameters set around typical psychological functioning (e.g., pathways #7, #9, #10, and #11). This highlights that, while near typical functioning is maintained on the stressor day (t0) and several days after (t3), functioning between days may be far from typical boundaries. This seemingly casts doubt on the labelling of this group as stress may not be resisted consistently across all days. Post-hoc inspections of standardised stress response data belonging to 'stress-resistant' participants were performed to assess magnitudes of deviations across days. Inspection revealed that deviations across days were relatively minor in majority of cases. While not a conclusive measure, this provides

confidence that individuals in this group, in general, exhibited consistent resistance to stress across days, and the labelling of this group was appropriate.

b) High frequency of irregular pathways. Irregular pathways characterised patterns of responding poorly represented by linear, quadratic, and exponential functions. In such cases cubic functions were applied to ascertain exact shapes of responses. Irregular pathways involved peak and trough combinations where, in one pathway, the trough precedes the peak (#10) while the opposite is true in the other (#11). All linear trajectory groups included numerous instances of irregular pathways. This suggests that stress responses, regardless of reactivity or recovery patterns, may involve a sudden reversal of symptomatology.

A noteworthy observation of these pathways is the varied degrees to which the magnitudes of peaks and troughs can manifest, even between irregular pathways observed within the same linear trajectory groups (see Figure 6 below). As shown in Figure 6, irregular pathways may involve variation within groups due to differences in the size of peaks and troughs. This highlights a third level⁶ of heterogeneity in psychological responses, indicating additional variability in stress-accumulation properties among irregular pathways (e.g., low magnitude vs high magnitude). Classifying differences between irregular pathways requires additional methodological procedures beyond those presented in the current study.

⁶ Level 1 = Heterogeneity between linear trajectories of responding.

Level 2 = Heterogeneity between non-linear pathways, nested within linear trajectories of responding.

Level 3 = Heterogeneity between irregular pathways, nested within non-linear pathways, nested within linear trajectories of responding.

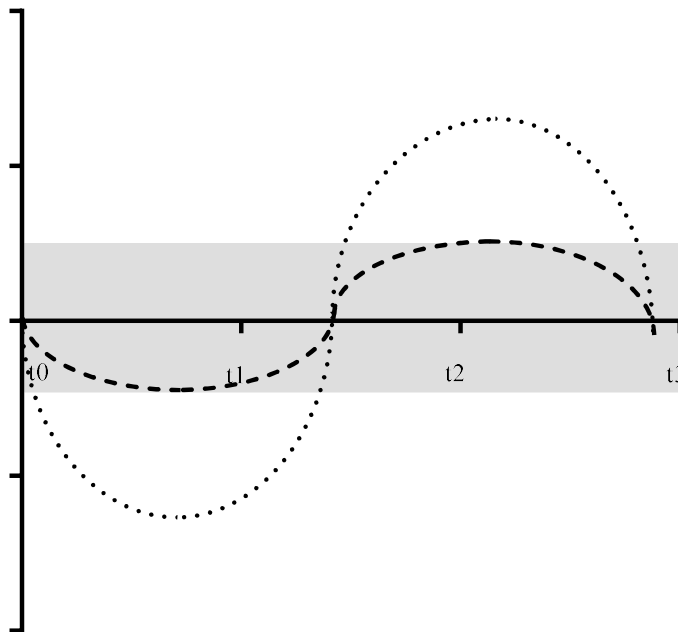


Figure 6. An example of heterogeneous irregular pathways manifesting within the same linear trajectory group (stress-resistant).

It is important to note, however, that additional levels of classification may be problematic for studies aiming to identify person-specific factors predicting membership into particular trajectory groups. This is because additional levels of classification pose risks of small group sizes, reducing practicality (by means of lowered statistical power) conducting robust statistical analyses. Although increased differentiation is beneficial for precise characterisation of psychological responses, added levels of classification increase the number of groups into which participants can be grouped. Excessive differentiation is therefore likely to result a large number of small groups. This highlights a prominent challenge for prospective researchers: achieving an acceptable balance between capturing classifiable similarities in patterns of responding while maintaining pragmatic group sizes to permit valid statistical analyses.

c) Mismatches in direction trends between non-linear pathways and trajectory groups. Findings revealed anomalous mismatching of directional trends between non-linear pathways and trajectory groups to which they belong⁷. For example, while the recovery trajectory generally exhibits a descending trend, non-linear trajectories with neutral (horizontal) trends were observed within this group (e.g., pathways #7 and #9). Similarly, non-linear pathways with descending trends were observed within the vulnerable group which is characterised by a neutral trend (e.g., pathways #4 and #5). Although this appears to highlight the variable and untidy ways individuals respond to stress, such observations are likely due to limitations associated with defining typical levels of psychological functioning using discrete boundaries. In order to meaningfully define change from typical levels of functioning, cut-off points were selected in line with previous research (Bonanno et al., 2002). While this was necessary to establish a range of typical functioning, setting only these parameters creates opportunity for any non-linear pathway to manifest outside such thresholds. Additionally, rigid thresholds can be insensitive to scores near (but not exceeding) cut-off points, leading to similar mismatches and also misclassifications—examples are illustrated in Figures 7A and 7B.

As can be seen in Figure 7A, potentially all non-linear pathway can manifest in the vulnerable group providing both reactivity and recovery point scores exceed upper bounds of typical functioning. This is possible as no boundaries exist outside limits defining typical levels of psychological functioning ($\pm 1SD$). This is not problematic in principle as responses above typical levels of functioning likely pose psychological vulnerabilities irrespective of manifested pathways. Moreover, this is less likely to occur in remaining groups as the stress-

⁷ 'Mismatching' or 'mismatches' mentioned henceforth refer to this notion.

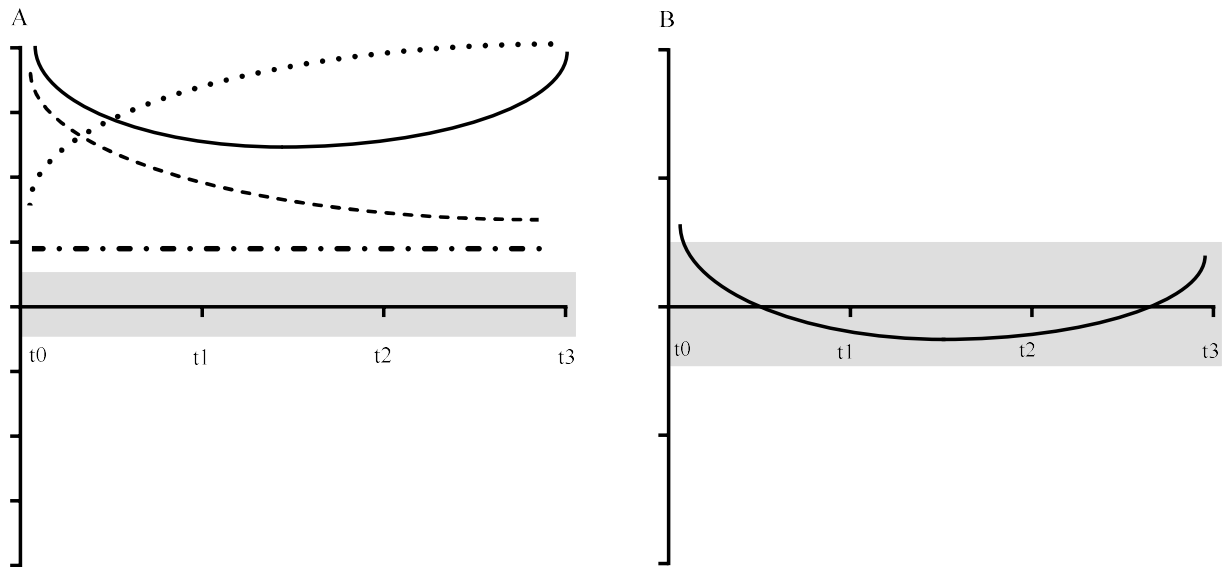


Figure 7. An illustration of A) several non-linear pathways manifesting in the vulnerable group, and B) pathway #9 (exhibiting a neutral trend) manifesting reactivity (t0) and recovery points (t3) resulting in classification into a recovery group (associated with a descending trend)—NB, grey areas represent bounds of typical psychological functioning, $\pm 1SD$.

resistant group is defined within narrow limits, and the delayed and recovery groups involve disparate reactivity/recovery patterns making it impossible for certain non-linear pathways to manifest (e.g., pathway #1 manifesting in the recovery group or pathway #6 in the delayed group).

Mismatches may also occur due to rigidity of bounds surrounding typical psychological functioning—illustrated in Figure 7B. In this example, an individual exhibits a ‘U’ shaped non-linear pathway (#4) with depressive symptoms slightly above typical levels of functioning at t0 and within typical levels at t3. While the standardised initial reactivity (t0) and recovery point (t3) scores did not perfectly match, a quadratic model provided the best R^2 value and was selected as best representing this pattern of responding. This reactivity/recovery pattern classifies the individual into the recovery group despite responding with a pathway exhibiting an overall neutral trend. Mismatching in this case is

more problematic, highlighting susceptibility for questionable classifications, and is a limitation of the current research methodology. For instance, despite meeting the criteria for classification into the recovery group, the psychological response illustrated in Figure 7B may more appropriately be classified as a stress-resistant trajectory.

As it is possible for reactivity or recovery points to fall close but not cross boundaries surrounding typical psychological functioning, slight variations in these scores can result in misleading classifications into linear trajectory groups. Misclassifications reduce validity of groups and, in turn, cast doubt on any associations identified with predictor variables in future research. Future research can avoid dubious classifications by flagging instances where reactivity and recovery point scores fall near boundary limits. Appropriate non-linear models can be applied to suspect data (as outlined in the current study) for visual inspection. These can be checked against linear trajectory classifications, and reclassifications can be performed accordingly. Such checks can serve to improve the accuracy of classifications, address limitations described above, and increase validity of linear trajectory groups⁸.

Strengths

A major strength of the current study was the temporally sensitive nature with which data were collected. This was achieved through the use of a smartphone ESA which afforded continual, daily assessments of psychological functioning and stressor experiences (Arjmand & Rickard, 2018). The use of daily assessments enabled observation of varying forms of heterogeneity in stress responses. Specifically, using two assessments (t0 and t3) revealed an initial level of heterogeneity, which was magnified as the number of assessments was increased (t0, t1, t2 and t3). This magnification was deemed a strength as it highlighted the possibility that stress-accumulation properties can vary between, and within, different classification levels: between linear trajectories (level 1); between non-linear pathways nested

⁸ These checks were performed in the current study and no instances of reclassification were deemed necessary.

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within linear trajectories (level 2); and between irregular pathways nested within non-linear pathways nested within linear trajectories (level 3). Consideration of such heterogeneity is useful for future research studies examining factors differentiating between favourable and unfavourable psychological response groups. This can help direct researchers' efforts toward investigating influences of different individual characteristics at different levels of response classification. Daily assessments also permitted non-linear examinations of stress responses which prompted deeper investigations regarding the label ascribed to the stress-resistant group. Such investigations endorsed such labelling and strengthened the validity of classification.

The ESA also enabled observation of the full context in which major daily stressors occurred. This methodological feature highlighted challenges associated with collecting high quality data, and permitted statistical means to manage them. For example, collecting 'artefact-free' data (grade 1) was found to be relatively uncommon, as the majority of useable data involved major and minor daily stressors, in various sequences and combinations, surrounding the major daily stressor of interest. This made uniform (free of confounds) assessments of psychological responses difficult due to differential stressor experiences among participants. To accommodate these differences, the current study retained participant data involving peripheral stressor experiences and assigned them into grades of data quality; this permitted analyses exploring whether linear trajectory groups were unevenly influenced by specific sequences of stressor experiences. Findings indicated that trajectory groups were not unevenly influenced as such, and overrepresentations of particular grades of data quality (reflecting patterns of stressor exposure) did not manifest in any particular trajectory group. To illustrate, in the current study, the vulnerable group *did not* comprise only participants possessing grade 4 or 5 data only; as such, the assertion that the ascribed 'vulnerability' of this group may be due to most group members experiencing successive major daily stressors

is discounted. Instead, it appears more likely that responses reflect a propensity to respond unfavourably to a major daily stressor, driven by a range of factors separate from an individual's peripheral stressor experiences (Almeida, 2005). This underscores a limitation of previous research studies which often assess trajectories of responding with a sole focus on a stressor of interest without consideration of the additive effects on stress generated by peripheral stressors (e.g., Bonanno et al., 2004; Bonanno et al., 2008; Bonanno, Moskowitz, et al., 2005; Bonanno, Rennie, et al., 2005; Norris et al., 2009; Quale & Shanke, 2010). Unlike the current study, such research is unable to assess the extent to which trajectory groups may be influenced by specific sequences of peripheral stressors, and is consequently left susceptible to assertions discounted in this study. As daily stressors (both major and minor) can occur frequently and in close succession, continual monitoring of stressor experiences appears essential to afford such assessments.

Conclusion

The current study outlines the development and implementation of purpose-designed, research methods developed to capture variations in psychological responses following a major daily stressor. The methodology coupled useful aspects of previous methods used in PTE and daily stressor research, and adopted contemporary means of data collection. This paper outlines procedural steps to capture and explore trajectory-based psychological responses using experience-sampling data collected from a smartphone-based ESA (Rickard et al., 2016; Arjmand & Rickard, 2018). Using this methodology, four distinct linear trajectories were classified: 1) a vulnerable trajectory characterised by a maintained increase in symptoms of depression following stressor exposure, 2) a delayed trajectory characterised by minimal initial reactivity following exposure, and an increase in symptoms after several days, 3) a recovery trajectory characterised by a large initial reactivity, coupled with a recovery toward typical levels of depressive symptoms, and 4) a stress-resistant trajectory

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characterised by a general maintenance of typical levels of symptoms following stressor exposure. Response trajectories illustrated in this study represent first depictions of ways individuals respond to major daily stressors. Responses reflect different patterns of stress dissipation, and highlight varied risks of stress-accumulation. Methodological procedures also enabled non-linear assessments of psychological responses. These highlighted further levels of heterogeneity in the ways individuals respond to major daily stressors, and accentuated finer distinctions between linear stress responses. Non-linear examinations also permit detection, and enable rectification, of potential trajectory group misclassifications promoting its application in future research studies.

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Extended analyses

Due to word count restrictions associated with journal publication, further analyses examining the sensitivity of research findings to specific parameters set in the study could not be included in the submitted manuscript. Two supplementary sensitivity analyses are provided here which investigate potential differences in research findings across 1) the inclusion of varied levels of data quality, and 2) the use of different thresholds defining meaningful change away from typical levels of psychological functioning.

Examination of Trajectory Group Sizes Across the Inclusion of Different Ranges of Data Quality

As discussed in this chapter, participants' data sets were classified into a variety of grades of data quality which reflect specific sequences of peripheral stressor experiences. Trajectories of responding become difficult to interpret as the number and severity of peripheral stressors experienced increases. The most straightforward and interpretable data sets are artefact-free, indicating no experience of peripheral stressors around the primary major daily stressor of interest—these were classed as “grade 1” data. Less desirable data sets included various sequences of peripheral stressor experiences around the stressor of interest, and were classed from “grade 2” to “grade 5”. Naturally, the inclusion of higher grades, and exclusion of lower grades, of data quality is preferable. This, however, may be impractical as it can lead to large reductions in sample size. In the current chapter, out of 122 participants, only 15 achieved grade 1 classifications, while the remaining 107 participants possessed comparatively less interpretable data, with many ($N = 35$) receiving grade 5 classifications. To investigate the effects of removing undesirable data sets on study findings, trajectory group classifications were conducted at different levels of data quality inclusion. Figure 8 shows changes in group sizes of each trajectory group across different levels of data quality

inclusion, and Figure 9 shows these changes in proportion to each group's original size (including all grades of data quality).

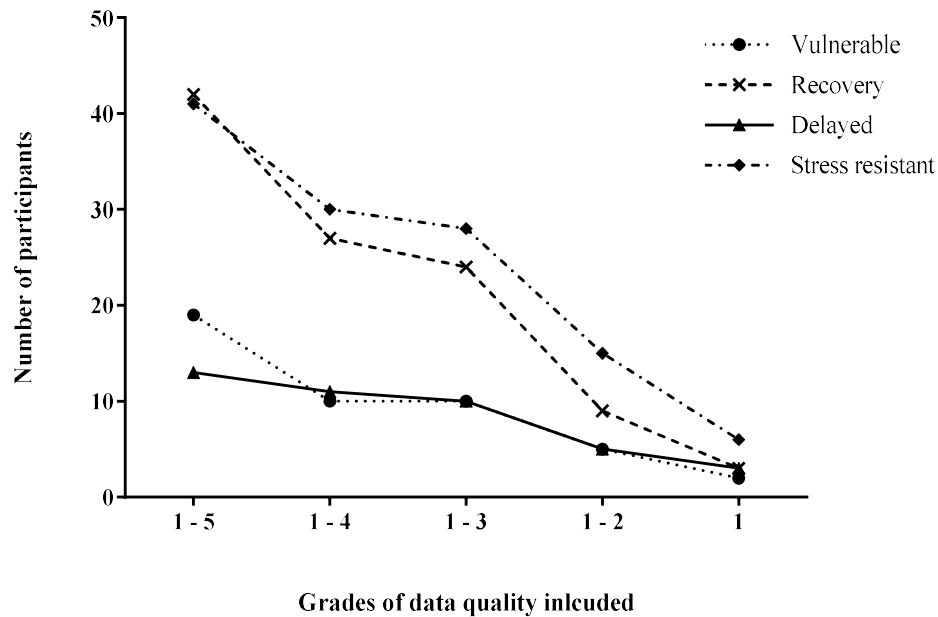


Figure 8. Variations in trajectory group sizes across the inclusion of different sets of data quality ranging from grade 1 only (most desirable) to including all grades (less desirable).

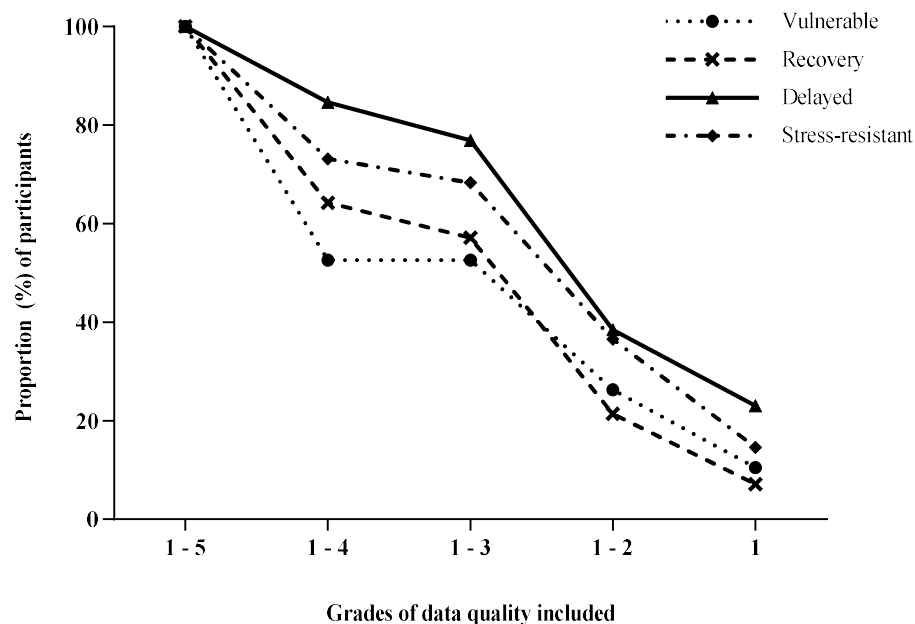


Figure 9. Proportions of participants in each group (relative to the group's original size) across the inclusion of different sets of data quality ranging from grade 1 only (most desirable) to including all grades (less desirable)

The results show that removing less desirable grades of data quality from study analyses leads to an overall decline in group sizes across all trajectory patterns (Figure 8). When including only ideal (grade 1) data sets, the disparity between group sizes is minimal. As poorer grades of data quality are sequentially introduced, this disparity increases and illustrates the relative prevalence of each trajectory of psychological responding. Importantly, the rate of decline in group sizes appears similar for each trajectory group overall, as illustrated in Figure 9. One exception to this can be noted at the change that occurs when including all data sets (1-5) to only including grades 1 to 4 (1-4). Here, the proportion of participants removed from each group appears exaggerated in the vulnerable and recovery groups as compared to the delayed and stress-resistant groups.

These findings indicate that obtaining ideal, artefact-free, grade 1 data is infrequent (relative to other grades), and conducting study analyses using this quality of data alone may lead to underrepresented frequency rates of each trajectory of responding. This is important as the exclusion of other grades of data quality (grades 2 to 5) would have resulted in a failure to identify the greater prevalence of favourable trajectories (stress-resistant and recovery) as compared to unfavourable ones (vulnerable and delayed) observed in the current study. Additionally, the overall consistent rate of decline in group sizes indicates an even spread of data quality grades across groups. This consistency, was not observed in the transition from including grades 1 to 5 to only including grades 1 to 4 for the vulnerable and recovery groups. For these groups, at this transition, a larger proportion of participants were removed, indicating a greater presence of participants with grade 5 data (as compared to the delayed and stress-resistant groups). A greater frequency or over-representation of poor grades of data quality in a particular trajectory group casts doubt on the validity of group classification; in such cases interpretation of response patterns becomes difficult as many participants in the group experienced additional stressors outside the primary stressor of interest. Results

obtained in Paper #2, from analyses assessing whether particular grades of data quality were over-represented in specific trajectory group (p. 101), however, suggest that it is unlikely that trajectory group classifications were confounded by over-representation of specific sequences of peripheral stressor experiences (as captured by grades of data quality). As such, the apparent greater proportion of grade 5 data in the recovery and vulnerable groups (as compared to the delayed and stress-resistant groups) does not appear substantial, and trajectory groups identified in the current study likely represent valid psychological patterns of responding to major daily stressors. Taken together, the findings highlight the utility and practicality of including a range of different grades of data quality, and support analytical approaches utilised in the thesis to achieve an enhanced sample size.

Assessment of Study Findings Using Different Parameters Defining Meaningful Change in Depressive Symptoms Following a Major Daily Stressor

In order to capture trajectories of psychological responding, a threshold of $\pm 1SD$ was set in Paper #2 to define change away from typical psychological functioning at t_0 and t_3 . This threshold was selected in line with previous research (e.g., Bonanno et al., 2002), and with the intention to increase sensitivity toward identifying manifestations of resilience (stress-resistance). It may be argued, however, that a threshold of $\pm 1SD$ may be too liberal, and lead to an over-classification of ‘meaningful change’. For example, assuming a normal distribution, 68% of data is expected to fall within a range of $\pm 1SD$ from the mean. Naturally, 32% of data points are expected to fall beyond this threshold by chance. Over a four-day window, this translates to at least one day exceeding this threshold, regardless of stressors experienced. As such, the data relevant to this chapter were re-analysed using a range of different thresholds ($\pm 1.5SD$, $\pm 2SD$, $\pm 2.5SD$, and $\pm 3SD$), and the effects on group sizes and average reactivity (t_0) and recovery point (t_3) scores for each group were examined. These effects are illustrated in Figures 10 and 11, respectively.

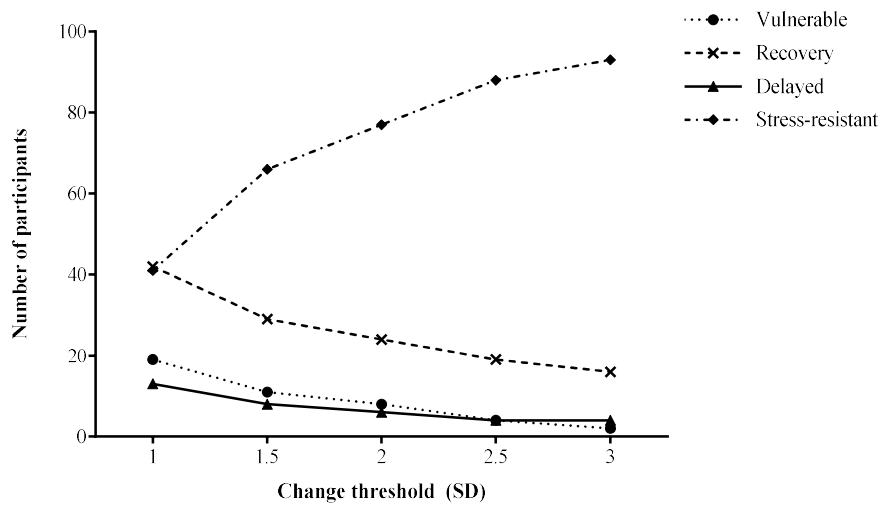


Figure 10. Changes in trajectory group sizes across stepped increases in threshold parameters defining ‘meaningful change’ away from typical symptoms of depression.

With incremental increases ($\pm 0.5SD$) in parameters defining meaningful change, an increasing proportion of participants are reclassified from the vulnerable, recovery, and delayed trajectory groups, into the stress-resistant group. This is because stress-resistant group classification involved exhibiting a ‘no change’ response at both t_0 and t_3 ; ‘no change’ responses were attributed to standardised depressive symptom scores that fell within the set threshold defining meaningful change. As such, as this threshold is increased, more participant symptom scores fall within this range, and eligibility of stress-resistant classification increases throughout the sample. Although a threshold of $\pm 3SD$ would encompass 99.7% of expected depressive symptom scores (assuming a normal distribution) and represent a more conservative approach to defining meaningful change, it results in the classification of the majority of participants (80%) into the stress-resistant trajectory group. Indeed, in previous studies (examining PTEs), resilient trajectories of responding are most common; the prevalence of these responses, however, is only around 35-46% (Bonanno et al., 2011) which is more consistent with prevalence rates of stress-resistance achieved using the

± 1 SD threshold in the current study (36%). Increasing ‘change threshold’ parameters therefore appears to reduce the sensitivity of the present methodology to differentiate between classes of psychological responses, and provides little insight regarding the variety of trajectories psychological responses may follow following a major daily stressor experience. As such, the use of a ± 1 SD threshold appears to be a more practical and informative analytical strategy, and its use in the current thesis appears acceptable.

