DISSERTATION

EMOTION REGULATION IN THE CONTEXT OF DAILY STRESS ACROSS THE ADULT LIFESPAN

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY HELENA CHUI ENTITLED EMOTION REGULATION IN THE CONTEXT OF DAILY STRESS ACROSS THE ADULT LIFESPAN BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

EMOTION REGULATION IN THE CONTEXT OF DAILY STRESS ACROSS THE ADULT LIFESPAN

Emotion regulation plays a crucial role in psychological functioning across the lifespan. This study examined within-person variability and between-person differences in emotion regulation in adults of different ages. Participants (N = 239) filled out daily diaries and were interviewed daily for 30 consecutive days. Using the dynamical systems approach, emotion regulation was conceptualized as the tendency for affect to return towards the equilibrium. The study specifically examined the regulation of affect to return towards equilibrium in response to daily stressors. Results indicated that positive and negative affect showed a self-regulatory pattern, such that daily affect oscillated around the equilibrium and excessive departure from the equilibrium was avoided. For positive affect, the effect of daily stressors became non-significant when the control variable, physical symptoms, was entered in the model. Physical symptoms were associated with a faster return towards equilibrium when positive affect was above equilibrium. Whereas, when positive affect was below equilibrium, physical symptoms were associated with a slower return towards equilibrium. Neuroticism, self-concept incoherence, and age did not predict the regulation of positive and negative affect. The control variable, mean positive affect across 30 days, showed a significant cross-level interaction effect with daily stressors on the regulation of positive affect. Substantively, for individuals with higher positive affect in general, the effect of daily stressors on the regulation of positive affect was weaker. No within-person or between-person variables predicted the regulation of negative affect. Overall, these findings provided partial support that positive affect has a protective effect on emotion regulation. This study extends the current understanding of the regulation of daily affect and raises further questions for future research to test how emotion is regulated and how features of daily stressors are associated with the pattern of emotion regulation.

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CHAPTER 1

INTRODUCTION

Since the growth of research on successful aging in the 1990s, emotion regulation has increasingly attracted interests from lifespan researchers. In the search for evidence of the positive aspects of aging, studies of emotions across the adult lifespan showed promising results. In contrast to general declines in physical and cognitive functions, findings showed that emotional experiences are generally well maintained across adulthood in various areas, such as life satisfaction (Diener & Suh, 1998), psychological well-being (Ryff & Keyes, 1995), positive affect (Charles, Reynolds, & Gatz, 2001; Consedine & Magai, 2006; Mroczek & Kolarz, 1998), and emotion complexity (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000). For emotion regulation in particular, there appears to be gains in increasing emotional control (Gross, et al., 1997; Lawton, Kleban, Rajagopal, & Dean, 1992; Magai, Consedine, Krivoshekova, Kudadjie-Gyamfi, & McPherson, 2006) and sustained levels of positive affect across the adult lifespan (Carstensen, et al., 2000). Emotion regulation has attracted growing interests because of its possible links to coping, social relationships, and physical and mental health (Koole, 2009). From a lifespan perspective, emotion regulation is expected to maintain and even improve with age (Carstensen, 1995).

Emotion Regulation

Despite the increased attention to processes of emotion regulation, Gross (1999, 2008) noted that there is a good deal of confusion and ambiguity in the use of the term “emotion regulation.” Any definition of emotion regulation needs to address two basic questions (Koole, 2009). First, how is emotion regulated? Second, what is being regulated? Gross’ (1998) definition of emotion regulation addresses the first question. He defined emotion regulation as “the processes by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions” (p. 275). In Gross’ definition, emotion regulation concerns the heterogeneous set of strategies that individuals use to regulate their own emotions, which includes a variety of processes that may be automatic or controlled, conscious or unconscious, and effortful or effortless. On the basis of the emotion component targeted for regulation, these strategies may be categorized into five families of emotion regulation strategies, namely, situation selection, situation modification, attentional deployment, cognitive change, and response modulation (Gross, 1998, 2008).

Drawing on Gross’ (1998) definition, Koole (2009) addressed the second question regarding what is being regulated in emotion regulation. Emotion regulation was defined as “the set of processes whereby people seek to redirect the spontaneous flow of their emotions” (Koole, 2009, p. 6). In this definition, emotion regulation concerns three aspects of emotional experiences. First, emotion regulation concerns people’s management of all emotionally charged states, including moods, stress, and positive and negative affect; whereas, other researchers distinguish between different types of emotional experiences, such as moods, emotions, and affect (Larsen, 2000). Koole (2009) noted that constructs closely related to emotion regulation, such as mood regulation, affect regulation, and coping with stress, share substantive construct overlap. It was suggested that studies of emotion regulation may be the most productive to conceptualize emotion regulation in a broader sense to mean the management of all emotionally charged states (Koole, 2009). In the present study, I adopted Koole's (2009) definition of emotion regulation and used the terms mood, emotions, and affect interchangeably.