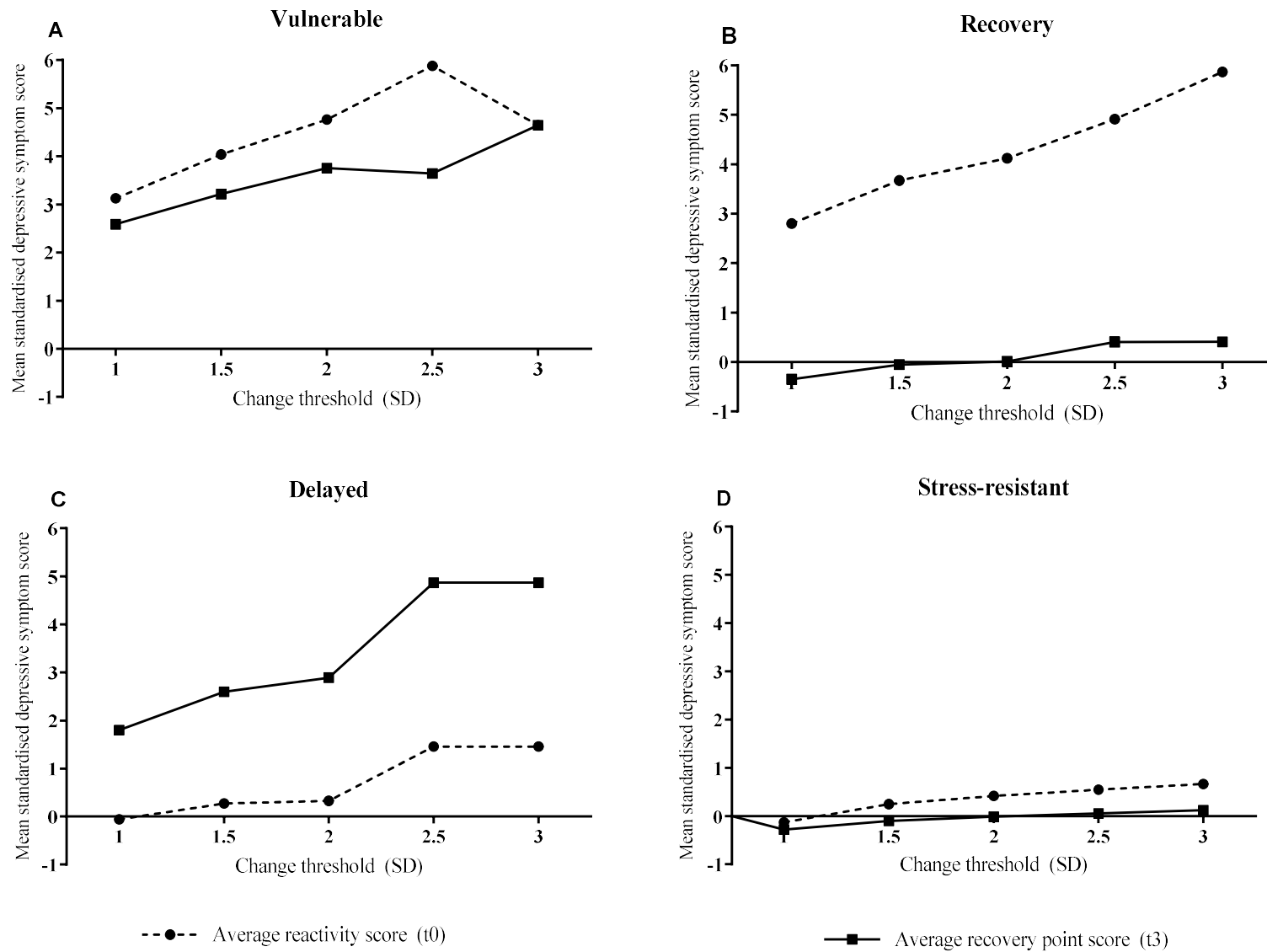


Figure 11. Changes in average reactivity (t0, dotted line) and recovery point (t3, solid line) scores across increasing threshold parameters defining ‘meaningful change’ away from typical symptoms of depression for the A) vulnerable, B) recovery, C) delayed, and D), stress-resistant trajectories.

Concerning average reactivity (t_0) and recovery point (t_3) scores, there is an overall increase in both scores for each group as change threshold parameters are incrementally increased. This occurs because increases in change threshold parameters increase the proportion of participants in each group with higher t_0 and t_3 scores. For example, at a change threshold of $\pm 2SD$, individuals classified into the recovery group using a $\pm 1SD$ threshold would be classified in the stress-resistant group if their t_0 score was between 1 and 2SD. This leaves only participants with t_0 scores above 2SD, thereby raising the average reactivity score for the recovery group. In the current sample, this leads to an exaggeration of response patterns in each trajectory group—that is, the vulnerable group appears more vulnerable with higher t_0 and t_3 scores, and the gradients of trajectories in the recovery and delayed groups become steeper. Although this effect occurs in all trajectory groups, it appears attenuated in the stress-resistant group. In the stress-resistant group, increases in change threshold parameters leads to only slight increases in the average t_0 and t_3 scores. This could be due to the large initial group size of the stress-resistant and recovery groups (together around 72% of total sample). The stress-resistant group ($N = 41$) would naturally comprise low t_0 and t_3 scores (according to the classification procedures outlined in this chapter), and addition of participants from the relatively smaller delayed and vulnerable groups would have only small influences on the average t_0 and t_3 scores. Adding participants from the recovery group would not likely have a large impact on the average t_3 score as t_3 scores in this group would be within $\pm 1SD$. While it could be reasoned addition of participants from the recovery group would markedly increase the average t_0 score (as these would be above $\pm 1SD$ by definition), this was not reflected in supplementary analyses (see Figure 11D). This indicates that most of the recovery participants' t_0 scores were near the $\pm 1SD$ threshold (average t_0 score = 2.79) having only relatively small influences on increasing the average t_0 score once absorbed into the stress-resistant group.

Concluding remarks:

This chapter demonstrated the implementation of research methods designed to capture and explore psychological responses following a major daily stressor. Classifications achieved in this paper represent the first illustrations of the typical ways individuals respond to this form of adversity. Importantly, this was accomplished using a trajectory-based methodology which enabled holistic analysis of stress responses. Such analyses accommodated a more complete theoretical understanding of stress responding as compared to previous studies which assess initial reactivity to daily stressors only.

Having executed methodological procedures to convert experience-sampling data into trajectories of psychological responding, with subsequent classification into prototypical response groups, Paper #2 accomplishes component (b) of objective 1. In conjunction with Paper #1—which accomplished component (a)—these papers showcase a tailored methodology designed to capture variations in psychological responses following a major daily stressor, resulting in the collective fulfilment of the thesis' first objective.

Chapter 4: Paper #3.

Influences of age, self-esteem, and perceived social support on psychological responses following a major daily stressor

Social Indicators Research, Manuscript submitted for publication.

Restatement of thesis objectives:

1. Developing tailored research methods to capture and explore variations in psychological responses following a major daily stressor. This comprised two components:
 - a) Implementing a contemporary and temporally sensitive means of data collection suited to examinations of resilience to daily stressors.
 - b) Executing methodological procedures to convert experience-sampling data into trajectories of psychological responding, with subsequent classification into prototypical response groups.
 2. Utilising these methods to investigate mechanisms facilitating resilience to major daily stressors.
-

Chapter Introduction:

Accomplishing components (a) and (b) of objective 1 enabled the exploration of relationships between person-specific factors and different patterns of psychological responding (objective 2), which is reported in Paper #3. The smartphone-based ESA collected relevant data to core principles of resilience, and methodological procedures outlined in the previous chapter provided means to classify participants into distinct groups of psychological responding. Group classifications allow differentiation between individual patterns of psychological responding which reflect varying degrees of resilience. Such differentiation provides a platform from which to explore factors which may be facilitating more resilient

patterns of responding. As discussed in Chapter 1, Almeida's (2005) model of daily stress indicates a range of person-specific and stressor-specific factors which function to have direct and interactive effects on well-being outcomes. Exploring relationships between such factors and particular patterns of responding would be useful to determine what factors may confer protection or vulnerability to negative effects of major daily stressors.

In this chapter, aforementioned relationships are examined using a multi-variable approach in a sample of 90 participants selected from the previous study (25 participants were excluded from the original sample of 115, as they had missing data pertaining to person-specific factors investigated in Paper #3). This permits analyses of main effects as well as interactions between factors. In addition to examining this question through the temporally sensitive lens of an ESM, these methodological features may provide greater insight into mechanisms underlying processes of resilience following major daily stressors beyond findings of previous studies.

Note: the paper presented in this chapter is followed by an extended analyses section which includes supplementary analyses which could not be included in the submitted manuscript due to word count limits.

Reprint of Submitted Manuscript

Influences of age, self-esteem, and perceived social support on psychological responses
following a major daily stressor

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Abstract

Major daily stressors represent a relatively unexplored form of event-based adversity in resilience research. These stressors possess combined risks associated with potentially traumatic events and minor daily stressors. That is, major daily stressors and can evoke large direct impacts on psychological functioning and also engender risks of stress-accumulation (Arjmand & Rickard, 2018b). Little research has explored protective and vulnerability factors influencing outcomes following such experiences. The current study utilised a multi-variable approach and investigated the influences of age, social support, and self-esteem on psychological responses following a major daily stressor. Trajectory classifications of a sample of 90 participants (30 male, 60 female; $M_{age} = 29.82$), achieved in a study conducted by Arjmand and Rickard (2018b), were analysed with survey data collected through a smartphone-based Experience-Sampling-Application (ESA). Findings indicated that, individually, age and social support confer susceptibility to an unfavourable pattern of responding, however interact to promote stress-resistance. This suggests that older individuals who perceive high social support are more likely to manifest resilience following a major daily stressor, as compared to individuals older in age or with high social support alone. Study findings highlight the differential effects that age and social support may have on shaping psychological responses to major daily stressors, and emphasise their individual and interactive roles within resilience processes.

FACTORS INFLUENCING RESPONSES TO DAILY STRESSORS

Daily stressors encompass the stresses and strains characterising everyday life (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982; Kanner, Coyne, Schaefer, & Lazarus, 1981). These have unique impacts on physical and psychological health distinct from potentially traumatic events (PTEs) or chronic adversities (Pearlin, Liberman, Menaghan, & Mullan, 198; Serido, Almeida, & Wethington, 2004; Zautra, 2003). Daily stressors involve irritants and frustrations that occur during everyday transactions with the environment, such as arguments with spouses or colleagues, overly bureaucratic encounters, or unexpected fines and expenses. Minor events like these occur frequently with people often experiencing at least one per day (Almeida, Wethington, & Kessler, 2002), and studies have shown that daily stressor experiences contribute to unfavourable outcomes such as symptoms of depression, anxiety, somatization, and externalising behaviour (DeLongis et al., 1982; DeLongis, Folkman, & Lazarus, 1988; Cassidy, 2000; Chang & Sanna, 2003; Johnson & Sherman, 1997; Kanner et al., 1981; Lohaus, Beyer, & Klein-Heßling, 2004; van Eck, Nicolson, & Berkhof, 1998).

Despite being relatively minor experiences, negative effects generated from daily stressors have been argued to be at times more severe than effects resulting from significant life events (DuBois, Felner, Brand, Adan, & Evans, 1992). This is because, like significant events, daily stressors have individual, immediate, and direct impacts on health and well-being, however also engender risks of stress accumulation as daily stressors occur frequently and often in succession (Almeida, 2005; Arjmand & Rickard, 2018a, 2018b; Gleason, Iida, Shrout, & Bolger, 2008). The experience of successive stressors is common in adults and has negative consequences for physical and psychological well-being (Bolger & Schilling, 1991; Grzywacz, Almeida, & McDonald, 2002; Schilling & Diehl, 2014). For example, successive stressors experienced in a short time period, or ‘stressor pile-up’, has been associated with increased negative affect exceeding effects of concurrent stressors alone (Schilling & Diehl,

2014). This highlights an incremental accrual of distress from individual stressors experienced in close succession, giving rise to exaggerated emotional responses. As such, stress accumulation is one mechanism through which daily stressors can negatively influence mental health and increase vulnerability to developing psychological disturbances (Lazarus, 1999; Zautra, 2003)

Although daily stressors are typically rated ‘low’ in severity (Almeida et al., 2002), they have also been reported as highly negative experiences (Arjmand & Rickard, 2018a, 2018b). Experiences like these may be viewed as a subset of daily stressors which are appraised with high negativity, or ‘major daily stressors’. These events share characteristics with typical daily stressors and PTEs, and harbour risks associated with each. That is, major daily stressors can have large direct impacts on psychological functioning requiring several days to restore psychological equilibrium, while also occurring frequently enough to pose stress accumulation risks (Arjmand & Rickard, 2018b). Examples include experiencing a minor car accident, getting a poor night’s sleep, or dealing with slow internet speeds.

A recent research study conducted by Arjmand and Rickard (2018b) has explored the construct of resilience in the context of major daily stressors. In this study, a tailored methodology was implemented to classify individual trajectories of psychological responding following a major daily stressor; this yielded classification of four heterogeneous groups exhibiting patterns differentiated by: (1) initial reactivity to the stressor, and (2) patterns of recovery following initial reactions—these are illustrated in Figure 1.

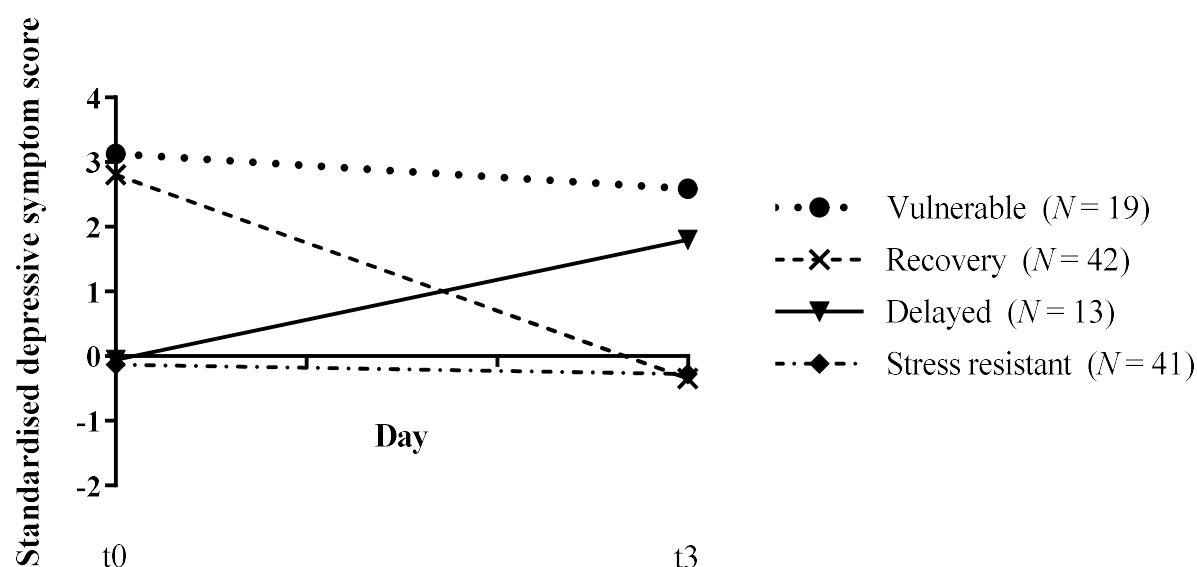


Figure 1. Prototypical response trajectories following a major daily stressor (source: Arjmand & Rickard, 2018b).

Patterns of recovery are an important component of stress responding to consider as they reflect variations in rates of stress dissipation. Individual capacities to dissipate stress are crucial to processes of stress accumulation, and therefore relevant in the context of daily stressors (Bergeman & Deboeck, 2014; Deboeck & Bergeman, 2013). According to Deboeck & Bergman's (2013) reservoir model, stress accumulation is least likely to occur where distress is efficiently dissipated or resisted. In such cases, psychological equilibrium is swiftly re-established leaving little or no unresolved distress, or 'emotional residue' (Scott, Ram, Smyth, Almeida, & Sliwinski, 2017), available for accumulation. With respect to trajectories observed in Arjmand and Rickard (2018b), stress accumulation appears least likely to occur for the stress-resistant trajectory of responding. Here, minimal distress is generated following a major daily stressor, positioning individuals favourably to confront additional stressors. This manifestation of resilience provides an opportunity to explore individual characteristics unique to such individuals. This can provide insights regarding protective factors involved in

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daily stress processes, and therefore possible mechanisms facilitating resilience to major daily stressors.

A Model of Daily Stress

Almeida (2005) provides a conceptual model describing primary factors involved in daily stress processes. Divided into two sections, the model describes variables which interact to influence well-being outcomes: (1) stressor-specific and (2) person-specific variables. *Stressor-specific* variables involve objective characteristics differentiating stressor events from one another (frequency of occurrence, focus of content, and severity). This acknowledges the variety of forms in which stressors can present (minor daily stressors, major daily stressors, or PTEs), and the unique risks to psychological well-being imposed by each. *Person-specific* variables involve individual characteristics conferring protective influences or vulnerability to stressor experiences. These factors coalesce to have direct influences on psychological responses and well-being outcomes. A variety of different person-specific factors has been explored throughout resilience research, and includes variables such as age, self-esteem, and social support. These factors have often been positively implicated in the context of stress management, and researchers have postulated specific mechanisms through which stress-buffering effects are generated.

Age. Much research has been conducted examining the role of age in daily stress processes (Charles & Luong, 2013; Charles & Piazza, 2009; Diehl, Hay, & Chui, 2012; Schilling & Diehl, 2015). Several experience-sampling studies examine emotional responses to daily stressors, with many finding age-related decreases in negative emotional responding (Brose, Schmiedek, Lövdén, & Lindenberger, 2011; Charles, Piazza, Luong, & Almeida, 2009; Neupert, Almeida, & Charles, 2007; Stawski, Almeida, Lachman, Tun, & Rosnick, 2010). For example, a study conducted by Uchino, Berg, Smith, Pearce, and Skinner (2006) found that older individuals showed decreased affective reactivity (smaller increases in

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negative affect) in response to daily stressors as compared to younger counterparts. Recent research has also shown that older age is associated with fewer stressor-related increases in negative affect over time following stressor exposure (Scott et al., 2017). Studies such as these suggest that older age confers protection against daily stressor experiences. As living longer provides grants more life experience, older individuals may be afforded more opportunities to better understand personal ways of coping with daily stressors, and develop a sense of familiarity and predictability of the occurrence of specific stressors over time (Charles, 2010; Blanchard-Fields, 2007). Older individuals may also develop an understanding of personal reactions that stressors evoke, as well as the success or failure of behavioural or cognitive attempts to manage them (Charles & Luong, 2013). As a result, older individuals may be better at minimising, or avoiding, negative effects evoked by daily stressors due to greater experience in dealing with them.

Other studies, however, have revealed associations between older age and *increased* affective and physiological reactivity to daily stressors (Mroczek & Almeida, 2004; Sliwinski, Almeida, Smyth, & Stawski, 2009; Uchino et al., 2006; Uchino, Birmingham, & Berg, 2010). These studies suggest that natural deterioration associated with aging may render the older individuals more vulnerable to negative effects of stressor experiences. Aging may reduce flexibility of stress responses, hampering capacities to down-regulate physiological and psychological arousal following daily stressors (Charles, Piazza, Mogle, Sliwinski, & Almeida, 2013). Moreover, older individuals may have repeated exposure to age-related stressors (for example, memory problems or physical disability) which may lead to sensitisation of neural systems mediating affective responding, resulting in easier activation during stressful situations (Mroczek & Almeida, 2004).

Diehl et al., (2012) suggest that inconsistencies observed across research studies may be attributable to the single-variable approaches typically adopted in studies exploring risk

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and resilience factors in the context of daily stressors. To accommodate this, they recommend utilising a multi-variable approach. Multi-variable approaches enable investigation of interactions between several factors to reveal nuanced and holistic expressions of resilience. Other person-specific or separate stressor-specific factors may interact with age to confer protective effects under specific circumstances (e.g., following specific stressors only or for older individuals possessing specific personality traits), and could potentially provide clarity to abovementioned inconsistencies.

Social support. Social support is considered an important component of well-being maintenance during, and following, adversity. It is a multidimensional construct referring to individual perceptions of general support, or specific supportive behaviours a person receives from others (Cohen, 2004; Malecki & Demaray, 2003). The relationship between social support and several positive outcomes is well established in psychological literature, with a strong body of evidence supporting the importance of social relationships for physical and mental health (Berkman, Glass, Brissette, & Seeman, 2000; Cohen & Wills, 1985; Holt-Lunstad, Smith, & Layton, 2010; Peng et al., 2012; Rueger, Malecki, Pyun, Aycock, & Coyle, 2016; Smith & Christakis, 2008; Thoits, 2011; Uchino et al., 2012). Stress-buffering models of social support posit that social ties are related to well-being under situations of stress, and temper associations between stressor experiences and psychological distress (Beverly, Miller, & Wray, 2008; Cobb, 1976; Cohen & Wills, 1985; Uchino, 2009). Such effects have been observed in the context of various adversities. For example, resilient outcomes have repeatedly been observed in children possess positive social resources reared in toxic environments (Garmezy, Masten, & Tellegen, 1984; Masten, 2001; Werner, 1986, 1989, 2000) and similar positive outcomes have been achieved in adults following significant life events and everyday hassles (Bonanno et al., 2008; Cichy, Stawski, & Almeida, 2014; Gan, Xie, Wang, Rodriguez, & Tang, 2013; Herman-Stahl & Petersen, 1996; Jang & Wang,

2009; Quale & Schanke, 2010). Social resources provide opportunity for mental health support in several ways including emotional, instrumental, informational, and appraisal support (Barrera, 1986; House, 1981; House & Kahn, 1985; Tilden & Weinert, 1987). Through these mechanisms, possessing quality social resources can help bolster a person's situation in life, reinforce positive social behaviours, reduce harmful behaviours, and minimise negative appraisals in order to effectively navigate stressor experiences (Rozanski, Blumenthal, & Kaplan, 1999; Fontana, Kerns, Rosenberg, & Colonese, 1989; Reblin & Uchino, 2008; Uchino, 2006).

Social support, however, has also been shown to entail costs to psychological health and well-being. Several studies of support transactions have found negative associations between social support receipt and health outcomes (physical and psychological) (Barrera, 1981; Bolger, Zuckerman, & Kessler, 2000; Gleason et al., 2008; Liang, Krause, & Bennet, 2001; Nadler, 1987; Nadler, Fisher, & Streufert 1976; Rook, August, Choi, Franks, Stephens, 2016; Shrout, Herman, & Bolger, 2006). Theorists have argued that receiving social support may entail costs to psychological functioning as it can undermine recipients' evaluation of competence, self-efficacy, and coping abilities (Matire, Stephens, Druley, & Wojno, 2002; McClure et al., 2014). Moreover recipients may feel indebted to supporters and feel obligated to repay support; in cases where support cannot be repaid, individuals may feel ashamed or remorseful and doubt their position and usefulness in relationships (Gleason, Iida, Bolger, & Shrout, 2003). As such, although many research studies implicate positive notions of social support in daily stress processes, receiving such support may in some cases *reduce* psychological well-being and hinder stress management following stressor experiences. As discussed above, multi-variable approaches may elucidate contrasting findings of previous research, possibly revealing protective effects of social support under specific circumstances.

Self-esteem. Self-esteem is a commonly considered psychosocial factor moderating associations between the experience of adversity and poor outcomes. Self-esteem is widely viewed a critical element in health human development and refers to the extent to which individuals like, value, accept, and respect themselves (Rosenberg, 2015). In general, psychological research studies have observed associations between low self-esteem and undesirable outcomes, such as depression and negative affect, while higher self-esteem has been linked to better psychological functioning (Brown, 2010; DuBois & Flay, 2004; Dusek, 2000; Creswell et al. 2005; Crocker & Wolfe, 2001; Nezlek & Plesko, 2003; Orth, Robins, Trzesniewski, Maes, & Schmitt, 2009; Trzesniewski, Donnelan, & Robins, 2003). In the context of adversity, individuals with low self-esteem are thought to respond poorly when compared to individuals with higher self-esteem, who appear buffered against distress. Higher self-esteem has been associated with better outcomes (depression, anxiety, physical symptoms, and autonomic reactivity) in response to a range of stressors, including discrimination (Corning, 2002), laboratory-induced stress (Rector & Roger, 1997), rejection from an opposite sex partner (Ford & Collins, 2005), failure or mistakes (Johnson, Panagioti, Bass, Ramsey, & Harrison, 2017), general daily hassles (Dumont & Provost, 1999), stressful life events (Metalsky, Joiner, Hardin, & Abramson, 1993; Fernandez, Mutran, & Reitzs, 1998), and chronic adversities, (Bookwala, 2014; Prati & Pietrantonio, 2010; Sapouna & Wolke, 2013).

Self-esteem may impart differential effects on psychological responses through differences in coping strategies and thinking styles employed by individuals with high versus low self-esteem. For example, individuals with lower self-esteem have been found to engage in maladaptive forms of coping, such as withdrawal, avoidant, passive, and emotion-oriented, to manage stress (Aspinwall & Taylor, 1992; Lo, 2002; Mullis & Chapman, 2000; Rector & Roger, 1997). In contrast, individuals with higher self-esteem appear to apply more adaptive

strategies such as problem-focused (action-oriented) coping (Mantzicopoulos, 1990).

Individuals with higher self-esteem also engage in positive thinking styles which limit negative cognitive appraisals and reduce impacts of depressogenic thoughts on psychological functioning (Smith & Petty, 1995). Such individuals demonstrate positive cognitions when under threat, attack the credibility of sources of negative feedback, and maintain positive illusions and self-evaluations about their abilities (Baumeister, 1982; Bernichon, Cook, & Brown, 2003; Southall & Roberts, 2002; Swann, Hixon, Stein-Seroussi & Gilbert, 1990; Taylor & Brown, 1988; Tesser, 1986), while individual with low or unstable self-esteem engage in negative cognitive appraisals, self-criticism, and overgeneralise negative thoughts (Carver & Ganellen, 1983; Kernis et al., 1998). These mechanisms may explain differences in psychological outcomes achieved between individuals with varying levels of self-esteem, support stress-buffering notions of higher self-esteem following stressors, and render self-esteem a worthy person-specific variable to explore in process of resilience to daily stress.

The aim of the current study was to extend findings of a previous research study to explore person-specific factors associated with favourable patterns of responding following a major daily stressor. This was investigated using a multi-variable approach exploring both main and interacting effects of age, self-esteem, and social support in influencing classifications into trajectory groups identified by Arjmand and Rickard (2018b). The stress-resistant trajectory of responding was deemed the most favourable response pattern and was used as a comparison group to explore whether the aforementioned variables improved the odds of participants exhibiting stress-resistance as compared to other responses. It was hypothesised that older age, higher self-esteem, and higher social support scores would significantly increase the odds of classification into the stress-resistant group as compared to the vulnerable, recovery, or delayed groups. While the current study accommodated

possibilities of interactions between variables, due to the exploratory nature of assessing such interactions, specific hypotheses were not formed in this regard.

Method

Participants

A sample of 90 participants was recruited as part of the promotion of a mental health support app, MoodPrism. MoodPrism was promoted to the general public through various means including online promotion (e.g., Facebook and Twitter), presentations for organisations and schools, and word of mouth. Participant recruitment was aimed at selecting individuals from a diverse range of backgrounds (see Table 1).

Materials

The application. Data were collected using a purposed designed Experience-Sampling-Application (ESA) (MoodPrism; www.moodprismapp.com) which participants downloaded onto personal smartphone devices. Full details regarding the development and use, as well as sources of all surveys presented in the application (app) are outlined in separate papers (see Arjmand & Rickard, 2018a; Rickard, Arjmand, Bakker, & Seabrook, 2016). In brief, participants input responses in three components of the app: ‘on-boarding’ surveys, daily experience sampling reports (ESRs), and ‘off-boarding’ surveys. Data relevant to the current study were collected in the ‘on-boarding’ and daily ESR components of the app.

‘On-boarding’ surveys comprised 15 surveys to capture individual differences across several different outcome variables. Surveys relevant to the current study included a demographics questionnaire (capturing participants’ age), a measure of self-esteem, and a measure of perceived social support. The ESR component of the app provided data which were used to form trajectory groups using procedures outlined by Arjmand and Rickard (2018b). Individual ESRs comprised 15 items and were presented to participants once a day

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Table 1.

Sample frequencies and percentages across age, gender, and education level, as well as means, standard deviations, minimum and maximum scores across age, social support, self-esteem.

	N	%		
Age				
Under 18	6	6.7		
18-30	51	56.7		
31-40	16	17.8		
41-50	12	13.3		
50+	5	5.6		
Gender				
Male	30	33.3		
Female	60	66.6		
Highest level of Education				
Primary	22	24.4		
Secondary	20	20.0		
Tertiary	35	41.7		
Post Graduate	13	12.2		
	M	SD	Min	Max
Age	29.82	10.91	14	57
Multidimensional Scale of Perceived Social Support	4.8	1.15	1.4	7
Single item Self-esteem scale	2.3	1.1	0	5

at a random time within permitted time-frames specified by the user. Relevant items presented in ESRs included a single item assessing the experience and rating of stressor events (for identification of major daily stressors), and two items assessing daily symptoms of depression (for generating trajectories of responding following stressor onset). All surveys and ESRs were completed within the app using the touch-screen interface.

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Two-item Patient health questionnaire. Daily symptoms of depression were assessed using the two-item Patient Health Questionnaire (PHQ-2) (Löwe, Kroenke, & Gräfe, 2005). These items ask participants to rate how much they currently feel “little interest or pleasure in doing things”, and “feeling down, depressed, or hopeless”. Rated on a five-point Likert scale ranging from “not at all” (1) to “extremely” (5), items are summed to given an overall score ranging from 2 to 10 with higher scores indicating higher symptoms of depression. This selection of items has shown good internal consistency (Cronbach’s $\alpha = .83$) and correlates highly with established depression measures (Löwe et al., 2005).

Stressor experience report. Daily stressor experiences were tracked using a single experimenter authored item. This question asked participants “What is the most negative thing that has happened to you today?” Items in this list originally included specific events sourced from various questionnaires assessing stressor experiences (Cheng, 1997; Coddington, 1972; Newcomb, Huba, & Bentler, 1981; Swearingen & Cohen, 1985; Waaktaar, Borge, Fundingsrud, Christie, & Torgersen, 2004). A list of the most frequently reported stressor events was compiled and adjusted to relate to both adult and adolescent populations. Following feedback during a beta trial of MoodPrism (Rickard et al., 2016) the items were revised to be broader and briefer, and were subsequently converted into domains of living where negative events may occur. Each domain addressed an area of life common to multiple stressors in the original list; negative social experience (with friends, family, strangers, etc.), loss of valued material item (misplaced, theft, etc.), negative experience at school/work, negative experience outside of school/work, personal health problems (illness, injury, etc.), and health problems of someone close to you (illness, injury, death, etc.). These reflected similar domains included in previous methodologies (Almeida et al., 2002), permitted a broader line of inquiry encompassing the vast range of possible negative events that can occur, while reducing the number of item selections in the list. The list also included

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a “nothing negative happened” option as well as an “other” option where participants could manually type in any stressor event not covered by domains provided on screen. If participants select any option indicating the experience of a negative event, an additional question was presented asking participants to rate the degree of negativity of the event on a four-point Likert scale ranging from “slightly” to “extremely”. As daily stressors are generally rated as low in severity, (Almeida et al., 2002), stressors rated as ‘slightly’ or ‘moderately’ negative were considered minor, while stressors rated as ‘very’ or ‘extremely’ negative were considered major daily stressors.

Social support. Social support was measured using the Multidimensional Scale of Perceived Social Support (MSPSS; Zimet, Dahlem, Zimet, & Farley, 1988). The MSPSS is a 12-item self-report inventory that assesses perceived social support from friends and family. The MSPSS contains various subcategories including perceived social support from a significant other, family, and friends. Participants are asked to rate the degree to which they agree to items in the scale, for example “There is a special person with whom I can share my joys and sorrows”. Participants respond along a seven-point Likert scale ranging from “very strongly disagree” (1) to “very strongly agree” (7). In the current study, participants’ scores were summed to give a global score of perceived social support, with higher scores indicating greater perceived support. The MSPSS has good internal (α ranging from .84 to .92 as a global measure) and test-retest reliability, and has shown good construct validity in a variety of samples (Zimet et al., 1988; Zimet, Powell, Farley, Werkman, & Berkoff, 1990).

Self-esteem. Global self-esteem was measured using the Single-Item Self-esteem scale (SISE; Robins, Hendin, & Trzesniewski, 2001). Participants were asked to rate the degree of accuracy with which the statement “I have high self-esteem” characterises them. Participants responded along a five-point Likert scale ranging from “very inaccurate” (1) to “very accurate” (5), with higher scores indicating higher levels of self-esteem. The SISE has

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shown to be a valid, reliable, and practical alternative to the Rosenberg Self-esteem Scale (RSE; Rosenberg, 2015). Using the Heise procedure, the SISE has achieved good reliability estimates (0.75). The SISE has also shown good convergent validity with the RSE across genders, ethnic groups, community members, and occupation statuses, and maintained nearly identical correlations patterns, compared to the RSE, among several factors (personality, psychological and physical health, social desirability, demographic characteristics, and academic outcomes) (Robins et al., 2001).

Experimental Procedure

The ESA, MoodPrism, was freely available for download from the AppStore (iOS) and GooglePlay (Android). For users, MoodPrism promotes emotional awareness and encourages self-monitoring of well-being. The app also functions to provide guidance towards useful and relevant mental health tools and resources. While audiences were invited to download the app as a personal mental health support tool, they were also informed that it doubled as a research tool. Explanatory statements and consent forms were administered electronically through the app. For participants reporting a date of birth below 18 years of age, an additional consent form for minors was presented with checks for parental consent. Participants were made aware of a number of incentives built into the research design—extra feedback regarding positive and negative mood functioning (unlocked after one and two weeks, respectively), and entries to a prize draw for two cash vouchers (\$AU50) (offered after completing key milestones: first day, first week, second week, and one month). Ethical approval to conduct the current research study was approved by the Monash University Human Research Ethics Committee (Approval # CF14/968 – 2014000398).

Figure 2 below illustrates the data collection schedule used for each participant. Participants were first required to complete a battery of ‘on-boarding’ surveys in order to unlock the full functionality of the app. After completion, the first ESR is delivered and

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henceforth participants are prompted (via smartphone push notifications) on a daily basis to complete ESRs. After the 30-day experimental duration, participants were presented with small selection of ‘off-boarding’ surveys which included feedback and ratings of the app.

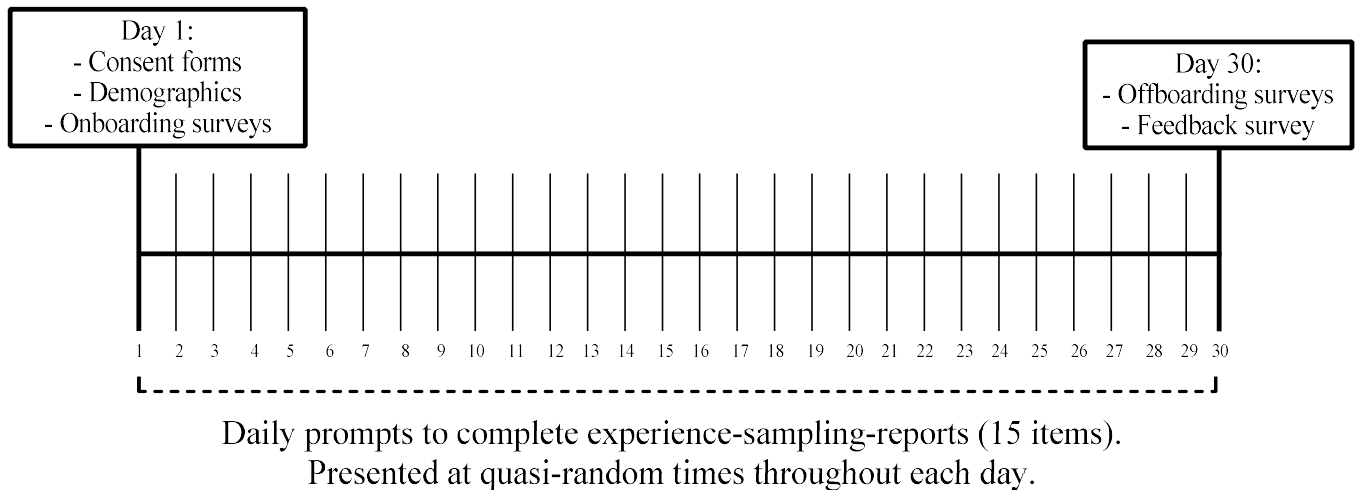


Figure 2. Experience-sampling data collection schedule over 30 days.

Data processing procedure

Full details of data processing procedures used to form trajectory groups are provided in Arjmand and Rickard (2018b). A brief description of these procedures is as follows: data representing individual participants’ ESRs were screened to identify and isolate useable sections of data, and targeted the experience of a major daily stressor. Relevant data comprised a 7-day span of ESRs including a major daily stressor on the 4th day. Experience-sampling data for each of these days included reports of depressive symptoms and stressor experiences. Across these days, stressor experience reports provided the context in which each major stressor event had occurred, and depressive symptom scores were used to form trajectories of responding. Symptom scores were standardised (according to participants regular mood) to reflect stress responses relative to participants’ typical levels of psychological functioning. Standardised data were then used to extract data points reflecting

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individual stress reactivity, and subsequent recovery, which were used together to classify participants into separate linear trajectory groups. As shown in Arjmand and Rickard (2018b), this resulted in the formation of four groups—vulnerable, delayed, recovery, and stress-resistant—representing distinct trajectory profiles of psychological responding.

Results

A multinomial logistic regression was conducted to model relationships between predictor variables (age, self-esteem, and social support) and the four trajectory groups. The stress-resistant group was selected as the comparison group as it represents the most favourable pattern of responding following a major daily stressor. The assumption of multicollinearity was met with all variables achieving tolerance levels above 0.1 and Variance Inflation Factor (VIF) values below 10 (Myers, 1990). The assumption of independent irrelevant alternatives was met using a suest-based Hausman test ($p > .05$ for all groups). No instances of missing data or any outliers were identified.

A custom model was constructed with main effects of age, self-esteem and social support included as forced entry items. Additionally, all two-way interactions were included as stepwise terms (forward entry). As it is possible that person-specific factors may confer particular effects in response to particular types of stressors (Hahn, Cichy, Small, & Almeida, 2014; Neupert et al., 2007), a ‘stressor type’ variable was also included stepwise to accommodate interactions between stressor types and predictor variables. Information concerning the type of stressors experienced was sourced from the stressor experience report presented in daily ESRs. Frequencies of stressor types reported by participants in the current sample are shown in Table 2.

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Table 2.

Frequencies and percentages of stressor types reported by participants.

	Frequency	Percentage
Negative social experience	25	27.8%
Loss of valued item	2	2.2%
Negative experience at school or work	28	31.1%
Negative experience outside of school or work	8	8.9%
Personal health problem	15	16.7%
Health problems of someone close	4	4.4%
Other	8	8.9%
Total	90	100%

Addition of predictors to a model containing only the intercept significantly improved the fit between the model and the data, $\chi^2(12, N = 90) = 21.75$, Nagelkerke $R^2 = .233$, $p = .04$. Both Pearson ($p = .428$) and Deviance ($p = .988$) goodness-of-fit statistics were non-significant indicating that predicted values were not significantly different from observed values, and that the new model was a good fit. Unique contributions of each predictor variable, and significant two-way interactions, are presented in Table 3.

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Table 3.

Unique contributions of age, social support, and self-esteem, as well as a significant interaction between age and social support, in the multinomial logistic regression (N = 90).

Predictor	χ^2	df	p
Age	11.56	3	.009
Social support	6.61	3	.085
Self-esteem	2.40	3	.493
Age*Social support	9.746	3	.021

Significant, unique contributions to the model were observed for age, and an interaction effect between age and social support. Parameter estimates are shown in Table 4, and the resulting classification table is shown in Table 5.

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Table 4.

Parameter estimates contrasting the stress-resistant group with the vulnerable, recovery, and delayed trajectory groups across age, social support, self-esteem, and age social support.*

Trajectory Group	Predictor variable	β	OR	<i>p</i>
Vulnerable	Age	0.39	1.47	.060
	Social support	1.64	5.17	.150
	Self-esteem	-0.48	0.62	.160
	Age*Social support	-0.07	0.93	.092
Recovery	Age	0.35	1.42	.053
	Social support	1.04	2.80	.256
	Self-esteem	-0.23	0.80	.419
	Age*Social support	-0.06	0.94	.081
Delayed	Age	0.70	2.00	.003
	Social support	3.30	26.49	.020
	Self-esteem	0.00	1.00	.994
	Age*Social support	-0.13	0.88	.005

Table 5.

Successful group classifications using the multinomial logistic regression model constructed in the current study.

Observed	Predicted				% Correct
	Vulnerable	Recovery	Delayed	Stress-resistant	
Vulnerable	0	7	0	9	0.0%
Recovery	1	25	0	10	69.44%
Delayed	0	5	1	3	11.11%
Stress-resistant	0	13	0	16	55.17%
Overall %	1.11%	55.56%	1.11%	42.22%	46.70%

Significant effects were observed only in comparisons between the stress-resistant and delayed trajectory groups. Results showed that for every one year increase in age, the odds of participant classification into the delayed group, as compared to the stress-resistant group, increased by a factor of 2.00. Results also showed that for every unit increase in social support the odds classification into the delayed group increased by a factor of 26.49, as compared to the stress-resistant group. This means that, in contrast to exhibiting stress-resistance, older participants and participants with higher social support scores were more likely to exhibit a delayed response trajectory.

A significant interaction was observed between age and social support. To illustrate this effect, participants' predicted probability of classification into the delayed trajectory group was plotted across different levels of social support for the oldest and youngest

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participants in the sample (Figure 3). This was achieved by splitting participants into two age groups—the oldest third ($N = 30$, $M_{age} = 42.71$, $SD = 7.29$) and youngest third ($N = 30$, $M_{age} = 19.40$, $SD = 2.37$)—and assigning them into categories reflecting different levels of perceived social support (low, medium, and high). These categories were derived by dividing the distribution of all participants' perceived social support scores into thirds.

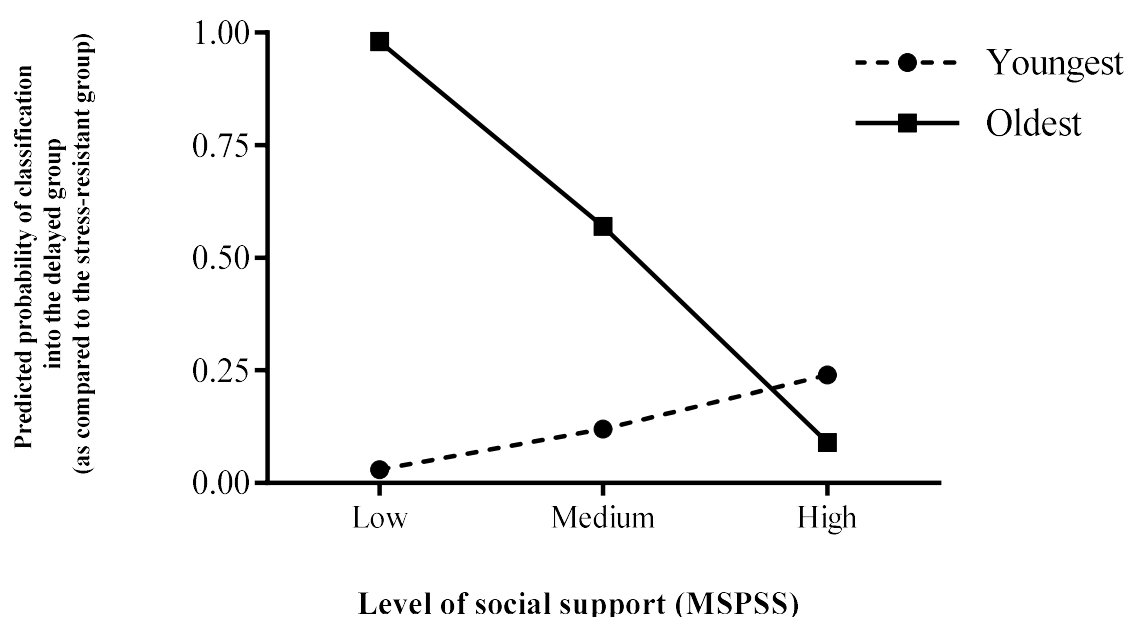


Figure 3. Predicted probabilities of classification into the delayed trajectory group (as compared to the stress-resistant group) for the oldest and youngest third of sample participants, across levels of perceived social support.

Together, Table 4 and Figure 3 show that for every one year increase in age, the odds of participants being classified into the delayed group, as compared to the stress-resistant group, decreases (by a factor of .88) as social support increases. This means that older participants were *less* likely (as compared to younger ones) to exhibit a delayed trajectory of psychological responding (as compared to stress-resistance) if they perceived higher levels of social support.

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No interactions were observed between stressor types and age, social support, or self-esteem. This may have been due to the low frequency of some stressor types (e.g., loss of valued item, negative experience outside of school or work, and health problems of someone close to me). Low frequencies may reduce sensitivity in detecting interactions between the more frequently experienced types and outcome variables. To increase this sensitivity infrequently occurring types were combined with the ‘other’ group, and analyses were re-run. Re-run analyses combining infrequently occurring stressor types with the ‘other’ group resulted in no changes. This means that interactions between stressor types and predictor variables provided no significant predictive power to the model.

Table 5 shows that, using a standard 50% percent probability threshold, 46.70% of overall participants were correctly classified across the four group classifications. The model performed superiorly to a proportional naive classification, in particular for the recovery and stress-resistant groups (69.44% and 55.17% correct respectively). Performance in predicting vulnerable and delayed groups was poorer (0% and 11.11% correct respectively) but not surprising given the relative low occurrence of these categorisations. While it is noted that alternative threshold values (and alternative methodologies) could improve classification performance, the model’s performance was considered satisfactory given our interest in modelling variable relationships rather than producing a predictive algorithm.

Discussion

The aim of the current study was to explore associations between age, social support, and self-esteem with linear trajectory groups identified in previous research (Arjmand & Rickard, 2018b). Trajectory groups reflect prototypical stress responses following a major daily stressor, and reflect varying degrees of resilience. It was hypothesised that older age, higher social support, and higher self-esteem would positively influence odds of classification into the stress-resistant group as compared to the vulnerable, recovery, or delayed group. This

hypothesis was generally unsupported as findings indicated that, compared to the stress-resistant group, older individuals and individuals with higher social support were at increased odds of classification into the delayed group. Additionally, no significant influence of self-esteem was observed. A significant interaction, however, generated unique effects on odds of group classification. Specifically, when considered together, the direction of main effects of age and social support were reversed. This indicated that older individuals are more likely to exhibit stress-resistance, as compared to a delayed response, with higher levels of social support.

Influences of Age on Trajectories of Psychological Responding

Older age was hypothesised to positively influence the odds of classification into the stress-resistant group. This was not directly supported as findings of the current study indicated that older individuals are more likely to exhibit a delayed trajectory following a major daily stressor as compared to a stress-resistant trajectory of responding. As the delayed trajectory represents an unfavourable stress response, this finding appears inconsistent with previous studies highlighting protections conferred through older age (Brose et al., 2011; Scott et al., 2017; Neupert et al., 2007; Stawski et al., 2010; Uchino et al., 2006).

Study findings appear consistent with a portion of previous research studies emphasising a hampered capacity to down-regulate physiological and psychological arousal associated with aging (Charles & Luong, 2013). Age-related declines in cognitive abilities and physical reserve capacities (Salthouse, 1996; Rook, Charles, & Heckhausen, 2007) are posited to lead to increased difficulty managing high levels of emotional arousal. For example, decreased cognitive processing abilities may lead to a reduction in employing effective emotion regulation strategies in response to stress (Knight et al., 2007), and reduced physiological flexibility may lead to difficulties in managing physiological activation

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(Deschenes, Carter, Matney, Potter, & Wilson, 2006). These mechanisms may explain the unfavourable response pattern observed among older adults in the current study.

It is important to note that the maximum age in the current sample was 57 years which lower than maximum ages (up to 85 years old) in previous samples, and relatively younger than ‘older adults’ referred to in previous research (Brose et al., 2011; Neupert et al., 2007; Stawski, et al., 2010; Teachman, 2006; Uchino et al., 2006). Older participants in the current study (upper quartile of age, $M = 46$ years) would more appropriately be considered being middle-aged (e.g., Neupert et al., 2007; Uchino et al., 2006). As such, the delayed trajectory associated with older participants in the current sample may be a poor representation of propensities to respond to stress among the elderly (60+).

The association between delayed trajectories and middle-aged participants may reflect a declining development toward more unfavourable patterns of responding across the life-span. Given mechanisms described above, it could reasonably be speculated that the elderly may exhibit stress responses following a vulnerable trajectory. Indeed, previous studies infer poorer capacities to manage stress through *increased* reactivity profiles (a key feature of the vulnerable trajectory) to daily stressors among older adults (Mroczek & Almeida, 2004; Sliwinski et al., 2009). Consequently, delayed trajectories observed in the current study may reflect a single point in an incremental decline of stress-management capacities across the life-span. That is to suggest that a) capacities to resist stress following daily stressors deteriorate with age, and b) the delayed trajectory represents the state of stress-management capacities at middle-age. For example, younger individuals may possess good stress-management capacities, manifested through a higher likelihood of exhibiting stress-resistant trajectories of responding; this capacity may decline over subsequent decades, and middle-aged individuals may manifest delayed trajectories of responding, only being able to resist initial stress reactions with subsequent increases in distress over time; as people approach

older adulthood, stress-management abilities may decline further to a point where vulnerable trajectories are most likely³. Although additional research is required to examine such speculation, it offers an appealing line of inquiry for future research: using trajectory-based assessments of psychological responding to illustrate the evolution of stress responses across the lifespan.

The use of trajectory-based assessments used to form groups examined in the current study may help explain inconsistencies between current findings and previous studies venerating the role of older age in daily stress processes. A salient feature common to these studies is the assessment of psychological responses to daily stressors using measures of initial reactivity only (Brose et al., 2011; Neupert et al., 2007; Stawski et al., 2010; Uchino et al., 2006). This contrasts with methods in the current study which utilised a two-dimensional assessment of responses (initial reactivity and patterns of recovery). With only a single dimension of stress responding, previous studies are unable to differentiate between individuals with shared reactivity profiles, such as the delayed and stress-resistant groups which both feature minimal initial reactions. Previous studies demonstrate reduced reactivity in older individuals without scope to observe whether subsequent patterns of responding followed a delayed or stress-resistant pathway. It may be possible that decreased reactivity to daily stressors observed among older individuals in previous research reflects reactivity profiles of the delayed trajectory. Previous studies may have inferred protective benefits of older age based upon restricted observations of stress responses encompassing only initial reactivity. Consequently, reduced reactivity observed among older individuals in previous research may not be representative of a positive outcome (i.e., stress-resistance); it may instead reflect the minimal initial reactivity feature inherent in delayed trajectories.

³ The elderly, as well as middle-age adults, may rely on external resources to support coping efforts and aid management of psychological distress following daily stressors in order to avoid unfavourable outcomes.

Influences of Social Support (and Interaction with Age) on Trajectories of Psychological Responding

Higher levels of social support were also hypothesised to positive influence odds of classification into the stress-resistant group. This was not directly supported as findings indicated that individuals are more likely to express a delayed trajectory of responding, as compared to stress-resistance, with increasing levels of social support. This is inconsistent with positive notions of social support in management of well-being during stress (Beverly et al., 2008; Cobb, 1976; Cohen & Wills, 1985; Uchino, 2009), but supports contentions emphasising potential detrimental effects associated with receiving social support (Matire et al., 2002; McClure et al., 2014). This may be explained by a greater presence of younger participants in the current sample. Younger populations often feel expected to be able to cope effectively and manage personal difficulties alone (Quine et al., 2003). As such, support is likely to render these individuals feeling incapable, or unable, to cope effectively alone, and reduce feelings of self-efficacy. Moreover, as making friends and successful social integration is particularly important at younger age groups (Buote, et al., 2007; Collins & Steinberg, 2006), social support receipt may lead to psychological distress from being over-benefitted or indebted. Individuals receiving support may feel obliged to repay the support and, if they cannot, may question their status and utility in vital social relationships (Gleason et al., 2003). While the current study measured perceived (and not received social), support, such perceptions could lead to expectations of receiving social support, possibly generating similar psychological effects.

Analyses conducted in the current study enabled assessment of interactions between included variables, and different effects of social support could be examined across age. A significant interaction was observed which reversed the direction of main effects for both factors. Specifically, findings indicated that older age increases odds of exhibiting stress-

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resistance, as compared to a delayed trajectory, with increasing levels of social support. This suggests that, while older age and social support alone are associated with exhibiting unfavourable responses following a major daily stressor, protective benefits are conferred if an individual is older *and* feels socially supported. This suggests that older individuals avoid potential psychological costs associated with possessing greater social support, which may be experienced among younger counterparts. This may be because of a reliance on smaller, well-established, and familiar social groups among adults (Bhattacharya, Ghosh, Monsivais, Dunbar, & Kaski, 2016); as such, middle-aged adults may be more likely to access perceived social support from such secure social contacts with less susceptibility toward questioning their utility in friendships if support cannot be repaid. Moreover, granted with maturity of age, such individuals may come to understand the importance of collaboration and accessing peer networks to achieve goals (emotional or otherwise) (Dixon, 1992; Dixon & Gould, 1998; Strough & Margaret, 2002; Stautinger & Baltes, 1996; Strough, McFall, Flinn, & Schuller, 2008) thereby reducing threats to coping self-efficacy.

The interaction between age and social support highlights the utility of multi-variable approaches to comprehensively examine influences of person-specific factors on individual resilience. While previous studies yield inconsistent findings, the current study promotes reconciliation by demonstrating how these factors may confer differential effects on psychological responses to daily stressors. For example, although older age is thought to confer advantages to stress-management following stressor experiences (Charles, 2010; Charles & Piazza, 2009), these effects may be dependant on levels of perceived social support. The protective benefits of older age observed in some studies (Stawski et al., 2010; Uchino et al., 2006) may therefore be limited in other studies which might have recruited a sample including older participants possessing lower perceived availability of social resources (Mroczek & Almeida, 2004; Sliwinski et al., 2009).

Influences of Self-esteem on Trajectories of Psychological Responding

Higher levels of self-esteem were hypothesised to increase odds of classification into the stress-resistant group. Contrary to this, findings indicated no significant influences of self-esteem on group classification. As recovery trajectories often comprise pathways characterised by rapid recovery to typical levels of functioning (Arjmand & Rickard, 2018b), they can be considered a favourable pattern of responding. As such, while higher self-esteem may not increase the odds of exhibiting stress-resistance, it may facilitate a separate favourable response (i.e., recovery) as compared to unfavourable response trajectories (i.e., vulnerable and delayed). To explore this possibility, analyses were re-run with the recovery group as the comparison group, to explore the possibility that higher self-esteem increases odds of exhibiting a recovery trajectory as compared to vulnerable or delayed trajectories. Findings did not support this notion as self-esteem did not significantly influence odds of group classification as described.

Study findings may instead indicate that self-esteem has limited relevance for differentiation between trajectories of responding classified at gross levels (in this study, linear trajectories) (Arjmand & Rickard, 2018b). Variations in self-esteem may more effectively explain differences between groups classified at finer grained levels of assessment, such as non-linear pathways manifesting within linear trajectory groups. Finer grained classifications of responses, however, yield numerous groups reflecting highly individualised pathways of responding. For example, using guidelines outlined in a separate paper, non-linear assessments of individual responses in the current sample would yield roughly 26 small groups (average $N = 4.81$) (see Arjmand & Rickard, 2018b). This is problematic as small group sizes reduce statistical power, and running analyses performed in the current study at finer levels of classification would unlikely yield meaningful results. As such, while self-esteem appears unrelated to linear trajectories of responding following a

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major daily stressor, more significant findings may be achieved in future studies conducting finer grained assessments of responses in a larger sample with sizeable groups.

Strengths and Limitations

A primary strength of the current study was enabled through the use of research methods developed by Arjmand and Rickard (2018b) which utilised trajectory-based assessments of psychological responding. This methodology extended conceptualisations of psychological responding from reactivity alone, to also incorporate subsequent patterns of responding following major daily stressors. Previous research, confined to assessing reactivity only, observed decreased reactivity amongst older individuals which naturally led to inferences esteeming the role of older age in daily stress processes. While not conclusive, findings of the current study suggest such inferences may be overstated, and provide alternative explanations. Adopting a trajectory-based research methodology permitted a more detailed view of stress responses, and trajectories with distinct pathways could be differentiated. Findings of the current study ultimately highlighted that older individuals appear more likely to exhibit delayed trajectories of responding which, in previous studies, may have appeared as a favourable response as they could only observe the initial reactivity portion of stress responses.

A second strength was the use of a multi-variable approach in the current study. This accommodated multifaceted conceptualisations of resilience as a process (Almeida, 2005; Kumpfer, 2002) involving several interacting factors which influence well-being outcomes. In the current study, several person-specific factors, and a stressor-specific factor, were entered into analyses to provide a comprehensive exploration of resilience. Findings of the current study revealed significant interactions between age and social support which highlighted differences in the way these factors influence psychological outcomes following daily stressors. Without a multi-variable approach, findings regarding age and social support

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alone would be limited to supporting a single side of discrepant findings in previous literature, providing little clarity to the source of inconsistencies, and limiting development of the research field. The multi-variable approach deepened interpretability of study findings and provided insight regarding the different ways person-specific factors may function to confer particular effects. Such information is useful as it provides possible explanations to clarify inconsistencies of previous research, as advocated by Diehl et al. (2012). The model constructed in the current study also accommodated possible interactions between person-specific factors and stressor types (the focus of content of stressors, or ‘stressor domain’). As no significant interactions were observed, non-significant main effects observed in the current study were unlikely to be explained by the potential for age, self-esteem, or social support to facilitate stress-resistance in response to specific types of stressor experiences only (e.g., negative social experience, loss of a valued item, negative experience at school/work). Such findings can help direct future researchers to explore interactions with other, more meaningful, factors which may explain null findings.

Despite these strengths, the current study was limited to investigating factors involved in resilience processes between groups classified using methods capturing *gross* differences in stress responding (that is, linear trajectories). Despite associations with positive outcomes in previous research, self-esteem was not found in the current study to influence classification into trajectory groups. Although finer grained assessment using nonlinear pathways within groups could provide further insights regarding the role of self-esteem in daily stress processes, this was not feasible in the current study due to the modest sample size. The current study was also limited in its capacity to predict group classification using the variables included in analyses. While findings indicated that variables included in the final model appear to play a role in resilience to daily stressors, the model was only successful in classifying roughly 47% of participants. This indicates that the variables included in the

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current study represent only a limited subset of the full range of individual characteristics involved in shaping trajectories of responding. Numerous other factors are likely involved in resilience processes which can be investigated in future research, in conjunction with factors included in the current study, to progress towards a thorough understanding of principal factors influencing psychological responses to major daily stressors.

Conclusion

The current study aimed to explore associations between person-specific factors (age, self-esteem, and social support) and groups representing distinct psychological trajectory profiles following the experience of a major daily stressor—vulnerable, recovery, delayed, and stress-resistant. Findings indicated that older individuals and individuals higher in social support were more likely to exhibit an unfavourable response to a major daily stressor as compared to a favourable response. A significant interaction, however, reversed this effect. Specifically, when considered together, age and social interacted to increase odds of exhibiting stress-resistance as compared to a delayed trajectory of responding. This suggests that older age confers positive influences on stress-responding following exposure to a major daily stressor, with increasing levels of social support. No significant effects were observed involving self-esteem or the focus of content of stressors experienced (stressor type). Strengths of the current study included utilisation of trajectory-based assessments of responding following a major daily stressor and the multi-variable approach used in statistical analyses. The former permitted more holistic assessments of stress responses, which highlighted possible causes of inconsistencies observed in previous studies about the role of age in resilience. The latter afforded a comprehensive and dynamic examination of factors involved in resilience processes. Specifically, the multi-variable approach illustrated how person-specific variables may produce differential influences on stress responses following

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daily stressors, where in some contexts they may confer resilience while in others they may confer vulnerability.

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Extended Analyses

Due to word count restrictions associated with journal publication, additional analyses examining speculations offered in the study could not be included in the submitted manuscript. Two supplementary analyses are presented in this section to provide added depth to research findings. These analyses examine 1) speculations regarding the role of self-efficacy in explaining differential effects conferred by increased social support between younger and older participants, and 2) between group differences across a range of person-specific variables to explore the potential for other factors (not included in the current study) to better explain study findings, and guide variable selection in future studies.

Examining Age Differences in Threats to Self-efficacy with Increases in Social Support

Interaction effects observed in Paper #3 indicated that older individuals are more likely to exhibit stress-resistance, as compared to delayed trajectories, with increasing levels of social support. To investigate the possibility that this may be due to differences in the way in which younger and older individuals experience threats to coping self-efficacy resulting from social support, a two-way ANOVA was conducted to examine interaction effects between levels of perceived social support and age on coping self-efficacy outcomes.

Participants of the current study were split into two age groups: the oldest third ($N = 30$, $M_{age} = 42.71$, $SD = 7.29$) and youngest third ($N = 30$, $M_{age} = 19.40$, $SD = 2.37$). These participants were allocated into groups reflecting different levels of social support (low, medium, and high) which were derived by dividing the distribution of all participants' perceived social support scores into thirds. Participants' level of coping self-efficacy was assessed using the Coping Self-Efficacy Scale (CSE; Chesney, Neilands, Chambers, Taylor, & Folkman, 2006) which was administered through the 'on-boarding' surveys presented in the MoodPrism app.

The Coping Self-efficacy Scale

Coping self-efficacy was measured using 26 items assessing perceived self-efficacy for coping with threats and challenges. Participants are asked to rate on an 11-point scale the extent to which they believe they could perform behaviours important to adaptive coping following this prompt: “when things aren’t going well, or when you’re having problems, how confident or certain are you that you can do the following”. The scale includes anchor points at 1 (‘cannot do at all’), 6 (‘moderately certain can do’), and 11 (‘certain can do’). Examples of items in the scale include “sort out what can be changed, and what cannot be changed”, “break an upsetting problem down into smaller parts”, and “look for something good in a negative situation”. Item scores are summed to give an overall coping self-efficacy score. The CSE has shown good construct validity and internal consistency ($\alpha = .95$) (Chesney et al., 2006).

Participants’ age groups, self-esteem level, and coping self-efficacy scores were entered into SPSS statistics version 24. Assumptions of normality were met and assessed using a Kolmogorov-Smirnov test, $D(90) = .08, p = .20$. A univariate two-way ANOVA was conducted with age group and self-esteem level as group factors, and coping self-efficacy as the outcome variable. Results showed that the age by social support interaction was non-significant, $F(2, 54) = 0.47, p > .05$. Coping self-efficacy scores across low, medium, and high levels of social support are illustrated for oldest versus youngest participants in Figure 4.

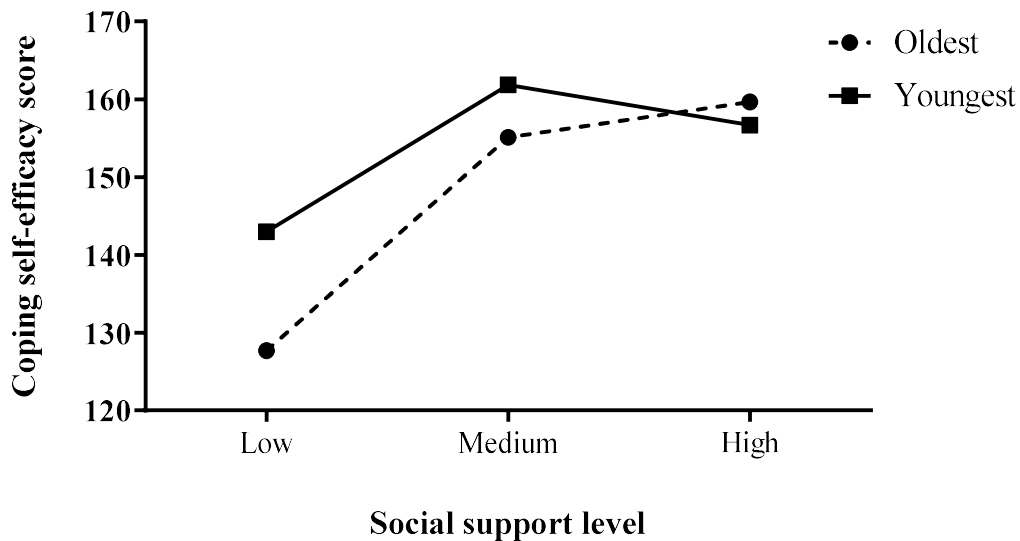


Figure 4. Profile plot illustrating the non-significant interaction between age and perceived social support on coping self-efficacy.

As can be seen in Figure 4, changes in self-efficacy scores across increasing levels of social support were similar across older and younger participants. This shows that the relationship between coping self-efficacy and social support did not greatly differ across age groups. Younger individuals do not appear to experience reductions in self-efficacy as a result of higher perceived social support as speculated in Paper #3. This suggests that increased likelihoods of older (versus younger) individuals exhibiting stress-resistance (versus a delayed response) with increases in social support are unlikely due to differences in the effects social support may have on coping self-efficacy across age. Other mechanisms (e.g., feelings of indebtedness) may be examined in future research studies to better explain study findings.

Between Group Differences Across Auxiliary Person-specific Factors

Discussions in Paper #3 allude to the involvement of other variables in processes underlying psychological responses to daily stressors. As such, preliminary analyses were conducted to examine differences between trajectory groups across a range of variables

collected from ‘on-boarding’ component of the MoodPrism app, which were not examined in the paper. This may help direct investigations of future studies conducted similarly to Paper #3 by drawing researchers’ attention to variables likely involved in differentiating groups.

Variables included measures of depression⁴ and anxiety⁵, well-being⁶, coping self-efficacy⁷, personality⁸ (extraversion, agreeableness, conscientiousness, neuroticism, imagination), and emotional self-awareness⁹. Due to violations of assumptions of normality across several variables, non-parametric tests were used. Kruskal-Wallis tests were conducted to explore differences between the vulnerable, recovery, delayed, and stress-resistant trajectory groups across each variable. Resultant findings are presented in Table 6.

Overall, no significant differences were observed between trajectory groups across variables. Only agreeableness significantly differed between trajectory groups, $H(3) = 10.34$, $p = 0.016$. Mann-Whitney tests were used to follow up this result. A Bonferroni correction was applied and so effects are reported at an adjusted criterion alpha level of .0125. Results revealed that agreeableness was only significantly lower in the vulnerable group ($Mdn = 15$) as compared to the recovery group ($Mdn = 17$), $U = 224$, $z = -3.06$, $p = .003$, $r = -.39$. The effect size was medium. Significant differences were not observed with, or between, the stress-resistant or delayed response groups.

⁴ Patient Health Questionnaire (Kroenke et al., 2006)

⁵ General Anxiety Disorder Scale (Spitzer et al., 2006)

⁶ Warwick-Edinburgh Mental Well-Being Scale (Tennant, 2007)

⁷ Coping Self-Efficacy Scale (Chesney et al., 2005)

⁸ Mini-IPIP (Donnellan et al., 2006)

⁹ Emotional Self-Awareness Scale (Kauer et al., 2012)

Table 6.

Means (and standard deviations) of auxiliary variables not included in the study across vulnerable, delayed, recovery, and stress-resistant trajectory groups.

	Vulnerable	Delayed	Recovery	Stress-resistant
Depression	19.20 (5.01)	18.41 (6.20)	21.63 (5.86)	20.20 (5.88)
Anxiety	16.55 (4.33)	13.83 (5.15)	16.79 (5.21)	15.50 (5.43)
Well-being	38.81 (7.03)	42.07 (10.77)	39.67 (8.77)	41.25 (8.58)
Coping self-efficacy	137.40 (37.86)	153.67 (44.56)	149.93 (25.97)	145.50 (24.86)
Extraversion	9.85 (4.11)	9.58 (3.94)	10.60 (3.61)	10.13 (3.76)
*Agreeableness	14.00 (3.49)	16.33 (2.23)	16.72 (2.53)	15.95 (2.82)
Conscientiousness	14.25 (3.09)	13.67 (4.00)	13.47 (3.65)	13.08 (3.17)
Neuroticism	15.50 (2.87)	12.75 (3.89)	14.81 (2.95)	14.40 (3.22)
Imagination	3.89 (0.82)	3.71 (0.86)	3.91 (0.75)	3.74 (0.84)
Emotional self-awareness	96.10 (10.04)	94.91 (10.36)	96.86 (15.26)	97.13 (13.39)

* Significant difference observed between groups ($p = .016$)

Together, the person-specific factors measured in the ‘on-boarding’ component of the MoodPrism app did not appear to differ among groups overall. Including these variables in the model constructed in Paper #3 would therefore be unlikely to add substantial predictive power. The difference in agreeableness across the vulnerable and recovery group is noteworthy. As recovery responses are largely favourable, and vulnerable responses unfavourable, future studies may benefit from more detailed examinations of possible influences agreeableness may have on promoting recovery in lieu of a poorer, vulnerable outcome. This could not be conducted in the current study due to sample size constraints. Including an extra variable into study analyses would exceed the recommended rule of thumb concerning appropriate sized samples for conducting multinomial logistic regressions: a

minimum of 10 participants per effect (main or interaction) (Homer, Lemeshow, & Sturdivant, 2013).

Concluding remarks:

In this chapter, methods implemented in Papers #1 and #2 were utilised to provide an in depth exploration of relationships between person-specific factors and different patterns of psychological responding. Central findings reported in Paper #3 revealed the complex influences of age and social support on psychological patterns of responding to a major daily stressor. Findings demonstrated that when considered alone, both factors favour undesirable patterns of responding; however, when considered together, age and social support interact generating a positive association with a resilient pattern of responding. The paper presented in this chapter accomplishes the second objective of the current thesis and represents a culmination toward its overarching aim.

Chapter 5: General Discussion

The overarching aim of this thesis was to provide a working example of a purpose-designed research methodology enabling investigation of resilience in the context of major daily stressors. This aim was achieved through fulfilment of two objectives:

1. Developing tailored research methods to capture and explore variations in psychological responses following a major daily stressor. This comprised two components:
 - a) Implementing a contemporary and temporally sensitive means of data collection suited to examinations of resilience to daily stressors (Paper #1).
 - b) Executing methodological procedures to convert experience-sampling data into trajectories of psychological responding, with subsequent classification into prototypical response groups (Paper #2).
2. Utilising these methods to investigate mechanisms facilitating resilience to major daily stressors (Paper #3).

An integrated discussion concerning the fulfilment of each objective is provided below. This comprises a summary of outcomes and discussions regarding primary research contributions, limitations, directions for future research, and real world applications. These are discussed with respect to each objective, and are followed by a general conclusion.

Objective 1: Developing tailored research methods to capture and explore variations in psychological responses following a major daily stressor

1.1. Summary of Outcomes

1.1.1. Utility of the Experience-Sampling-Application (ESA). In the current thesis, an ESM was adopted as a suitable method of data collection to accommodate challenges associated with the temporality of daily stressors. To overcome methodological constraints of

former implementations, the ESM was delivered through a contemporary adaptation of approaches used in previous studies. This involved capitalising on the substantial proliferation and advances in smartphone technology. As such, a contemporary smartphone-based ESA, “MoodPrism”, was deployed to facilitate the collection of data relevant to core principals of resilience, while reducing levels of intrusiveness and experimental burden on participants, and the improving accessibility to the ESM.

Through a daily assessment schedule, the app was found to successfully collect data suited to the study of resilience. Each ESR queried participants regarding current psychological functioning (symptoms of depression) and details about the most negative stressor experienced for the day (date, content, and severity). With the collected data, individual reports could be sequenced, providing access into participants’ daily lives in aspects relevant to core principles of resilience. Experience-sampling data was contrasted with a retrospective datum of the same measure, revealing the superior sensitivity of experience-sampling data. The data provided by retrospective reports were limited, presenting as flat averaged levels of functioning over an extend duration. Connecting individual ESRs provided flow-like illustrations of day-to-day psychological functioning, with exposures to discrete stressors pinpointed across a given duration period. While these findings are comparable to data collected in previous studies (Almeida et al., 2002; Diehl & Hay, 2010, 2013), the smartphone-based ESA also extends experience-sampling utility beyond data collection capabilities alone.

As compared with previous implementation of the ESM, the MoodPrism ESA has added utility in positively influencing user experiences and participant engagement. The architecture, aesthetic appeal, and experience-sampling design of the ESA prioritised simplicity, brevity, and user-friendliness. Simplicity and user-friendliness promoted ease-of use and effective guidance toward meaningful use of the app without requirements of

specialised training. The brevity with which items in the app were presented helped reduce experimental burden and intrusion into daily life. The micro-surveys constituting individual ESRs required less than 2 minutes per day, and also informed non-monetary incentives to participants through continued app use. Such incentives (e.g., mood tracking and scientifically informed psychological feedback) encouraged continued participation, wilful engagement with the app, and tendered an inherently rewarding app experience. Additionally, the ESA capitalises on personally owned smartphone devices to deploy the ESM. This was convenient for participants as it made use of familiar devices, and circumvented the need to carry daily diaries, booklets, or foreign electronic devices. Using personally owned devices also improved ecological validity of the data as smartphones are often carried throughout daily life; this permitted participants to use the app in any place and at convenient times. Together, these factors extend the utility of the ESM by yielding an overall positive user experience which minimises experimental burdens and increases attraction to research participation.

The utility of ESA also extends to prospective researchers by increasing accessibility to the ESM for investigations of resilience. Collecting experience-sampling data using an ESA can reduce resource demands associated with previous ESM study designs. Interestingly, this is conferred through similar benefits afforded to users. For example, in the current thesis, due to minimised experimental burdens and intrusion into daily life, monetary incentives encouraging continued participation were relatively cheap (\$31,000USD) in comparison to previous research methods (\$58,500USD) (Diehl & Hay, 2010; Hay & Diehl, 2010). Non-monetary incentives supplemented this, further reducing cost and adding value to meaningful participation. Costs were also reduced through the use of participants' personally owned smartphone devices; this negated requirements to purchase and loan costly foreign devices to participants. The power and capabilities afforded by modern smartphones

also reduced personnel requirements to collect data. Smartphone technology enables presentation of all content (explanatory statements, consent forms, psychological surveys, daily mood reports, etc.) through the touchscreen interface. This evades requirements to contact participants (excluding prize draw reasons) as content delivery is completely automated, and all data are wirelessly uploaded to a secure, online, back-end database available for access at any time. Developing ESAs like MoodPrism offer cost-effective alternatives to instruments used in previous ESMs, encouraging research growth and facilitating advancement of methods to collect data for the study of resilience.

1.1.2. Implementation of trajectory-based classification procedures. The experience-sampling data provided by the ESA, enabled the implementation of novel trajectory-based classification procedures. This comprised several steps: a) identification and isolation of suitable data; b) assessment of data quality; c) response standardisation; d) group classification; and e) additional curve-fitting of finer grained assessments of stress-responses. Application of these procedures revealed distinct ways in which individuals respond to major daily stressors, and highlighted differential stress accumulation risks associated with each response pattern. These response trajectory classifications are illustrated in Figure 1 and summarised below.

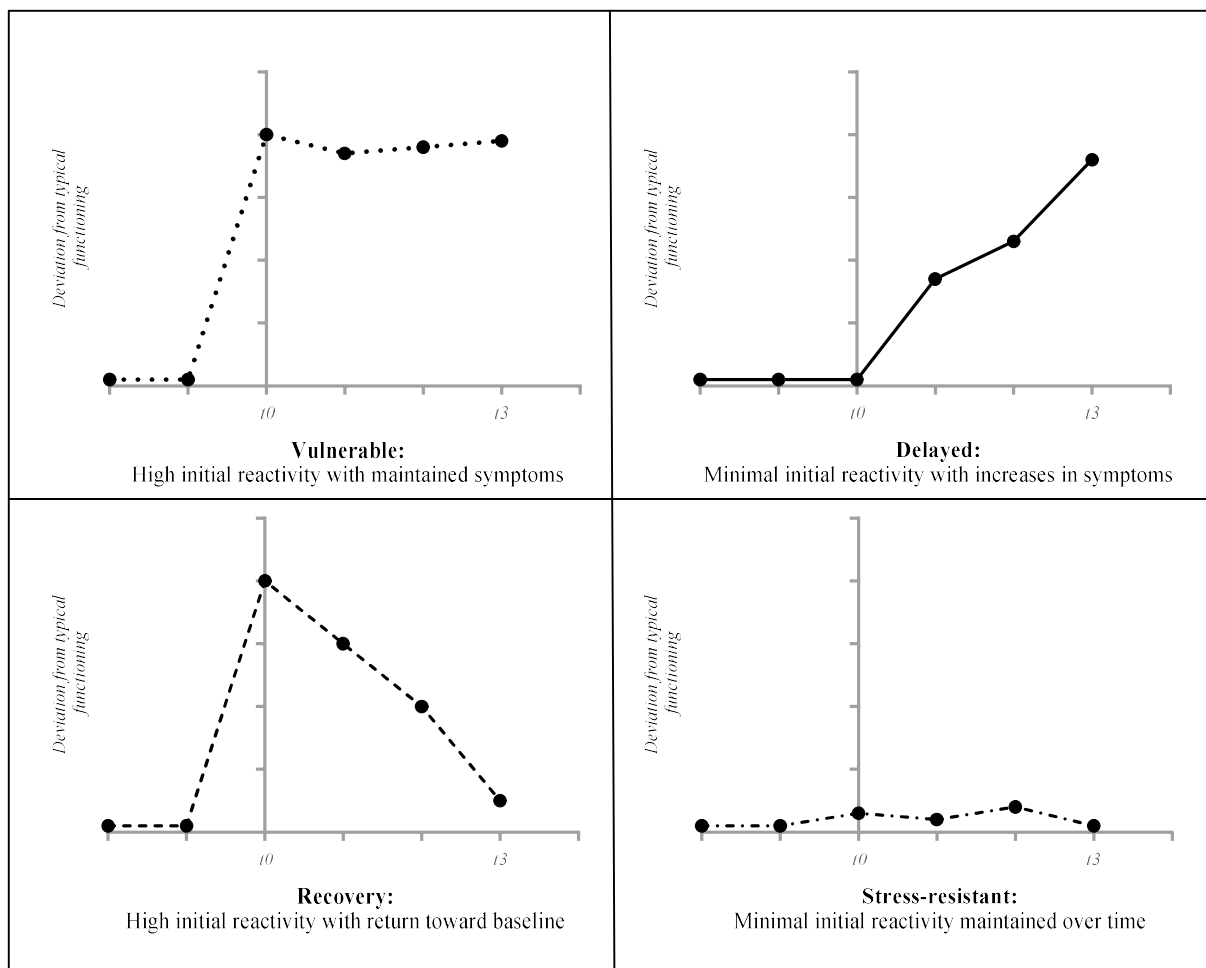


Figure 1. Conceptual illustrations of prototypical response trajectories following major daily stressors—NB, t_0 = stressor day.

Vulnerable: A vulnerable response comprised large increases in psychological dysfunction (symptoms of depression) which are maintained after several days. Individuals exhibiting this response appear to have difficulty mitigating immediate effects of the stressor and recovering effectively over time. Such individuals are rendered vulnerable to risks of stress-accumulation as generated stress is not dissipated effectively, and remains high.

Delayed: A delayed response exhibited minimal initial increases in psychological dysfunction. After several days, however, levels of distress increase. Despite successful mitigation of immediate effects, such individuals appear challenged in maintaining initial positive responses. Here, distress is not immediately apparent, and manifests across several days. In lieu of stress dissipation, stress grows over time in the delayed trajectory and generates an incremental vulnerability to stress-accumulation.

Recovery: Recovery responses exhibited large immediate increases in psychological dysfunction which recover after several days. Odds of stress accumulation are minimised in such responses, as stress is dissipated over time. Dissipation of stress reduces the amount of unresolved stress is available for accumulation. Manifesting this trajectory following a major daily stressor is consequently more desirable than the previous two.

Stress-resistant: The stress-resistant trajectory represents the most favourable pattern of responding, and most aptly resembles resilience. Individuals exhibiting this response experience minimal immediate increases in psychological dysfunction. Unlike individuals in the delayed group, however, this positive reaction is maintained. In such cases, both mechanisms of risk associated with major daily stressors are resisted. Individuals exhibiting stress resistance are positioned favourably to confront future stressors as minimal distress is generated. This leaves little unresolved distress for stress-accumulation and facilitates a psychological preparedness to engage with future stressors.

Classification of these trajectories is novel within resilience research literature. Although these trajectories have been observed in previous research, this has been in the context of PTEs only (Bonanno, 2004, 2005; Bonanno & Diminich, 2013; Bonanno & Mancini, 2008). No studies, to my knowledge, have executed focused investigations of prototypical ways individuals react and recover following daily stressor experiences (major or minor); findings of Paper #2 therefore present the first example of this, which has great utility in the study of resilience to daily stressors.

Such holistic assessments are advocated in contemporary daily stress theory (Scott et al., 2017; Smyth et al., 2017) and are useful as they enrich conceptualisations of resilience to daily stressors by enabling sensitivity to stress accumulation and dissipation. Due to stress-accumulation risks engendered by daily stressors, notions of stress-dissipation are highly relevant in understandings of resilience to daily stressors (Bergeman & Deboeck, 2014;

Lazarus, 1999; Smyth et al., 2017 Zautra, 2003). Previous research studies only focus on initial reactions to daily stressors, and overlook patterns of responding following daily stressors (Almeida et al., 2016; Charles et al., 2009; Mroczek & Almeida, 2004; Neupert et al., 2007; Stawski et al., 2010). These reveal limited accounts of psychological responses, and grant only partial judgements of resilience. Monitoring patterns of recovery following initial reactions demonstrate individual capacities to dissipate stress and capture overlooked details of stress responses in previous research methods. Incorporating this element of stress responding therefore extends traditional assessments to provide a comprehensive conceptualisation of resilience which more fully encapsulates daily stressor risks.

Capturing individual patterns of recovery also provides the first empirical representations of the stress outlet described in Deboeck and Bergeman's (2013) reservoir model of daily stress (introduced in Chapter 1). In this model, the outlet situated at the bottom of the reservoir allows 'liquid' (or stress) to drain from the vessel. As the reservoir represents a vessel in which stress can accumulate, the outlet represents an individuals' capacity to dissipate stress. Potential differences in outlet sizes are depicted in the range of patterns of recovery observed across trajectories classified in this thesis. Such depictions are novel in the research literature and, as such, findings of the thesis supplement the reservoir model. Specifically, while the reservoir model provided a metaphorical analogue exemplifying stress-accumulation/dissipation processes, findings of the current thesis illustrate real-life manifestations of such processes. For example, trajectories manifesting high psychological dysfunction several days after stressor exposure (vulnerable and delayed) exhibit suboptimal capacities to dissipate stress, and are indicative of small stress outlets (relative to the amount of stress entering the vessel). Trajectories which return to, or maintain, typical levels of functioning after several days (stress-resistant and recovery) appear to have better stress dissipation capacities which suggests a larger stress outlet.

1.2. Research Contributions

The combination of methods presented hitherto forms a complete method of research which can be used to investigate resilience to major daily stressors. Specifically it provides:

- a) A contemporary, burden light, accessible, and effective means to track temporal phenomena central to the study of resilience.
- b) Data processing procedures transforming collected data into meaningful trajectories of psychological responding.

The smartphone-based ESA endows researchers with highly detailed and temporally specific method of data collection which provides experience-sampling data suited for the study of resilience. Importantly, ESAs permits collection of such data while reducing user efforts to participate in, and researcher efforts to conduct, psychological research. To examine factors potentially facilitating resilience, this method of data collection can be coupled with methodological classification procedures provided in Paper #2. Classifying groups representing distinct trajectories of psychological responding afford differentiation between individuals exhibiting favourable responses, or resilience, from those exhibiting poorer outcomes. This can be used to examine relationships between person-specific factors and favourable vs unfavourable patterns of psychological responding, and forms a basis from which factors underlying resilience can be investigated.

1.3. Limitations

A highly advantageous feature granted to researchers by ESAs is the flexibility to customise apps according to researcher interests. Smartphone apps, however, are relatively inflexible after development is complete. While the MoodPrism app can be reused for other research studies, the scope of such studies is currently limited to fixed features, items, and surveys in the app. The MoodPrism app was developed according to author specifications with particular research purposes in mind, which may not cover interests of other researchers.

Research requiring even slight differences in the app's content requires development of a completely new app, or replication and adjustment of the existing app. As such, development of numerous individual apps may be needed to cater for the differing needs of researchers. This is inefficient and arguably still costly despite substantial reductions as compared to previous research methods. Forecasting potential uses of ESAs beyond immediate research users can increase cost-effectiveness of app development. Caution is advised in this endeavour as researchers must be wary not to overload apps with excessive content. Including extra content for future reuse of the app can threaten user experiences as apps may become cluttered, difficult to navigate, and may increase participation time. A practical alternative to this, and a direction for future researchers, involves development a ESAs with inbuilt content management system, permitting flexibility in app content without app redevelopment.

1.4. Directions for Future Research

A customisable, all-in-one, ESA with a flexible, online, back-end content-management system would significantly streamline the application of ESM in empirical research. This contemporary methodology would enable researchers from all fields to modify content presented in the app including surveys administered to participants and experience-sampling features (e.g., prompt times for ESRs, content of daily prompts, or informational feedback based on responses to daily prompts). Such content may be managed through a centralised website where researchers can register and upload desired content/experience-sampling features to be included in their respective app adaptation. The web system can provide different researchers individualised codes to share with respective samples. Codes entered into the all-in-one ESA can then load corresponding content and experience-sampling specifications detailed by the recruiting researcher. The code can also function as an access-key for researchers to retrieve participant data on a centralised website. Although

development of such a system would undoubtedly incur costs exceeding development of a traditional ESA, only a single system would be required. Such a system could be commercialised, offering researchers time-limited licenses for a small fee. Here, researchers could be offered a contemporary iteration of the ESM for empirical research for the fraction of the cost of developing a stand-alone ESA.

Another direction for future research concerns the potential utility of ESAs for the study of PTEs. For example, methods established by Bonanno and colleagues (Bonanno & Mancini, 2012; Bonanno et al., 2011), may be improved through the use of ESAs. ESAs can be programmed to prompt participants across long time scales (1 year), across regular intervals (weekly, fortnightly, monthly). Advantages gained through ESAs allow this to be achieved in a less intrusive manner. Researchers may capitalise on this non-intrusiveness and increase frequencies of assessments to collect more data points across time. This increases the resolution of trajectory illustrations as more detail is provided to inform individual trajectories of responding. Increased frequency of prompting also reduces retrospective biases as participants may only need to recall events experienced over, for example, two weeks as compared to six month intervals as conducted in previous research.

1.5. Real World Applications

While application of methods reported in this thesis primarily relate to uses in empirical research, it could also extend to real-world applications. Monitoring individual responses to daily stressor experiences could have utility for promoting stress-response awareness, and encouraging self-management of personal resilience. Individuals could gather data regarding personal experiences of major daily stressors, and track changes in mood over time; this can offer insights into levels of accumulated stress, and flag critical points of where needs of stress dissipation are highest. Identifying such cases may impel individuals to implement a range of stress-management and behavioural coping strategies to effectively

dissipate stress and re-establish psychological equilibrium. Here, partnering with other fields of psychological research, like coping and positive psychology literature, appears useful. Tailored coping strategies and systems of education could be developed to heighten awareness regarding resilience to daily stressors, educate the wider population about methods to combat daily stress, and present effective ways to cultivate resilience.

Self-management of personal resilience could also be supplemented through technological means. For example, a ‘resilience application’ may be developed to present daily mood reports and convert resulting data into useful feedback for users. Algorithms could automatically deconstruct responses in real-time according to procedures outlined in this thesis. Details could then be fed back to users regarding psychological responses to individual stressor experiences, indicating the degree of resilience demonstrated in each circumstance. Presenting illustrations of how users respond to stressors provides opportunity to reflect on environmental circumstances or personal factors which users may feel are central to shaping their stress responses. This offers a convenient means through which to be mindful of emotional responses to stressors and support efforts to adjust these responses in ways that increase manifestations of resilience. While this can be adopted for personal use, it can also be used to supplement clinical therapies; patients can review a history of stress-responses recorded within the app with clinicians and form personalised interventions centred on factors common to resilient responses and management of factors associated with less favourable responses.

Understanding the ways trajectory-based stress responses manifest may also have potential preventative utility, in the form of screening and early identification of psychopathology or mood disturbances. Specifically, the ways in which individuals persistently respond to major daily stressors could potentially serve as a marker of psychopathological risk. Psychological disturbances are known to negatively impact an

individual's capacity for effective mood-regulation (Aldao, Nolen-Hoeksema, & Schweizer, 2009; Joorman, Siemer, & Gotlib, 2007; Kring & Sloan, 2009); as such, they may be associated with particular patterns of responding following major daily stressors. For example, individuals suffering from a mental illness like anxiety or depression may persistently exhibit vulnerable or delayed patterns of responding. As these response trajectories appear more prone to accumulations of stress, repeated manifestations in response to major daily stressors may create a downward spiral of psychological well-being. For example, several maladaptive responses to daily stressors could lead to an accumulation of stress. This may reduce an individual's capacity to respond effectively to future stressors. In such cases, if additional stressors are experienced, individuals may be more likely to exhibit maladaptive responses, accumulating even more stress. This creates an undesirable feedback loop which could be a contributing factor to psychopathology. This information could be used to screen for individuals at risk of psychopathological development, and identify them in the early stages where intervention is most effective.

The ways in which individuals consistently respond to major daily stressors could also operate as an indicator of how a person may respond to more significant traumas. Although major daily stressors are not traumatic in nature and constitute everyday living, they are still subjectively experienced as highly negative events. Because of this, trait-like propensities to respond to major daily stressors could relate to an individual's capacity to adapt to highly distressing adversity. For example, individuals consistently manifesting vulnerable responses to major daily stressors may be at higher risk for exhibiting similar patterns of responding to PTEs, like the chronic trajectory described in previous research (Bonanno et al., 2011; Bonanno & Mancini, 2012). Although additional research is required, if supported, this association could aid the early identification of individuals likely to respond poorly to trauma,

and direct such individuals toward mental health support in order to improve resilience and psychological preparedness to confront future trauma.

Objective 2: Investigating mechanisms facilitating resilience to major daily stressors

2.1. Summary of Outcomes

Utilising methods presented in Papers #1 and #2, distinct groups of individuals exhibiting varying degrees of resilience were identified. Building on this, Paper #3 examined associations between person-specific factors and identified groups. Specific variables explored in the current thesis were guided by previous research literature and comprised age, self-esteem, and social support.

Findings showed that age and social support, but not self-esteem, were significantly associated with particular trajectory groups. Considered alone, age and social support were both positively associated with a delayed response trajectory, as compared to stress-resistance. That is, the older and more socially supported individuals appeared more likely to exhibit an unfavourable pattern of responding following the experience of a major daily stressor. Considered alone, these findings only support one side of disparate research associating vulnerability to older age and higher social support. Analyses of interactions between variables, however, showed that age and social support are interrelated person-specific factors which interact to confer a positive association with resilient responding. That is, older individuals reporting higher levels of social support were more likely to exhibit stress-resistance, as compared to a delayed response.

2.2. Research Contributions

The thesis contributes new knowledge to the existing body of resilience literature as the findings represent the first exploration of factors potentially underlying resilience to major daily stressors. Major daily stressors represent a relatively unexplored form of daily

stressor, which engenders combined risks of PTEs and minor daily stressors. Findings in the current thesis highlighted the roles of age, social-support, and self-esteem in producing direct, and interactive, influences on resilient and non-resilient patterns of psychological responding. Importantly, such findings were achieved using research methods which address methodological and theoretical limitations of previous research studies (achieved in the first objective of this thesis). Overcoming limitations of previous research methods is important as it aids investigating resilience in reliable and valid ways (discussed in Chapter 1). This is crucial for accurate and comprehensive modelling of resilience processes which has real-world utility in the development of effective interventions and programs aimed at cultivating everyday resilience (discussed below in section 2.5).

Although it is yet to be determined whether current research findings can be generalised in the context of minor daily stressors, unique design features utilised in the final study reported in this thesis also stand as noteworthy research contributions. For example, the utility of multi-variable approach was demonstrated as it permitted analyses of interactions between variables to better explain the ways in which person-specific variables may confer different effects. Specifically, findings indicated that age and social support can confer differential influences on stress-responses in a mutually dependent manner. This provides an explanation that could reconcile inconsistencies observed in previous research regarding the roles of age and social support in resilience processes—namely, that inconsistencies could have resulted from unobserved differences in levels of social support across age (or vice versa). For example, studies inferring protective effects of older age may have sampled older individuals with higher perceived social support. In contrast, studies supporting notions of vulnerability among older participants may have recruited socially unsupported samples. As such, study findings draw attention to the value of using a multi-variable approach, and echo

suggestions advocated by Diehl et al (2103) to incorporate this methodological feature into future research studies.

In a similar vein, demonstrating the utility of trajectory-based assessments of psychological responses is also a significant research contribution. This study design feature provided comprehensive examination of individual stress responses. Previous daily stressor studies have lauded the role of older age in conferring protective effects on account of decreased reactivity to daily stressors (Brose et al., 2011; Neupert et al., 2007; Stawski et al., 2010; Uchino et al., 2006). These studies, however, did not utilise trajectory-based assessments and consequently lacked scope to determine participants' patterns of recovery following initial reactivity. Trajectory-based assessments conducted in the current thesis revealed how minimal reactivity profiles could reflect both favourable (stress-resistant trajectory) and unfavourable responses (delayed trajectory). As such, in previous studies, it is unclear whether decreased reactivity profiles truly reflect stress-resistance, or the early stages of a delayed trajectory. Trajectory-based assessments developed in the current thesis enabled differentiation in such cases, and revealed that older individuals appeared more likely to exhibit the *delayed* trajectory (when age is considered alone). This could suggest that assessing reactivity profiles alone, as conducted in previous studies, may lead to misleading inferences due to limited views stress-responses. When judged independently, minimal reactivity profiles appear favourable, imply resilience, and explain positive inferences made concerning the role of older age in resilience processes. Considered holistically, however, minimal reactivity profiles developing into delayed trajectories of responding imply vulnerability and corroborate studies associating risk with older age.

2.3. Limitations

A primary limitation of the overall thesis concerns the modest sample size used to investigate mechanisms underlying resilience. Although several findings reached

significance, other outcomes approached, but did not exceed, significance levels (for example, main effects of age when comparing recovery and vulnerable groups with the stress-resistance group). A larger sample size would grant greater power to identify meaningful changes and could potentially have resulted in different interpretations of study findings. Homer, Lemeshow, and Sturdivant (2013) suggest a minimum of 10 observations per variable for multinomial logistic regression analyses. Although this was achieved in the final study, Homer et al. (2013) also caution that 20 observations per variable should be sought where possible. This would increase statistical power and provide added confidence to thesis findings.

The modest sample size also limits possibilities to conduct finer grained classification of stress responses. Such assessments distribute participants into a substantially increased number of groups yielding numerous groups with small sample sizes. This also reduces power and practicality of running meaningful statistical analyses. Larger sample sizes would increase likelihoods of achieving appropriately sized groups at finer levels of group classification. In such cases, statistical analyses become a viable option to examine whether non-significant variables (e.g., self-esteem at gross levels of classification) have influence at finer levels of classification. In the current thesis, the sample size restricted such explorations, limiting interpretation of findings. An increase in sample size would ultimately improve interpretability of research findings, shed light on speculative interpretations, and enable additional investigations regarding the role of person-specific variables in resilience processes.

Finally, small sample sizes also threaten generalisability of research findings to the greater population. The methods of recruitment and mode of delivery of the ESM (via smartphones) may have attracted certain types of users, limiting the extent to which the sample could be considered representative of the general population. Overall a moderately

positively skew toward lower levels of depression and anxiety, and moderately negatively skew toward higher levels of agreeableness was observed in Papers #2 and #3. The latter finding likely reflects the greater proportion of females in the study, who typically score higher in levels of agreeableness as compared to men (Weisberg, DeYoung, & Hirsh, 2011). In addition to this, a high positive skew was observed across the age distribution, reflecting the recruitment of primarily younger participants (between 18 and 30 years of age), with the oldest quartile of participants being in their middle-ages. As such, study findings could not be generalised to older age groups (60+) which comprise many samples of previous studies. Study findings would therefore be more relevant in populations which are younger and include a greater female presence.

2.4. Directions for Future Research

Future research could benefit from replicating the current research with the following extensions: 1) increasing the sample size; 2) adding new person-specific variables; and 3) extending the data collection across different adversities.

Achieving a greater size sample benefits future research by increasing statistical power and enabling additional analyses at different levels of group classification (gross vs fine). Such increases in statistical power provide a most robust investigation of factors influencing odds of group classification, and can also strengthen interpretations of research findings. With the ease of participant recruitment afforded by the smartphone-based ESA, an increase in sample size is a manageable and practical endeavour to improve future research.

Following increases in sample sizes, future studies could progress to incorporate additional person-specific factors (e.g., personal qualities, behavioural tendencies, health factors, stress-management strategies) into statistical models. This may reveal new insights concerning the factors which positively influence psychological responses to stress, and consequently improve individual resilience to daily stressors. It may also be useful to

examine possible interactions between person-specific factors and stress-specific factors like the focus of content of stressor experiences (e.g., work stressors, loss of valued item, personal health problems). Although the findings in the current thesis indicated no interaction with specific stressor types, this does not exclude potential interactions with other person-specific variables not included in analyses—for example, trait neuroticism may increase odds of exhibiting a vulnerable linear trajectory only in response to personal health problems. This would help elucidate how specific kinds of people are likely to respond to specific types of stressors.

Future research could also utilise the methods presented in this thesis to integrate separate streams of resilience research examining different forms of adversity (e.g., chronic adversity, PTEs, and daily stressors). The influences that person-specific factors maintain over well-being outcomes across different adversities are not fully understood; individual factors may function differently, or similarly, in response to different forms of adversity (Davydov, Stewart, Ritchie, & Chadiou, 2010). Using a consistent methodology, the effects of person-specific factors could be examined and contrasted across exposures to chronic adversity, PTEs, and minor daily stressors. This would represent an amalgamation of different streams of resilience research, typically investigating distinct forms of adversity separately, and deliver a holistic study of resilience.

2.5. Real World Applications

Findings of the current thesis highlight the complex ways in which person-specific factors may interact, and can be integrated into existing models of stress and resilience (e.g., Almeida, 2005; Kumpfer, 2002). Understanding the ways these factors function within resilience processes to influence psychological response to major daily stressors has utility in clinical and non-clinical settings. It may be useful for clinicians and developers of resilience interventions, community campaigns, and educational material, as it can improve the efficacy

and targeting of treatment approaches to reducing risks of stressor induced psychopathology among specific populations. For example, clinical therapies could target improving social resources among middle-aged adults, who would otherwise be at risk of exhibiting unfavourable response patterns following major daily stressors. Resilience-development programs may serve to disseminate similar information as educational material to increase awareness in the general population about potential risk associated with daily stressor experiences, and communicate home-based therapies which function to mitigate them. With study replication and additional research, a register of factors associated with resilient outcomes could be formed and made available online. This could provide detailed information regarding the efficacy of various person-specific factors or coping strategies within specific populations, and in response to particular stressors. Individuals may benefit from this information to enact targeted, personally driven interventions to improve individual resilience and prevent declines in mental health. Such approaches can be integrated into daily life to promote mental health hygiene and the self-management of stress, or act as an intermediary step before deciding to seek professional assistance to reduce burdens on mental health organisations and services.

General Conclusion

The aim of the current thesis was to provide a working example of a novel research methodology facilitating the exploration of mechanisms underlying resilience to major daily stressors. This aim was achieved through the fulfilment of two objectives: 1) developing tailored research methods to capture and explore variations in psychological responses following a major daily stressor, and 2) utilising this methodology to investigate mechanisms facilitating resilience in this context.

Methods to capture variations in stress responses (objective 1) comprised two components. The first component concerned the collection of data required to examine

responses. Paper #1 provided a positive use-case for smartphone-based ESAs to collect relevant data for the study of resilience while also reducing costs, and minimising experimental burdens, associated with implementing an ESM study design. The resulting data was used in Paper #2 which constituted the second component of this objective. This study outlined methodological procedures to convert experience-sampling data into a meaningful representation of an individual's psychological response to a major daily stressor. Findings of this study resulted in the classification of four trajectory-based stress responses which comprised a vulnerable, delayed, recovery, and stress-resistant group. Combined, Papers #1 and #2 form an innovative research methodology which provides a platform from which factors associated with resilience can be studied.

Group classifications resulting from methods showcased in objective 1 formed the basis of the second objective of the thesis aim. Fulfilment of this objective is demonstrated in Paper #3, which examined associations between person-specific factors of age, self-esteem, and perceived social support and membership to classified trajectory groups. Findings of this paper contributed new insights into the ways these factors may function within resilience processes, and unique features of the study design provided potential explanations for inconsistencies observed in previous research.

Each of the three research papers included in this thesis provided meaningful contributes to the resilience research literature. These papers denoted core components forming two primary objectives of the thesis, which underscore its principal aim. As each objective was successfully fulfilled, the aim of the thesis was achieved and ultimately provides researchers a working example of a complete research methodology to investigate mechanisms underlying daily resilience. The achievement of this aim is noteworthy in the context of the broader research literature as it offers means to study resilience while addressing theoretical and methodological limitations of methods utilised in previous

research. This serves towards advancing existing methodologies, and the development of comprehensive research methods with which to study resilience. Although this thesis presents an initial piloting of a novel research methodology, comprising studies yielding only modest research findings, several noteworthy research contributions are presented. Future studies may replicate, advance, and fine-tune these research methods to yield more robust research findings. Such findings may translate into the refinement of existing models of resilience, which can ultimately contribute toward improving mental health interventions and cultivating resilience in both clinical and community populations.

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Appendix A: Development of a mobile phone app to support self-monitoring of emotional well-being: A mental health digital innovation.

JMIR MENTAL HEALTH

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Original Paper

Development of a Mobile Phone App to Support Self-Monitoring of Emotional Well-Being: A Mental Health Digital Innovation

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Abstract

Background: Emotional well-being is a primary component of mental health and well-being. Monitoring changes in emotional state daily over extended periods is, however, difficult using traditional methodologies. Providing mental health support is also challenging when approximately only 1 in 2 people with mental health issues seek professional help. Mobile phone technology offers a sustainable means of enhancing self-management of emotional well-being.

Objective: This paper aims to describe the development of a mobile phone tool designed to monitor emotional changes in a natural everyday context and in real time.

Methods: This evidence-informed mobile phone app monitors emotional mental health and well-being, and it provides links to mental health organization websites and resources. The app obtains data via self-report psychological questionnaires, experience sampling methodology (ESM), and automated behavioral data collection.

Results: Feedback from 11 individuals (age range 16-52 years; 4 males, 7 females), who tested the app over 30 days, confirmed via survey and focus group methods that the app was functional and usable.

Conclusions: Recommendations for future researchers and developers of mental health apps to be used for research are also presented. The methodology described in this paper offers a powerful tool for a range of potential mental health research studies and provides a valuable standard against which development of future mental health apps should be considered.

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KEYWORDS

eHealth; emotions; mental health; mobile phone; feedback

Introduction

Background

Emotional well-being is broadly defined [1] as, “a positive sense of well-being and an underlying belief in our own and others’ dignity and worth” by the Mental Health Foundation (p. 8).

Consistent with dual models of well-being, it encompasses both positive functioning (happiness, a sense of control and self-efficacy, and social connectedness) and an absence of stress and depression [2,3]. Monitoring changes in emotional well-being is fundamental to mental health, with increases in emotional well-being associated with resilience, creative thinking, social connectivity, and physical health [4-9]. In

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contrast, significant and sustained decreases in emotional well-being are associated with the development of affective disorders such as depression and anxiety, and reduced physical health [4,5,7].

Monitoring for such changes is crucial for early detection of mental health problems. Rapid response to early risk indicators is one of the key predictors of better health outcomes, enabling preventative health approaches to be initiated early [10]. Regular monitoring of emotional health indices is therefore recommended by various national guidelines [11,12]. In practice, however, it remains difficult for clinicians or professional mental health service providers to obtain frequent monitoring in real time [13,14]. A priority challenge facing the health care system is to achieve practicable and sustainable means of supporting self-management of health and well-being. Self-monitoring is a particularly attractive goal for mental health care, given that many individuals with mental health needs do not seek professional health care support [15-17]. In addition, self-monitoring may develop an individual's insight into their need to seek help. In particular, young people consistently indicate that they prefer nonprofessional or self-managed strategies for addressing mental health issues [18,19]. Obtaining temporally sensitive (eg, daily) information on significant changes in emotional state has the potential to profoundly improve the capacity to promote emotional health [12].

Experience sampling methodologies (ESMs), or ecological momentary assessments, involve the systematic collection of self-report data from individuals at multiple time points throughout their everyday lives [20]. ESMs have been used to monitor changes in affective state, and to predict mental health with success to a certain extent [21,22]. In particular, the variability in emotional state over time provides more substantial information for understanding the causes and nature of psychopathology than do cross-sectional "snapshot" assessments. For example, when sampled multiple times a day for 6 days, negative affect was found to vary more in patients diagnosed with major depressive disorder than that in controls across the day [23]. ESM assessments in individuals diagnosed with panic disorder also revealed that the expectation of a panic attack was a significant precursor for the occurrence of a panic attack [24]. Ben-Zeev et al [25] also found that patients diagnosed with a major depressive disorder retrospectively reported higher levels of symptoms relating to anhedonia, suicidality, and sadness than captured in their ESM reports, highlighting the biases of traditional survey methods. To date, however, it has been methodologically difficult and obtrusive to obtain temporally regular and precise measures of emotional state [21]. The resources required to obtain such information repeatedly over lengthy time frames have made such an intensive monitoring prohibitive. In addition, the use of palm pilots and pagers (which were never as familiar to users as mobile phones have become) to prompt users for this information can be intrusive, and makes it less likely that users will continue to use this form of monitoring for extended periods [26].

Mobile phone technology offers an unprecedented opportunity to unobtrusively track everyday behavior and changes in emotional state, all in real time [27,28]. Mobile phone health tools also offer the potential of immediate response to the

outcome of this monitoring via delivery of mental health information contingent on changes in real-time emotional state [29]. This technology has not yet been fully leveraged for these purposes, despite mobile phones being one of the few pieces of technology that most people carry on their person every day [30]. This pervasiveness means that mobile phones offer a highly natural and regular means by which information on emotional state could be obtained. Mobile phones now penetrate 77%, 72%, and 68% of the Australian, US, and UK population, respectively [31], and are a cost-effective means of seeking help for mental health issues that may overcome socioeconomic and geographic boundaries [32,33].

Mobile phone health technology holds great potential for facilitating the management of emotional health through its ability to deliver flexible, user-oriented intervention and self-management tools; a feature particularly relevant for young people who often report fear of stigma associated with seeking professional services for sensitive mental health issues [34,35]. In a 2010 study, 76% of an Australian sample reported being interested in using mobile phones to monitor and manage their own mental health [32]. A large number of mobile phone apps are currently available that claim to promote mental health and well-being [36,37] and a subset of these also attempt to track mood or emotional state over time. However, empirical support for the efficacy of these apps is extremely limited [36]. For instance, in a systematic review of 5464 mental health app abstracts, less than 5 apps were found to have experimental evidence [37]. In addition, a few have capitalized on the benefits enabled by the mobile phone technology such as experience sampling and automated data collection in identifying and evaluating potential time-sensitive behavioral indicators of mental health change [36].

Of the mobile phone mental health programs that have utilized ESM to track mood over time, several favorable outcomes have been reported. For example, Reid et al [28,38] found that the majority of their adolescent sample using the mobile phone-based mental health app, *mobiletype*, completed their self-assessments, and that the use of the app increased the practitioners' understanding of their patients' mental health. Harrison et al [29] reported that the use of the mobile phone accessed Web-based cognitive behavioral therapy (CBT) course *MyCompass* for 6 weeks significantly reduced symptoms of depression and anxiety and improved self-efficacy. One of the barriers to sustainability of user engagement in such programs, however, is that they require extensive voluntary input from the user. When evaluated, a common theme is initial compliance, followed by high dropout and poor self-reporting rates (eg, less than 10% of the sample trialing *MyCompass* reported using it every day) [29]. Reasons for discontinued use include problems understanding how to use the program, invasiveness of the questions, the need for repetitive completion of questionnaires, insufficient personalization of the mental health advice, and little motivation to engage with the program [28,29].

An innovative way to meet this challenge is to monitor indices of emotional health using methods that require minimal insight or subjective report from the user. Mobile phones contain a range of embedded sensors and features, including accelerometers and global positioning systems and apps, which

can automatically record information about a user's behavior [39]. Two recent studies have obtained a combination of data from mobile phones in an attempt to predict participants' self-reported mood. LiKamWa et al [40] found that up to 93% of mood scores were accurately predicted by social activity, physical activity, and general mobile phone use data collected from mobile phones. Asselbergs et al [41] attempted to predict self-reported mood of 27 participants from metadata of 6 mobile phone indices (phone calls, text messages, screen time, app usage, accelerometer, and phone camera events). Although the accuracy of the models was no greater than models obtained without mobile phone data, the methodology was demonstrated to be technically feasible and to hold promise. The authors recommended that inclusion of more meaningful or relevant features from mobile phone data may be the key to improving prediction.

Interestingly, young people use mobile phones for music listening, fitness, and social networking more than any other demographic [42], and these are among the most effective strategies for optimizing emotional health [43-46]. For example, the frequency of app-switching and the content of social network messages were found to predict depression [43] even prior to its onset [47]. Music listening patterns also appear to predict emotional health [48-50] and given that approximately two thirds of music listening by young people is via mobile devices such as mobile phones [31], it is surprising that relatively few apps have attempted to use music for this purpose [27]. Vocal expression too has been found to be a useful index of emotional state [51,52]. Short voice samples have been found to demonstrate 70% accuracy for simple affect recognition [53]. Monitoring a combination of behavioral indices such as physical activity, online social interactions, and music choices therefore offers a promising means of nonintrusive but sensitive assessment of affective state. Advances in statistical methods available through machine learning also enable powerful analysis of this more complex level of individualized multilevel modeling [52,54].

Another limitation of most mental health apps currently available is that they tend to simplify the emotional well-being spectrum, with positive and negative affect anchors on a unidimensional rating scale. Contemporary conceptualizations of well-being however clearly show that optimal "emotional health and well-being" does not emerge from an absence of affective disorder alone, but also requires a state of positive functioning [2,55,56]. Although positive and negative emotional functioning are correlated, there is substantial evidence that they are orthogonal constructs [57]. Mobile phone technology that differentiates the quadrants created by categorizing according to mental illness or languishing and mental health or flourishing [3,55] is therefore encouraged.

Objective

In this paper, we capitalized on the extraordinary role that mobile phones play in people's lives to develop a tool that has the potential to significantly extend the understanding of emotional health and well-being. The aim of this paper was to describe the design of the mobile phone app, *MoodPrism*, which was developed to monitor emotional well-being in context and

in real time, and provide personalized feedback on the full spectrum of emotional well-being. The paper describes in detail the design and data collection functions of the app, which were incorporated to address major challenges for mental health research and practice, and presents feedback from a small sample of trial users (beta-testers), which tested the functionality and usability of the app.

Methods

Design and Development of the App

MoodPrism was designed and developed in collaboration with a commercial digital creation studio, Two Bulls (Melbourne, Australia). The app was prepared for both the iOS and Android mobile phone platforms and was distributed by the Web-based Apple and Google Play stores, respectively. The term "*MoodPrism*" was selected to reflect its primary purpose of collecting emotional state data across the entire spectrum of emotional health and well-being and converting this into an array of color-coded feedback to the user.

The development of *MoodPrism* involved designing 3 different methods of data collection within the software: (1) automated monitoring of selected online behavior, (2) experience sampling of emotional well-being self-reports, and (3) psychological assessment questionnaires. automated monitoring of selected online behavior, experience sampling of emotional well-being self-reports, and psychological assessment questionnaires. This triangulation of data collection is considered crucial for advancing the measurement of emotional state [58]. As part of the sign-up procedure to the app, permissions for sensitive data had to be obtained. Incentives to continue collecting data over an extended period were also generated.

The development of *MoodPrism* was completed in March 2015. The required forms of data collection were achieved by developing a suite of app components, which were then collated into a cohesive app. The outcomes of this development process are described in the following.

Sign Up

As part of the sign-up procedure for the app, options were offered to users to provide the app with access to social networking and music apps as well as general (postcode) location. These data were then collected continuously and without the need for user input over the month's research period. After sign up and consent procedures, *MoodPrism* administered the initial surveys that could be completed in multiple sittings and required 30-60 min in total to complete. The participants were then requested to use the app for at least thirty days, during which they would be prompted daily to answer a set of short questions, and weekly to complete a short audio recording. If they were unable to respond to daily prompts, *MoodPrism* advised they could complete them at a time of their convenience till midnight that day, or alternatively to ignore them. At the end of the 30 days, users were invited to complete a final set of surveys, which in total required 15-30 min to complete.

Users were incentivized to continue using *MoodPrism* through 3 strategies. First, daily mood and mental health feedback was provided to the user, with additional feedback unlocked after

sustained use ([Multimedia Appendix 2](#)). This promoted engagement by rewarding users and encouraging feelings of achievement, adhering to principles of gamification [59], which is recommended in mental health apps [36]. Second, completion of daily reports as well as the final surveys generated entries into a draw for 1 of the 4 \$AU100 (approximately US \$75) gift vouchers. Third, users were informed that their data were contributing to research into the value of mobile phone apps for monitoring mental health and well-being.

Automated Monitoring

MoodPrism acted as a portal for data accessed via several mobile phone sensors and apps. Two validated predictors of emotional state change were targeted: music use and web-based social network site activity. As a part of the sign-up process, users were invited to give permission for the app to access Facebook, Twitter, the user's music library, and location (postcode only).

Facebook, Twitter, and music use data were collected once every 24 h, and the information collected is provided in [Multimedia Appendix 1](#). Data were accessed from Facebook and Twitter through their relevant application programming interfaces (APIs). This allows third-party access to selected data collected by both Facebook and Twitter. Facebook and Twitter content was analyzed automatically and locally on the user's phone using several linguistic dictionaries from the Linguistic Inquiry and Word Count (LIWC) [60]. Summaries were obtained for frequencies of emotion words, which were supplemented with a range of emoticons and Internet slang expressions for emotions. Social words and personal pronoun counts were also obtained. A word count for the target categories in the dictionary was extracted and these counts were uploaded to the server. This was repeated every 24 h to collect the posts that occurred across the duration of *MoodPrism* use. The post content temporarily stored by *MoodPrism* was then deleted.

Experience Sampling

MoodPrism utilized ESM to deliver a short set of questions to users daily ([Figure 1](#)). Prompts were delivered at a quasi-random time between user-defined hours (eg, 9:00 am-9:00 pm) for 30 days.

The questions captured a real-time assessment of the user's emotional well-being, event-related experiences, and their context. Emotional state questions comprised 4 questions on psychological illhealth (depression and anxiety), 4 on emotional state (positive and negative affect, arousal, and control), and 4 on positive functioning (social connection, motivation, meaning, and self-esteem). Positive and negative event-related experiences were assessed by the type of event experienced and a rating of the event's affective strength (from "slightly" to "extremely positive or negative"). The type of event was selected from a range of options drawn from stressor event questionnaires [61-65] and modified as a short list of the most common event domains (eg, school or work, physical health, material possessions, or social experience domain). Context was assessed via 2 questions, 1 for social context (who the user was with at the time of the report) and environmental context (where they were at the time of the report). Specific questions are given in [Table 1](#).

In addition, a weekly prompt was delivered that requested a short voice recording to serve as an implicit measure of emotional state [51,53]. Users were prompted to read a standardized piece of text at the start and the end of the recording, and within that window to describe freely how they were feeling at that time.

Psychological Assessment Questionnaires

A number of questionnaires were available for completion at the onset of the app use, providing baseline measures of emotional well-being as well as data on potential moderators or confounding variables (see [Figure 2](#)). These questionnaires were categorized into survey "blocks" and displayed on the *MoodPrism* homescreen until their completion. This served to organize the questionnaires into manageable chunks for users to complete in their own time. A subset of these questionnaires was also delivered at the end of the month-long period to enable assessment of whether the app may have affected the well-being measures. A description of these questionnaires was provided in [Table 2](#).

Figure 1. Screen shots from app showing experience sampling method.



Figure 2. Screenshots showing examples of longer psychological questionnaires.

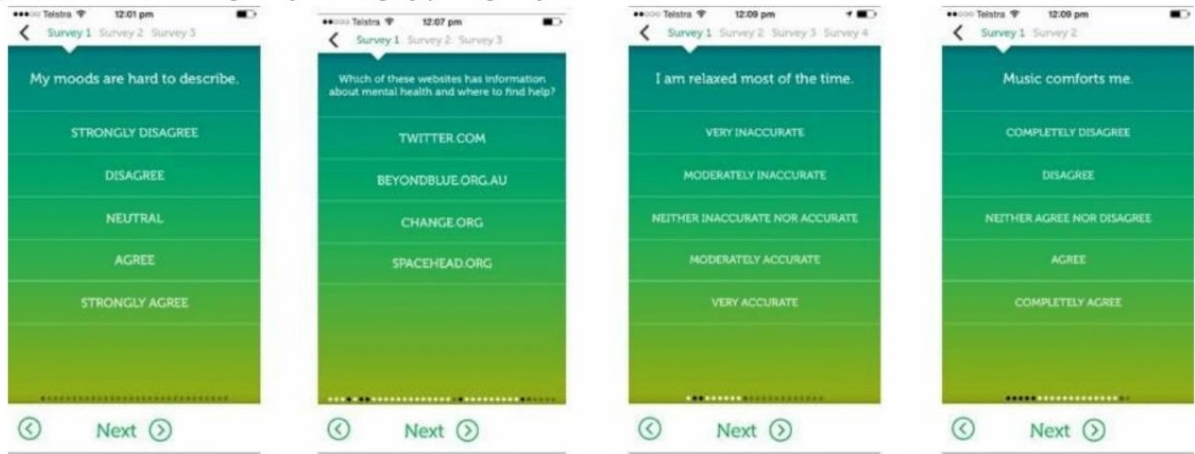


Table 1. Qualitative feedback: questions guiding qualitative feedback forums.

Broad question	Prompts
Was the app easy to use?	Privacy issues (eg, social networking sites) Was it clear to you why you were providing the information that you did? Why did you opt-in or opt-out of connecting your social media accounts? What things would be an incentive to opt-in? Can you imagine anyone using the app without incentives? Who do you think would benefit from using it? Was it clear to you that you were earning entries into a draw to win an iPad? Was it clear how the prize entries were being awarded? Did this consciously motivate you to use the app? Were the colors or emoticons used in the mood feedback helpful?
How did you find the daily prompts?	Did they get in the way at all? Were significant events captured? What kind of event did you feel was appropriate to report (major, minor, or both)?
How did you find the feedback?	Mood feedback Did you notice yourself paying more attention to the way you feel than usual? When you started using the app, was it made clear that reporting your mood could improve your mental health and well-being? Surveys Mental health info or contacts – did you explore any of these? Were they useful? Did you ever find the overview upsetting or negative?

Table 2. Sample feedback provided by beta-testers.

Theme	Sample responses
Positive feedback	
Aesthetically pleasant	It looks nice!
Easy to use	Seamless and smooth to use
Daily reports quick to complete	Simple set of responses takes only a few minutes daily – easy to use daily
Feedback useful and specific	Targeted questions give specific feedback about links between mood and daily activities Colored display of mood was useful representation [sic] Liked unlocking of content - motivated to keep using Feedback was not upsetting
Good to be able to get feedback about how feelings change daily	The ease of the app and being able to check in how exactly I'm feeling at a certain time
Negative feedback	
Wording of some questions confusing	Many questions in the introductory questionnaires are confusing double-negative repeats of previous questions, combined with putting negative responses near the top (where you expect positive ones) is confusing. I've never been irked when people expressed ideas very different from my own: "Yes or No". Is it possible to put Agree or Disagree instead?
Some content can make you feel negative	Quite morbid things in the list of "most negative thing to happen to you today" -- makes me imagine some pretty terrible rare events like "death of a loved one", etc. -- not a great thing to remind someone with depression to think about on a daily basis. / Many questions are quite negative like this -- you think about how stressed, worried, out of control, etc. you are -- creates a major disincentive to participating -- they're not things you want to dwell on when you're depressed.
Feedback clarity	The summary information for tracking well-being across times seems simplistic. For example, if I was in a good but deactivated mood, it said I was "on my way to thriving" - but of course it's not healthy to be highly activated ALL the time. The other thing I thought could be made clearer is what the numbers on the main screen mean - they're all different colors for the different days of the month but not sure what those numbers or colors mean
ESM functionality	There are a couple of categories I felt were missing when logging the things that happened today. On the "who are you with" screen, the option of "partner" would be useful. The "won something" category in the positive events screen was less useful. No positive event option for work
Privacy or information issues	Need trust in the app to give permission for social media sharing. So should give permission later on, perhaps after surveys, after built trust in app after some use Location information should be clarified to be postcode, not specific GPS point
Installation issues	Hard to download

Feedback

The final design feature of *MoodPrism* was the provision of a range of feedback to the user on their emotional well-being and mental health. This feedback was organized in consultation with the Australian mental health organizations *beyondblue* [66] and headspace [67], research literature on mental health and well-being, and expert advice on currently available mental health apps.

The feedback was available at several stages (see [Multimedia Appendix 2](#)):

- On the completion of a survey block, users were provided a summary of their general score on one of the surveys within that block.
- On completion of each daily report, users were provided with a color-coded brief description and custom emoticon representing their emotional state on that day. Weekly and

monthly overviews were also available when multiple ESMs were completed.

- On completion of 1 week's worth of ESMs, "positive mental health" data provided individualized feedback (based on their positive health responses), which included links to positive health websites and apps.
- On completion of 2 weeks' worth of ESMs, depression and anxiety data were collated to provide individualized feedback on mental illness risk (based on their PHQ-4 responses). Recommendations and supporting links to mental health websites or contacts were also provided, as well as advice suitable to the user's emotional functioning over the past 2 weeks.

Database Security and Storage

With such extensive and potentially identifiable information being collected by *MoodPrism*, data storage and data security became a major priority. The following considerations were

made regarding data storage in adherence with industry and University [68] standards, the *Privacy and Data Protection Act 2014*, and the *Guidelines for Ethical Practice in Psychological Research Online* as outlined by the British Psychological Society [69].

Immediately following the survey collection, data were stored on the user's mobile phone prior to being uploaded encrypted into a secure database every 24 h. All data uploaded from the user's phone was stored on an Amazon Web Services server. This database was protected by a firewall and regularly updated security protocols. The data stored were anonymized at the point of upload. All potentially identifiable information was removed from the data and only the device ID was retained (functioning as a randomly generated participant code). Data were only accessible online by authorized users via Secure Shell (SSH), which authenticates server access with digital certificates and encrypted passwords. All communication between authorized users and the server also occurred through HTTPS. This ensured that all information passed between the server and the researchers was encrypted and cannot be accessed or manipulated by a third party.

With regard to social media data, explicit consent to access Facebook or Twitter accounts ("opt-in") was provided by the user. Their social media credentials were stored locally on the phone but were never uploaded to the server. All Facebook and Twitter posts' content were processed locally in the mobile phone's memory and aggregated word counts were generated. Only the aggregate word count was uploaded to the storage server.

Results

The app was initially tested by both the researchers and the app developers for minor issues and bugs. A small convenience sample of independent, nonclinical users (N=11; age range=16-52 years; 4 males, 7 females) was then recruited to test the app to generate feedback on the functionality and usability of the app to the researchers and app developers. They used *MoodPrism* daily over a 30-day period and kept notes of their user experience. Information about the study was provided to the participants and electronic consent was required before the app could be used.

The test sample was invited to provide more intensive qualitative feedback by either Web-based questionnaire (n=5) or via attendance at a focus group session (n=6). Focus group participants also provided quantitative feedback by completing the Mobile Application Rating Scale (MARS) [70]. The MARS is a multidimensional measure for trialing and rating the quality of mobile phone apps, and has demonstrated interrater reliability and internal consistency. All beta-testers were also invited to discuss or provide emailed notes on their user experience. Broad

questions were posed, and prompts were provided where necessary (see Table 1). (No attempt was made to analyze the emotional well-being data from the beta-testers, as the sample was small, and this aim was beyond the scope of the current paper, the primary aim of which was to provide information on the development of the app.)

Themes extracted from the comments provided via the focus group or Web-based feedback are presented in Table 2.

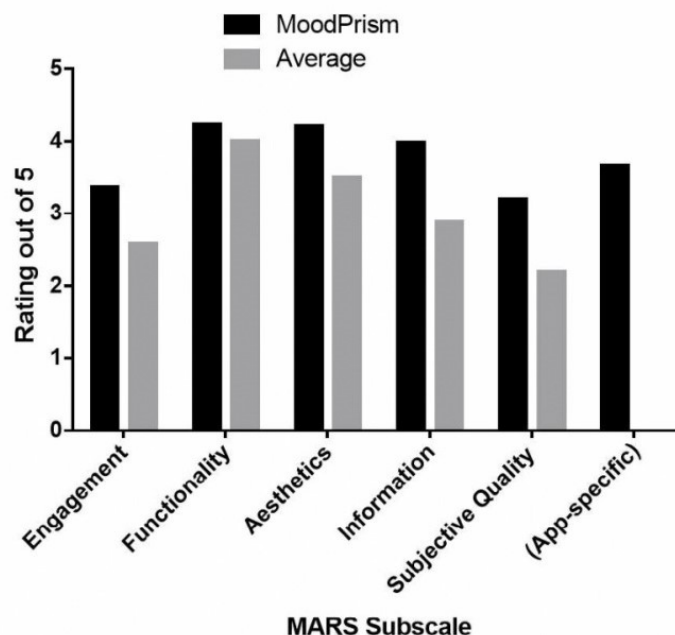
The testing of the app with this sample was approved by the Monash University Human Research Ethics Committee (Approval # CF14/968 – 2014000398). App development was completed in 2015 and tested over June-July 2015. The app was then revised in response to feedback received and the final version of the app prepared. The app was then released on the Google Play (Android) and Apple (iOS) stores. Future publications will report empirical data from this app, with the scope of the current publication limited to the development process only.

Feedback about the functionality and usability of the app was obtained from 11 beta-testers, who completed a standard survey of app usability, the MARS. The results are presented in Figure 3.

MARS ratings for the *MoodPrism* app exceeded the average rating for 50 apps reviewed by Stoyanov et al [70] for each MARS subscale. Highest satisfaction ratings were obtained for items relating to the app's graphics quality (eg, buttons, icons), gestural design (eg, swipes, scrolls), ease of use (eg, clear menus), credibility of the information sources, the layout aesthetics, and increased awareness of mood. Lowest ratings were obtained for entertainment value (eg, fun to use), customization options, likelihood to change behavior, motivations to address mood and interest, and likelihood to recommend to others.

The results from the focus group sessions and emailed responses from all 11 beta-testers are also summarized in Table 2.

The majority of issues identified by the beta-testers were addressed in the final version of the app. For instance, the order of positively or negatively worded options was made consistent across all questionnaires, additional information on how location and social networking data will be used was provided, with reassurance that information collected was deidentified was added, and an explanatory key was provided for interpreting colors and emoticons. The only issues that were not able to be addressed related to the integrity of psychometrically validated questionnaires (and therefore wording could not be altered), inclusion of negative content (which was important to the primary purpose of the app), or installation difficulties (as they related to the trial version only, and would not be present in the Apple and Android Web-based stores).

Figure 3. Quantitative feedback: beta-tester ratings on the Mobile Application Rating Scale (MARS) subscales (N=11).

Discussion

Principal Findings

In this paper, we demonstrated how mobile phone technology could be harnessed to overcome several challenges in current mental health research and practices. Key needs we aimed to meet by developing this tool included the following: real-time monitoring of emotional functioning, assessing the full spectrum of emotional well-being, confidential access to mental health support and information when required, and to reduce obtrusiveness of regular monitoring.

MoodPrism was developed on both iOS and Android mobile phone platforms as an app to monitor emotional well-being in real time. It achieved this using ESM and collection of behavioral data via mobile phone apps (addressing challenge 1). It included assessment of daily positive psychological functioning (or “flourishing” [55]) in addition to more traditional assessment of negative psychological functioning (depression and anxiety) (addressing challenge 2). *MoodPrism* offered users a range of resources and links to enhance mental health literacy and access to professional mental health support, which vary depending on their current emotional functioning (addressing challenge 3). *MoodPrism* also incorporated voice monitoring, social networking site, and music playlist data collection as the first steps toward less obtrusive monitoring of emotional well-being for extended periods (addressing challenge 4)—although extensive algorithmic modeling will be necessary to achieve this goal. In sum, *MoodPrism* successfully responded to 4 key challenges in the emotional mental health domain. A number of important learnings were also achieved during this project, which may be helpful to outline for future researchers considering developing a mental health app [36].

Considerations When Developing a Research-Based Mental Health App

Development of mental health apps is a relatively young field, and the guidelines to support researchers and app developers are not yet widespread. During the development of *MoodPrism*, a number of key issues were identified that could be helpful to researchers developing apps for mental health research and practice. These issues are briefly outlined in the following and then recommendations for consideration in future research are summarized in Figure 1.

First, it is important to recognize the different priorities of app developers and researchers (and mental health practitioners). For example, the *MoodPrism* researchers’ main goals were database integrity, psychometrically sound questionnaires, and ethical administration of sensitive content. The app developers’ main goals were an enjoyable user experience, good design, simple user interface, brief page content, and anonymous data storage. Identifying these goals and coming to an agreement on how they should be prioritized could help design an app that optimizes functionality (and therefore will be used by the participants) with integrity (so that the data are suitable for analysis). With *MoodPrism*, the researchers’ priority to maintain psychometric properties of questionnaires was in conflict with the app developers’ priority for good user interface and design. Administration of long questionnaires was overcome by creating brief checkpoints or “blocks” of surveys to complete, each with a portion of feedback provided as a reward to incentivize completion of long surveys. Similarly, the developers’ database priorities were guided by industry standards for data collection and storage. At times, this conflicted with the researchers’ need to obtain sufficient details; for example, anonymity of social media posts initially prevented the integrity of coding processes from being verified. Coding solutions were eventually achieved,

but considerable delays could have been avoided if the database requirements were thoroughly discussed at the project's outset. When these conflicting priorities were identified, a solution was often achieved that produced the unexpected benefit of optimizing outcomes for both stakeholders. For example, the chunking of questionnaires not only improved the user experience, but also was likely to improve the validity of data as participants were less likely to fatigue, or resort to nonserious responding.

Second, sufficient time should be quarantined at the outset for planning, and at the completion for beta testing and revision. App developers' schedules can overlook the details involved in translating research requirements into the app space, and as a result underestimate the time involved. Database APIs for commercial apps also tend to have simpler output requirements than is often essential for advanced statistical analyses. A failure to identify the more complex necessities of the app's function at the outset can result in over simplistic transition of features into the app, and subsequent delays in revision to meet research needs. Time spent presenting the entire app's contents clearly up front to app developers will help avoid significant delays during development. Time should also be sufficient at the outset for complete storyboarding and wireframing of the app to ensure both parties agree on the app's format and presentation. Aesthetics that work well in commercial apps do not always translate well for research content, which may out of a necessity include lengthier content or inflexible formatting or labeling of items (eg, traditional Likert-type scales in psychological questionnaires). Samples of similar app presentations that are known to work effectively with this type of content should if possible be reviewed and the best features identified. Allowing sufficient time for planning should also ensure that clear milestone dates are set, post which no further changes or additional content can be made by researchers or practitioners until trialing. Ongoing modifications can magnify delays for app developers and confuse versions being delivered. Sufficient time when the app is being finalized is also critical. Users should be allowed a sufficient trial period to allow testing of the app in various contexts, and the schedule should also ensure that they are able to report back both individually, and where

possible as a part of group discussion. Focus groups are invaluable for identifying common themes across users, as well as allowing more singular experiences to emerge.

Third, communication among app developers and researchers or practitioners should be managed centrally. A flexible Web-based platform (such as "Basecamp") provides project management tools such as discussion threads, allocation of tasks, a central file repository, and reminders. Progress of tasks should be monitored regularly and updates provided when item check off is delayed. Clear assignment of tasks avoids tasks being overlooked, and ensures accountability.

Fourth, methods to evaluate the app should be included within the app itself. Commercial apps can contain simple "thumbs up" or star ratings, but this is unlikely to be sufficiently informative for research or practitioner needs. Importantly, it is helpful to obtain assessments of the various aspects of the app, including commercial considerations such as aesthetics and functionality as well as those of central interest to researchers, such as ethics or trust and integrity. Published app assessment measures such as the MARS for health apps should be considered if possible. This will allow standardization and comparability across apps in the mental health space, and to build integrity and an evidence base for improvement of mental health apps over time.

Our experiences researching and developing mental health apps have yielded a number of important practical insights of value to researchers in this field. The issues highlighted during the development of *MoodPrism*, taken together with our recommendations documented elsewhere [36], are summarized in Figure 4.

Potential Applications of *MoodPrism* in Psychological Research

The development of a research mobile phone tool such as *MoodPrism* has enormous potential within the mental health field. Several applications of *MoodPrism* currently in progress are summarized in the following to illustrate the power of flexible, real-time monitoring using this platform.

Figure 4. Recommended steps for researchers engaging in the app development process.

Automated Prediction of Mental Health Risk

One of the most exciting promises for data-rich apps like *MoodPrism* is the development of algorithms which allow automated prediction of emotional health. This modeling could determine the minimum number of constructs required to reliably predict significant changes in emotional well-being, which could be used to inform a more streamlined and userfriendly app. Importantly, it is unlikely that any 1 or 2 variables will provide reliable prediction of such changes; a strength of *MoodPrism* is that it provides a breadth of variables that can be used to answer diverse and important research questions. Various algorithms may be identified, for instance, which discriminate between periods of stability and decline, and *MoodPrism* could then unobtrusively monitor for this change, and provide targeted mental health support to the user. This extends previous research that demonstrates feasibility of such modeling [40,41,71] by utilizing predictors already established in previous research to be associated with mental health (such as online social networking) rather than only those mobile phone sensors that are convenient to record (such as app use and activity).

Improving Emotional Self-Awareness, Mental Health Literacy, and Mental Health and Well-Being Outcomes

Bakker et al [36] detail how mental health apps can be categorized as reflection-, education-, or problem-focused. *MoodPrism* is largely a reflection-focused app aimed at improving a user's emotional self-awareness by encouraging the user to report their thoughts, feelings, or behaviors and then reflect upon them. There is also an education component in *MoodPrism* that provides access to mental health information

and resources. Use of this type of mental health app may therefore result in improvements in mental health and well-being. Kauer et al [72] found evidence that using a mobile phone app that promotes self-reflection through mood tracking can increase ESA and decrease depressive symptoms. Furthermore, rigorous study is needed to explore the mental health benefits of *MoodPrism* and other similar reflection-focused or education-focused apps, as very few randomized controlled trials have been conducted to investigate the efficacy of mental health apps [37]. Importantly, mobile phone technology complements traditional emotion monitoring techniques such as CBT-based recording worksheets [73,74], by increasing recording of subtle changes in behavior in real time. The innovative pairing of changes in emotional well-being with rapid delivery of mental health information has the potential to improve a user's access to relevant resources such as Web-based health portals (eg, eheadspace, eHub), or local GPs when it is needed [75-77].

Leveraging Behavioral Data on Social Media to Gain Insight Into Mental Health and Social Context

Users of social networking sites leave rich digital traces of their social behavior, which includes the structure of their friendship networks and the written interactions between connections [78-80]. The quality of interactions on social network service (SNS) has been shown to hold important relationships with mental health. Positive interactions are associated with better mental health outcomes, and negative interactions may exacerbate mental illness [81-83]. However, how certain individual characteristics might lead a user to gain benefit or detriment from their SNS use is yet to be clearly described [84]. This requires access to both SNS data and the administration

of psychometrically sound surveys to profile the users of SNSs. By profiling SNS users and better tapping into the interindividual variation in SNS use, the accuracy of SNS language models for mental health prediction could be improved [85] and some of the conflicting findings around the use of SNS and its mental health impact could be disentangled [85]. Furthermore, apps like *MoodPrism* enable SNS data to be associated in real time with ESM assessments of mood and psychological surveys. Time-sensitive linking of self-reported mood change and emotional expression in SNS posts may also provide evidence to support the use of SNS data and language analysis as a tool for mood and mental health tracking overtime.

Predicting Resilience Patterns to Everyday Significant Events

Event-based resilience research explores individual capacities to maintain healthy psychological functioning in response to naturally occurring stressor events [86,87]. Previous research methodologies use cross-sectionally designed studies and typically rely on retrospective reports [88-90]. These provide only partial snapshots of an individual's capacity for resilient responding and can be subject to recall biases. The collection of *MoodPrism's* daily reports of psychological well-being, as well as the presence or absence of stressor events, is therefore pertinent to advancing event-based resilient research methodologies. Such methodological approaches allow for multiple snapshots in mood responding that, when compiled, create more representative, real-time observation of dynamic fluctuations that occur in an individual's mood responses to stressor events. Such data will permit a more accurate exploration and identification of the heterogeneous mood trajectories that individuals display following stressor

experiences [85,87,91-93]. Favorable patterns of responding, reflecting the maintenance of psychological functioning, can be identified and profiled to explore important factors that discriminate resilient individuals from other groups that reflect less-resilient patterns of responding.

Conclusions

Development of mental health apps such as *MoodPrism* maximize health impact by harnessing the opportunities offered by mobile phone technology. Approximately, three quarters of the US and Australian populations own a mobile phone, and around 3 in 4 of those never leave home without their mobile device [31,94]. People check their mobile phones up to 150 times a day [30], demonstrating that mobile devices offer unprecedented access to everyday behavior. Incorporating evidence-based monitoring of emotional health into routine mobile phone apps can provide a powerful and flexible methodology for increasing personal control over one's own emotional health. Capitalizing on inbuilt tools within mobile phones—such as music players, voice recorders, and social network media—to contribute data further enhances the potential of such apps to sensitively monitor emotional health over extended periods of time, while remaining unobtrusive. People (particularly young people) often find mobile phone technologies more engaging, anonymous, and less stigmatizing than other means of accessing help, and therefore are much more likely to use this methodology [16]. The new technologies described in this paper not only complement traditional approaches or educational tools supporting mental health but also have the potential to enhance their reach by overcoming many of the barriers currently challenging the reliable surveillance of emotional well-being.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Details on 3 forms of data (automatic, experience sampling, and psychological surveys) collected from *MoodPrism*.

[PDF File (Adobe PDF File), 55KB - [mental_v3i4e49_app1.pdf](#)]

Multimedia Appendix 2

Feedback generated by the subjects while using *MoodPrism*.

[PDF File (Adobe PDF File), 594KB - [mental_v3i4e49_app2.pdf](#)]

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Abbreviations

APIs: application programming interfaces
CBT: cognitive behavioral therapy
ESM: experience sampling methodology
LIWC: Linguistic Inquiry and Word Count
SSH: Secure shell
SNS: social network service

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Table 1. Details on 3 forms of data (Automatic, Experience sampling, and Psychological surveys) collected from MoodPrism.

Automated data collection		Experience sampling items		Psychological questionnaires		
Source	Data (downloaded once every 24 h, subject to user permissions)	Target and questions	Source	Questionnaire	Purpose	Source
Facebook	For each post in history (up to last 50): - Date and time of post - Length of message (characters) - Number of words in message - Number of positive, negative, self-pronoun, other-pronoun words - Number of likes - Number of comments - Number of tags - City and postcode (if available) of where posted	Emotional well-being How were you feeling just before you were prompted by this app? (rated on a 5-point scale from "not at all" to "extremely") 1. Nervous, anxious, or on edge 2. Not able to stop or control worrying 3. Little interest or pleasure doing things 4. Feeling down, depressed, or hopeless 5. Active or alert 6. Negative or unpleasant 7. Positive or pleasant 8. In control of what I'm doing 9. Socially connected and supported 10. Motivated, engaged, and interested 11. Life is meaningful and with purpose 12. Feeling good about myself	Drawn from PHQ-4 [59]; 3 dimensional models of affect [60,61]; The WHO* emotional well-being scales (WHO-5) [62]; positive health literature [55]; single item self-esteem measures [63]	At baseline only		
				Demographics	Sample description or Potential moderator or confounding variable	Custom developed
				Life event scale	Potential moderator or confounding variable	[69]
				Multidimensional scale of perceived social support	Potential moderator or confounding variable	[70]
				Social desirability scale	Assessment of reliable responding	[71]
				IPIP	Potential moderator or confounding variable	[72]
				Rosenberg's self-esteem	Potential moderator or confounding variable	[73]
				Barcelona music rewards scale	Potential moderator or confounding variable	[74]
				Technology use survey	Potential moderator or confounding variable	Custom developed except for 1 item drawn from [75]
				At baseline and 1 month follow up		

Twitter	For each tweet in timeline (up to last 50): - Date and time of tweet - Tweet client site or software or app used - Length of message (characters) - Number of words in message - Number of positive, negative, self-pronoun, other-pronoun words - Number of retweets - Number of favourites	Event-related experiences What's the most positive thing that's happened to you in the past 24 h? • Nothing positive happened • Positive social experience (with friends, family, strangers, etc) • Obtained material item (bought or won something, received a gift, etc) • Positive experience at work or school • Positive experience outside of work or school • Positive health or fitness experience • A happy occasion (e.g., birthday, wedding, holiday) • Other (with option to type in detail) What's the most negative thing that's	Items modified from various stressor event questionnaires [64-68]	Emotional self-awareness scale	Evaluation of emotional awareness change	[76]
				Warwick Edinburg well-being scale	Evaluation of well-being change	[77]
				PHQ-9 ^c	Evaluation of well-being change	[78]
				GAD-7 ^d	Evaluation of well-being change	[79]
Music library	For each song in the user's music library - Song Title - Genre - Artist - Album - Last Played - Play count - Rating - Release date - Duration			Mental health literacy questionnaire	Evaluation of mental health literacy change	Vignettes adapted from [80] Additional questions drawn from beyond blue website.
				Brief resilience scales	Evaluation of mental health literacy change	[81]
				Coping self-efficacy scale	Evaluation of mental health literacy change	[82]
At 1 month follow up only						

		happened to you in the past 24 hours? • Nothing negative happened • Negative social experience (with family, friends, strangers, etc) • Loss of valued material item (misplaced, theft, etc) • Negative experience at school or work • Negative experience outside of work or school • Personal health problems (illness, injury, etc) • Health problems of someone close to you (illness, injury, death, etc) • Other (with option to type in detail) Followed by options for all (except "nothing"): How positive or negative was it? • Slightly • Moderately		Feedback questionnaire	Assessment of app quality	Custom developed (although broadly consistent with factors of MARS [®]).
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^cPHQ-9: Patient Health Questionnaire-9

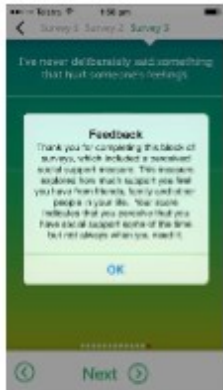
^dGAD-7: General Anxiety Disorder scale-7

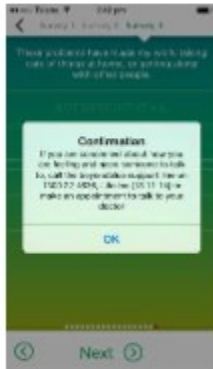
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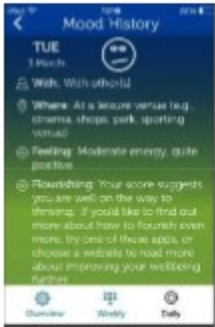
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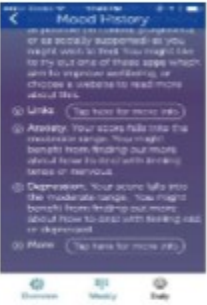
Multimedia Appendix 2

Feedback generated by the subjects while using *MoodPrism*

Feedback type	Trigger	Scoring	Sample
Psychological surveys			
Normative feedback	When block of surveys completed	Scoring based on published guidelines, and feedback based on published normative data). For example: (<45) in the lower range of positive health scores (less than 75% of people) (45-50) on the lower end of the average range of positive health scores (less than 50% of people) (51-56) on the higher end of the average range of positive health scores (more than 50% of people) (>56) in the higher range of positive health scores (more than 75% of people)	

Feedback type	Trigger	Scoring	Sample
Risk assessment			
Prompt to seek mental health support	Red flag high score	PHQ or GAD score above 15 (as per published recommendations)	

Feedback type	Trigger	Scoring	Sample
Experience sampling self-reports			
Visual (icon, colour) and descriptions of emotional state, as well as context information. Reported either in detailed (1 day), brief form (weekly), or overview (complete log) format.	On user request from day 1.	Based on 2-dimensional (arousal and valence) circumplex model of emotion (see below); color coding based on subjective convention.	Overview: 
Description of positive health function	On user request unlocked from day 8.	Scoring based on the sum of ESM items reflecting feelings of: positive, control, social connection or support, motivation or engagement, and meaning or purpose • 5-10: Low score • 11-19: Medium score • 20-25: High score	Weekly view: 
		Further information link options (rotating over time) include Smiling Mind, Healthy Habits, and Buddhify apps, and well-being websites such as "Authentic Happiness" and "Soul pancake"	Daily detail: 

Feedback type	Trigger	Scoring	Sample
Description of depression or anxiety levels	On user request unlocked from day 15.	Scoring based on PHQ or GAD frequency of behaviors over a 2-week period (none, less than half the days, around half the days, every or most of the days) Summed to produce 0-2: low 3-4: moderate 5-6: high Further information link options (rotating over time) include	
Progress toward entries into prize draw	Frequency counts and countdowns	Day 1-7: Counts down to unlocking further mood feedback (positive functioning feedback) Day 8-14: Counts down to unlocking further mood feedback (depression or anxiety feedback) Every day: Counts up number of days completed to yield number of entries into prize-draw.	

Appendix B: Human Ethics Certificate of Approval



Monash University Human Research Ethics Committee (MUHREC)
Research Office

Human Ethics Certificate of Approval

This is to certify that the project below was considered by the Monash University Human Research Ethics Committee. The Committee was satisfied that the proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research* and has granted approval.

Project Number: CF14/968 - 2014000398
Project Title: Monitoring emotional wellbeing via a mobile phone app
Chief Investigator: Assoc Prof Nikki Rickard
Approved: From: 10 June 2014 to 10 June 2019

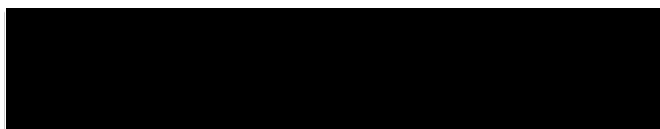
Terms of approval - Failure to comply with the terms below is in breach of your approval and the Australian Code for the Responsible Conduct of Research.

1. The Chief investigator is responsible for ensuring that permission letters are obtained, if relevant, before any data collection can occur at the specified organisation.
2. Approval is only valid whilst you hold a position at Monash University.
3. It is the responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as approved by MUHREC.
4. You should notify MUHREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
5. The Explanatory Statement must be on Monash University letterhead and the Monash University complaints clause must include your project number.
6. **Amendments to the approved project (including changes in personnel):** Require the submission of a Request for Amendment form to MUHREC and must not begin without written approval from MUHREC. Substantial variations may require a new application.
7. **Future correspondence:** Please quote the project number and project title above in any further correspondence.
8. **Annual reports:** Continued approval of this project is dependent on the submission of an Annual Report. This is determined by the date of your letter of approval.
9. **Final report:** A Final Report should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected date of completion.
10. **Monitoring:** Projects may be subject to an audit or any other form of monitoring by MUHREC at any time.
11. **Retention and storage of data:** The Chief Investigator is responsible for the storage and retention of original data pertaining to a project for a minimum period of five years.



Professor Nip Thomson
Chair, MUHREC

cc: Assoc Prof Dianne Vella-Brodrick; Mr Hussain-Abdulah Arjmand; Ms Elizabeth Seabrook; Mr David Bakker



Appendix C: Permission to Conduct Research in Victorian Government Schools



Department of
Education & Training
Strategy & Review Group



2015_002812

Mr Hussain-Abdulah Arjmand



Dear Mr Abdullah-Arjmand

Thank you for your application of 13 July 2015 in which you request permission to conduct research in Victorian government schools titled *Monitoring emotional wellbeing through smartphone technology*.

I am pleased to advise that on the basis of the information you have provided your research proposal is approved in principle subject to the conditions detailed below.

1. The research is conducted in accordance with the final documentation you provided to the Department of Education and Training.
2. Separate approval for the research needs to be sought from school principals. This is to be supported by the Department of Education and Training approved documentation and, if applicable, the letter of approval from a relevant and formally constituted Human Research Ethics Committee.
3. The project is commenced within 12 months of this approval letter and any extensions or variations to your study, including those requested by an ethics committee must be submitted to the Department of Education and Training for its consideration before you proceed.
4. As a matter of courtesy, you advise the relevant Regional Director of the schools or governing body of the early childhood settings that you intend to approach. An outline of your research and a copy of this letter should be provided to the Regional Director or governing body.
5. You acknowledge the support of the Department of Education Training in any publications arising from the research.
6. The Research Agreement conditions, which include the reporting requirements at the conclusion of your study, are upheld. A reminder will be sent for reports not submitted by the study's indicative completion date.

Your details will be dealt with in accordance with the Public Records Act 2014 and the Privacy and Data Protection Act 2014. Should you have any queries or wish to gain access to your personal information held by this department please contact our Privacy Officer at the above address.



I wish you well with your research. Should you have further questions on this matter, please contact
Youla Michaels, Project Support Officer, Insights and Evidence Branch, by telephone on
[REDACTED] or by email at [REDACTED]

Yours sincerely

[REDACTED]

Eleanor Williams
Acting Director
Insights and Evidence Branch

31/08/2015



Appendix D: Participant Information Sheet and Consent Process



USER INFORMATION SHEET

Project: **Monitoring emotional wellbeing via a mobile phone app**

Nikki Rickard

Department of Psychological Sciences

email: nikki.rickard@monash.edu

You are invited to take part in this study. Please read this Explanatory Statement in full before deciding whether or not to participate in this research. If you would like further information regarding any aspect of this project, you are encouraged to contact the researcher via the email address listed above.

What does the research involve?

The aim of this study is to explore whether people's mobile phone behaviours can help us understand or predict their emotional well-being.

If you agree to be in this study, you will be asked to:

- (1) Download the "MoodPrism" app on your smartphone, and leave the app on during the 1 month research period
- (2) Give permission to the researchers to automatically access your mobile phone behaviours (anonymous). The type of data that you will be asked to give researchers access to will include your music use details (e.g., artists and songs, time you listen), social networking information (e.g., which apps you use and for how long, your friend network size, and some anonymous content) and your activity levels and locations. All this information will only be stored ANONYMOUSLY (without any way of linking it to you).
- (3) The app will ask you to complete a set of surveys at the start and end of the 1 month. These surveys will take about an hour in total to complete, but can be broken up and completed at a few different times if you wish. The end surveys will only take about 20 minutes.
- (4) The app will also ask you to answer quick questions (less than 5 minutes each) including a voice recording when prompted at different times on most days during that 1 month
- (5) The app will also deliver some mental health messages to you. This will include information about your moods (which you can access at any time), whether you are flourishing, and after 2 weeks, information about depression and anxiety levels from mental health organizations such as Beyond Blue and Headspace.

We recommend that if you do feel any distress or concern when you are involved in this research, that you contact your doctor or school/university or work's welfare officer to discuss this, or seek help from help services such as:

Headspace Headspace provides mental and health wellbeing support, information and services to young people and their families across Australia. www.headspace.org.au	Kid's Help Line Free 24 hour telephone counselling service for young people aged 5-18. Phone: 1800 551 800	Lifeline Australia Lifeline Australia is a 24/7 phone counselling service. Phone: 13 11 14 Website: http://www.lifeline.org.au/
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Confidentiality

All information we collect from the app about you will be stored anonymously (without your name) on our secure and private servers. We will be publishing results of our study but there will be no way anyone could identify you and your individual information when we do this.

The only time we will ask for a name and contact details is if you wish to go into the draw to win one of the \$AU100 gift cards for being involved in the research. However, your details will be kept totally separate from the other information about you collected by the app, and the two could never be linked.

Storage and use of data

During data collection, data will be stored confidentially on a secure storage site behind a firewall. Only the research team will be able to access the server, via SSH (encrypted tunnel). All communications with the server will be via HTTPS.

Your information may also be used for future research projects by the researchers, but again only anonymously and as group data.

Results

If you are interested in finding out the results of this study, you can contact us at the end of 2017, when all data will have been analysed. Please contact nikki.rickard@monash.edu, and you will be advised where you can access our findings.

Complaints

Should you have any concerns or complaints about the conduct of the project, you are welcome to contact the

Executive Officer, Monash University Human Research Ethics (MUHREC):

Executive Officer

Monash University Human Research Ethics Committee (MUHREC)



Monash University VIC 3800

Consent Screens Presented in the MoodPrism app

Both screenshots show a top navigation bar with 'About', 'Rewards', 'Permissions' (highlighted), and 'Group'.

Screenshot (a): The main text reads 'Please read over the user information before proceeding. You can also email it to yourself for future reference.' Below this is a button labeled 'Read user information sheet'. The text 'I have read this and I want to proceed' is followed by a toggle switch labeled 'YES'.

Screenshot (b): The main text reads 'Please enter your date of birth'. Below this is a date picker showing '28 Jan 2004'. Below the date picker is a button labeled 'Read parent information sheet'. The text 'For parent/guardian' is followed by a toggle switch labeled 'YES'. Below this is the text 'I'm happy for them to do this' followed by a toggle switch labeled 'YES'.

Both screenshots have a bottom navigation bar with a back arrow, the text 'Next', and a forward arrow.

(a) Informed consent process presented to all participants

(b) Added parental consent screen for minors only

Appendix E: Relevant items from daily Experience-Sampling-Reports

Depressive Symptoms:

Two-item Patient Health Questionnaire (PHQ-2; Lowe et al., 2005).

How are you feeling today?	How are you feeling today?	How are you feeling today?
Which of the following best describes how you were feeling just before you were prompted by MoodPrism?	Little interest or pleasure doing things.	Feeling down, depressed or hopeless.
	NOT AT ALL	NOT AT ALL
	SLIGHTLY	SLIGHTLY
	MODERATELY	MODERATELY
	VERY	VERY
	EXTREMELY	EXTREMELY
Next	Next	Next

Stressor Experience:

How are you feeling today?	How are you feeling today?
What's the most negative thing that's happened to you in the past 24 hours?	How negative was it?
NOTHING NEGATIVE HAPPENED	SLIGHTLY
NEGATIVE SOCIAL EXPERIENCE (WITH FAMILY, FRIENDS, STRANGERS, ETC.)	MODERATELY
LOSS OF VALUED MATERIAL ITEM (MISPLACED, THEFT, ETC.)	VERY
NEGATIVE EXPERIENCE AT SCHOOL/WORK	EXTREMELY
NEGATIVE EXPERIENCE OUTSIDE OF WORK/SCHOOL	
PERSONAL HEALTH PROBLEMS (ILLNESS, INJURY, ETC.)	
Next	Next

Appendix F: Psychological Surveys

Note: in app formatting of full surveys is presented to participants as shown above (generally 1 question per screen), and similarly answered using the smartphone touch-screen interface.

Relevant Surveys from the ‘On-boarding’ Survey Battery:

1. *The Social Readjustment Scale* (SRRS; Holmes & Rahe, 1967).

Life is tough, we all have stuff happen in our lives. Select any that have happened to you over the past year:

1. Death of spouse
2. Divorce
3. Marital Separation from mate
4. Detention in jail or other institution
5. Death of a close family member
6. Major personal injury or illness
7. Marriage
8. Being fired at work
9. Marital reconciliation with mate
10. Retirement from work
11. Major change in the health or behavior of a family member
12. Pregnancy
13. Sexual Difficulties
14. Gaining a new family member (i.e. birth, adoption, older adult moving in, etc.)
15. Major business adjustment
16. Major change in financial state (i.e. a lot worse or better than usual)
17. Death of a close friend
18. Changing to a different line of work
19. Major change in number of arguments with spouse (i.e. a lot more or less)
20. Taking on a mortgage (for home, business, etc.)
21. Foreclosure on a mortgage or loan
22. Major change in responsibilities at work (i.e. promotion, demotion, etc.)
23. Son or daughter leaving home (marriage, college, military, etc.)
24. In-law troubles

25. Outstanding personal achievement
26. Spouse beginning or ceasing work outside the home
27. Beginning or ceasing formal schooling
28. Major change in living condition (i.e. new home, remodeling, deterioration, etc.)
29. Revision of personal habits (i.e. dress, associations, quit smoking, etc.)
30. Troubles with the boss
31. Major changes in working hours or conditions
32. Changes in residence
33. Changing to a new school
34. Major change in usual type and/or amount of recreation
35. Major change in church activity (i.e. a lot more or less)
36. Major change in social activities (i.e. clubs, movies, visiting, etc.)
37. Taking on a loan (i.e. car, tv, freezer, etc.)
38. Major change in sleeping habits (i.e. a lot more or less)
39. Major change in number of family get-togethers (i.e. a lot more or less)
40. Major change in eating habits (i.e. a lot more or less, eating hours, surroundings, etc)
41. Vacation
42. Major holidays
43. Minor violations of the law (i.e. traffic tickets, jaywalking, etc.)

2. *The Multidimensional Scale of Perceived Social support (MSPSS; Zimet et al., 1988)*

Pick either a given answer that best represents how you feel.

1 = Very strongly disagree

2 = Strong agree

3 = Disagree

4 = Neutral

5 = Agree

6 = Strongly agree

7 = Very Strongly agree

1. There is a special person who is around when I am in need
2. There is a special person with whom I can share my joys and sorrows
3. My family really tries to help me
4. I get the emotional help and support I need from my family
5. I have a special person who is a real source of comfort to me
6. My friends really try to help me
7. I can count on my friends when things go wrong
8. I can talk about my problems with my family
9. I have friends with whom I can share my joys and sorrows
10. There is a special person in my life who cares about my feelings
11. My family is willing to help me make decisions
12. I can talk about my problems with my friends

3. *Single-Item Self-Esteem Scale (SISE; Robins et al., 2001)*

Compared to others my age and gender..

1 = Very inaccurate

2 = Moderately inaccurate

3 = Neither inaccurate nor accurate

4 = Moderately accurate

5 = Very accurate

1. I have high self-esteem

4. *The Coping Self-Efficacy Scale* (CSE: Chesney et al., 2006)

For the questions in this section, pick either a given answer or a point between given answers that best represents how you feel. When things aren't going well for you, or when you're having problems, how confident or certain are you that you can do the following..

- 1 = Cannot do at all
- 2 = -----
- 3 = -----
- 4 = -----
- 5 = -----
- 6 = Moderately certain can do
- 7 = -----
- 8 = -----
- 9 = -----
- 10 = -----
- 11 = Certain can do

1. Keep from getting down in the dumps.
2. Talk positively to yourself.
3. Sort out what can be changed, and what can not be changed.
4. Get emotional support from friends and family.
5. Find solutions to your most difficult problems.
6. Break an upsetting problem down into smaller parts.
7. Leave options open when things get stressful.
8. Make a plan of action and follow it when confronted with a problem.
9. Develop new hobbies or recreations.
10. Take your mind off unpleasant thoughts.
11. Look for something good in a negative situation.
12. Keep from feeling sad.
13. See things from the other person's point of view during a heated argument.
14. Try other solutions to your problems if your first solutions don't work.
15. Stop yourself from being upset by unpleasant thoughts.
16. Make new friends.

17. Get friends to help you with the things you need.
18. Do something positive for yourself when you are feeling discouraged.
19. Make unpleasant thoughts go away.
20. Think about one part of the problem at a time.
21. Visualize a pleasant activity or place.
22. Keep yourself from feeling lonely.
23. Pray or meditate.
24. Get emotional support from community organizations or resources.
25. Stand your ground and fight for what you want.
26. Resist the impulse to act hastily when under pressure.

Relevant Surveys from the ‘Off-boarding’ Survey Battery:

1. *Patient Health Questionnaire* (PHQ-9; Kroenke et al., 2001)

Over the past 2 weeks, I have been bothered by the following:

- 1 = Not at all
- 2 = Several days
- 3 = More than half the days
- 4 = Nearly every day

1. Feeling down, depressed or hopeless
2. Little interest or pleasure in doing things
3. Trouble falling or staying asleep, or sleeping too much
4. Poor appetite or overeating.
5. Feeling tired or having little energy
6. Feeling bad about yourself — or that you are a failure or that you have let yourself or your family down
7. Trouble concentrating on things, such as reading the newspaper or watching TV
8. Moving or speaking so slowly that other people could have noticed? Or the opposite — being so fidgety or restless that you have been moving around a lot more than usual
9. Thoughts that you would be better off dead or of hurting yourself in some way

2. Items adapted from the *Mobile App Rating Scale* (MARS; Stoyanov et al., 2015)

Rate the degree to which you agree or disagree with the following:

- 1 = Strongly disagree
- 2 = Disagree
- 3 = Neither agree or disagree
- 4 = Agree
- 5 = Strongly agree

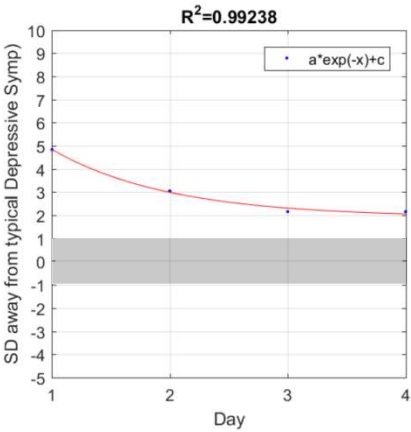
1. I enjoyed using MoodPrism^{*}
2. MoodPrism was interesting^{*}
3. MoodPrism suited people of my age
4. MoodPrism was interactive
5. It was easy to use and understand^{*}
6. It drained my battery
7. It was hard to navigate
8. It had a nice design and feel
9. It did what it said it would
10. It had the right amount of information
11. I felt I could trust MoodPrism
12. Using it got in the way of my everyday activities^{*}
13. The alerts everyday were a hassle^{*}
14. Using it motivated me
15. I would recommend it to people I know
16. Overall I was satisfied with MoodPrism

^{*} Items used in Paper #1

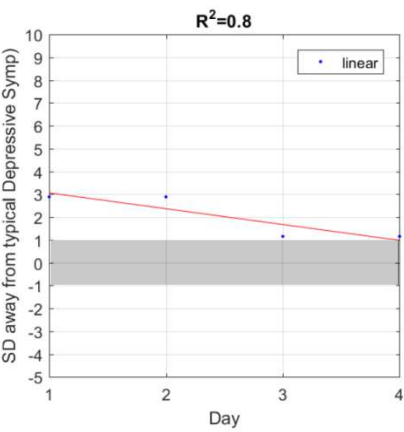
Appendix G: Sample Data Plots

1. Vulnerable Trajectory Group

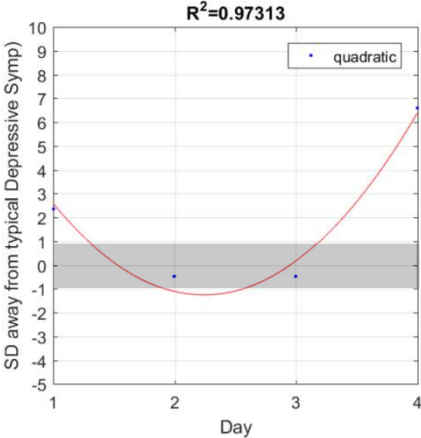
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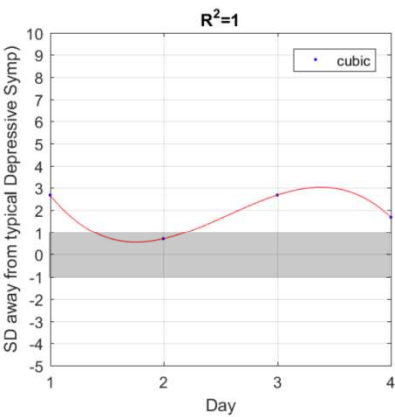
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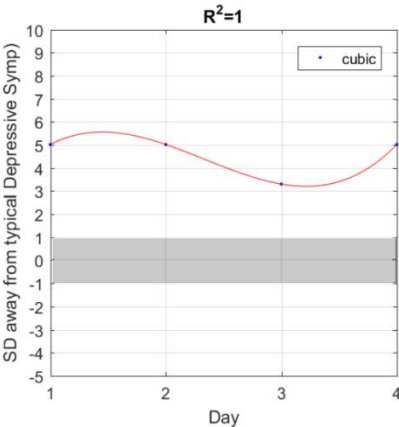
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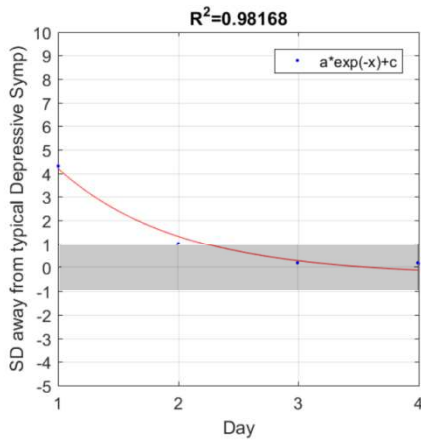


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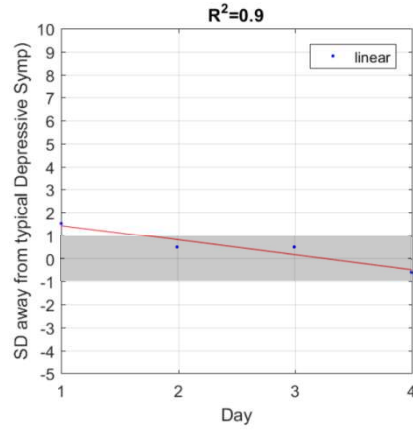


2. Recovery Trajectory Group

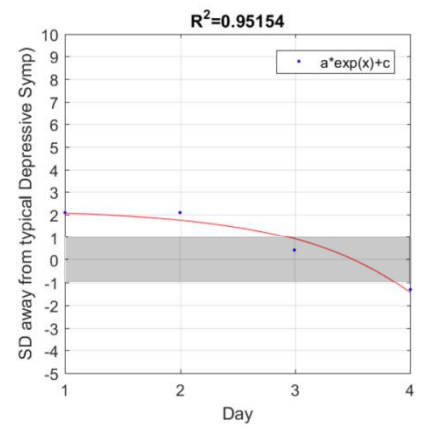
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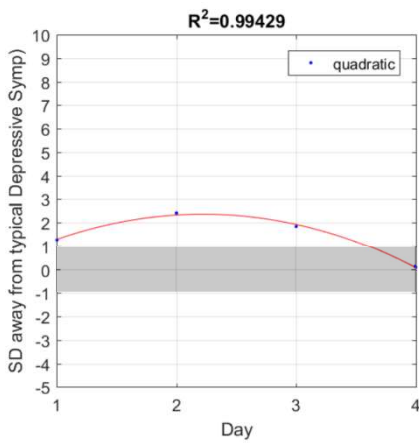
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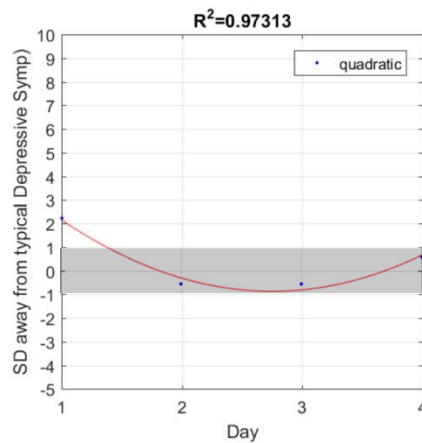
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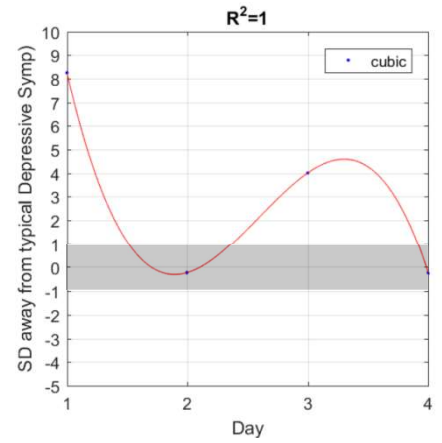
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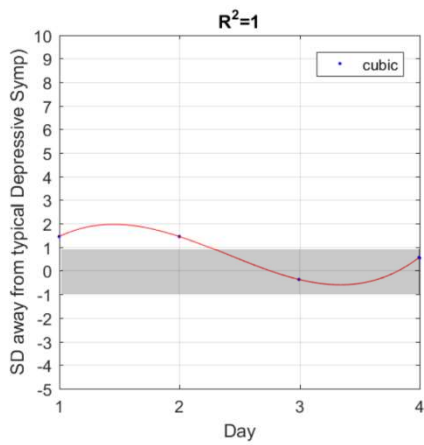
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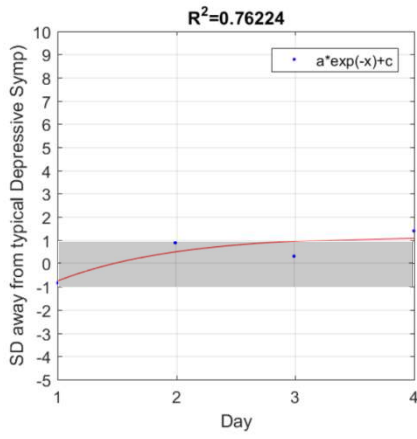


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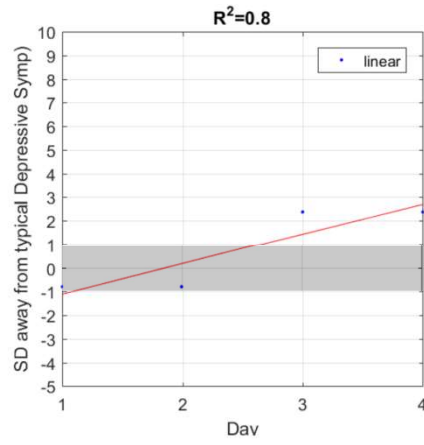


3. Delayed Trajectory Group

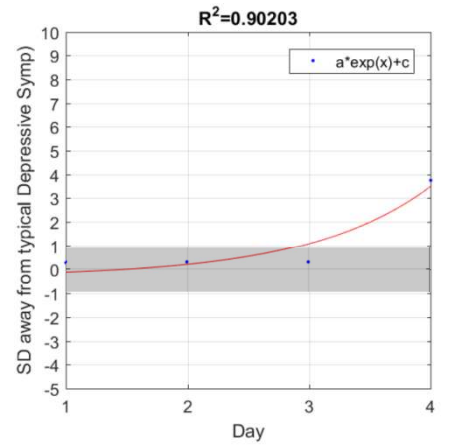
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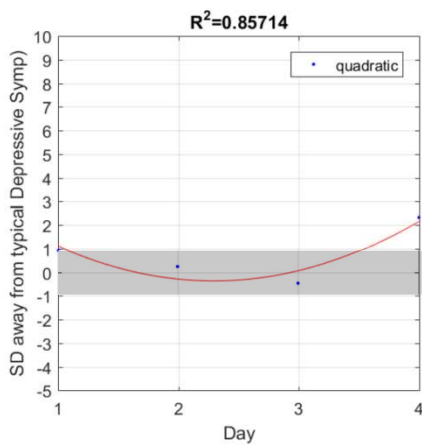
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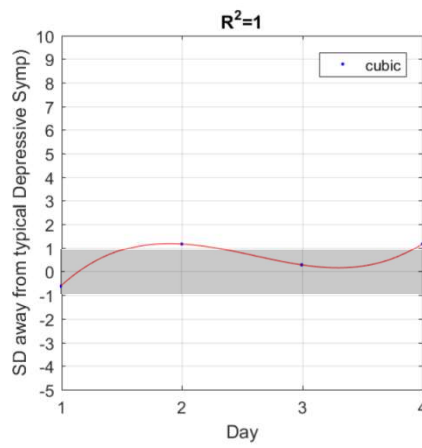
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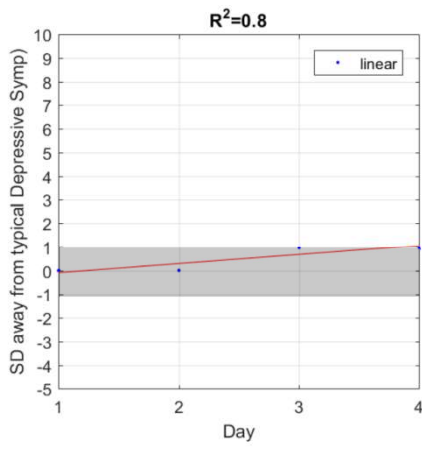


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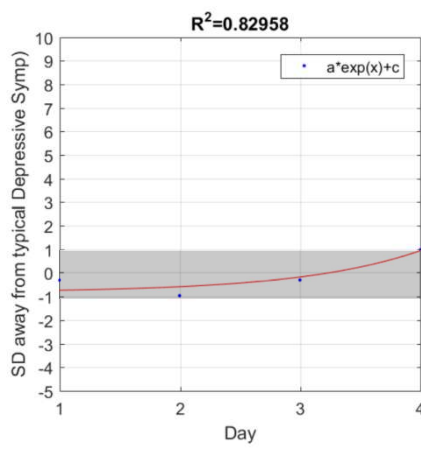


4. Stress-resistant Trajectory Group

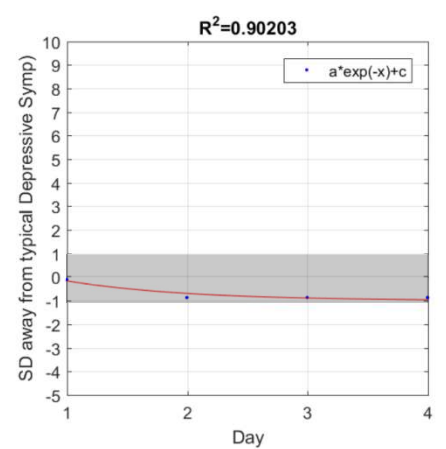
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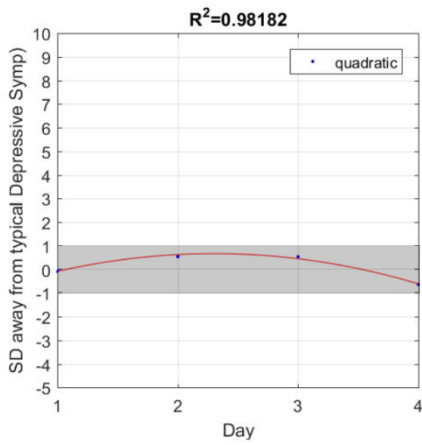
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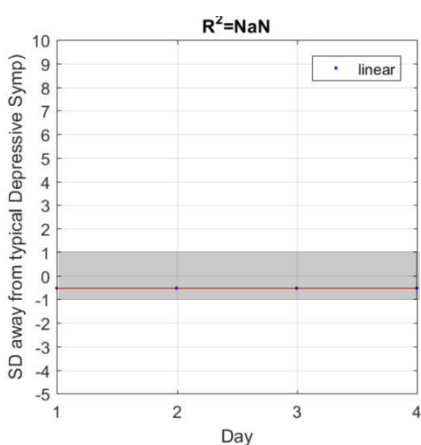
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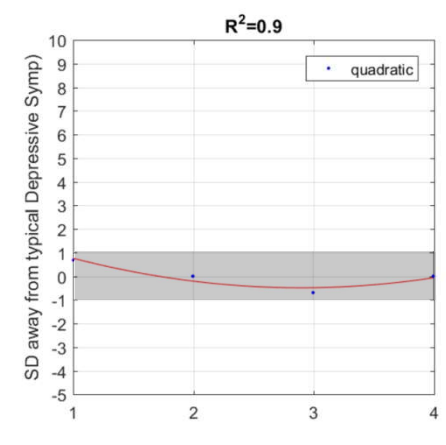
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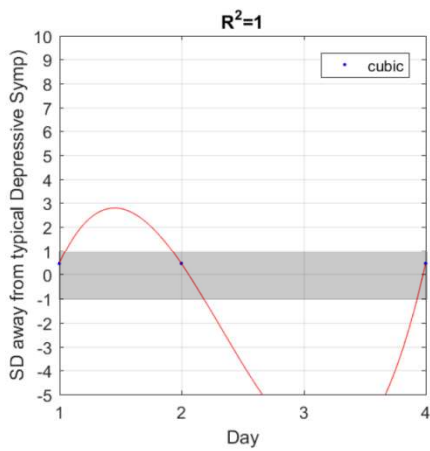
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Pathway #9



Pathway #10



Pathway #11