Second, emotion regulation concerns the spontaneous flow of emotions (Koole, 2009). Thus, the study of emotion regulation is to examine how emotions unfold over time. Individuals engage in constant regulation of their emotions to increase, maintain, or decrease their current emotional states, in the attempt to bring it closer to the emotional state that they desire (Gross, 1998, 2001). Thus, emotion regulation serves important functions for individuals' emotional well-being (Koole, 2009; Larsen & Prizmic, 2008; Zautra, 2003). For example, the regulation of positive and negative affect in a way that positive affect outweighs the negative promotes the satisfaction of hedonic needs, facilitates goal achievement, and optimizes overall psychosocial functioning (Fredrickson, 1998, 2001; Koole, 2009).

Drawing on Koole's (2009) definition, the study of emotion regulation involves the descriptive pattern of the instantaneous flow of emotions. To capture the instantaneous changes in human behaviors, dynamical systems theory has been applied in various fields in psychology, such as the development of psychomotor skills in infants (Thelen & Smith, 1995) and properties of electroencephalography (Babloyantz, 1991). Dynamical systems theory is an area in applied mathematics that employs differential equations or difference equation in the study of time-changing phenomena (Luenberger, 1979). It assumes that the state of a system at a given time depends in part on the previous state of the system (Boker & Nesselroade, 2002). The dynamical systems approach has several advantages. First, the dynamical systems approach captures the state of a system in the moment. Second, this approach enables the examination of the changing relationships of various elements in a system over time (Fogel, et al., 2008). Third, the dynamical systems approach enables answering questions of within-person variability across time. In particular, one application of the dynamical systems approach to psychology is the study of self-regulating systems, such as emotion regulation (Boker & Nesselroade, 2002). Using dynamical systems modeling, this study captured the systematic temporal patterns of emotional changes across a 30-day assessment period.

The third aspect of emotion regulation is the redirection of the flow of emotions. According to Koole (2009), emotion regulation takes place only when an unwanted emotionally charged state occurs. In the present study, it was assumed that daily stressors were associated with the occurrence of unwanted emotional experiences. I specifically examined how individuals redirected their flow of daily emotions to return towards equilibrium in response to daily stressors. I also examined the role of individual difference variables and age differences in the redirection of the flow of emotions.

The working definition of emotion regulation adopted for this study focused on individuals' tendency to redirect their flow of emotions towards equilibrium in response to daily stressors. This working definition is consistent with the idea that individuals engage in emotion regulation in response to environmental demands (Gross, 1999). As such, individuals change their immediate emotional reactions in a way to better meet the perceived demands from the environment.

Emotion Regulation and Age

Across the lifespan, emotion regulation has been considered as an important element in optimal psychological functioning. In one end of the age spectrum, emotion regulation in children has been studied in relation to social competence and behavior problems (Eisenberg & Fabes, 2006; Thompson, 1994). In the other end of the age spectrum, emotion regulation in adults has been studied in relation to various psychological health outcomes, such as conflict resolution (Charles, Piazza, Luong, & Almeida, 2009) and well-being (Phillips, Henry, Hosie, & Milne, 2006). Although emotion regulation plays an important role in psychological functioning across the lifespan, emotion regulation may be increasingly important with age. According to the Socioemotional Selectivity Theory (Carstensen, Isaacowitz, & Charles, 1999), as individuals grow older, they are aware of the increasingly limited time left in their lives and become more selective in seeking out social relationships that satisfy their emotional needs. It is expected that emotional experience, including emotion regulation, improves with age. Empirical findings show that older adults generally reported higher positive affect than young adults (Carstensen, et al., 2000; Charles, Reynolds, & Gatz, 2001).

Nevertheless, the notion that emotion regulation improves with age needs to be carefully evaluated for two reasons. First, as discussed earlier, emotion regulation is differently defined and measured by different researchers (Gross, 1999, 2008). Emotion regulation is more than just feeling good. Emotion regulation involves the redirection of emotional responses in response to environmental demands (Gross, 2008; Koole, 2009). The fact that older adults tend to report higher positive affect than young adults is at best partial evidence to support the notion that emotion regulation improves with age. Second, to say emotion regulation improves, a certain standard is needed to compare different levels or different types of emotion regulation. However, a widely-agreed-upon standard of emotion regulation does not seem to exist (Carstensen, et al., 1999; Labouvie-Vief, 2003).

The present study gave a partial answer to questions related to the development of emotion regulation in adulthood. Emotion regulation is conceptualized as the tendency for individuals' affect to return towards equilibrium. Specifically, I examined emotion regulation in terms of the tendency for affect to return towards equilibrium in response to daily stressors. Dynamical systems modeling was used to examine individual and age differences in emotion regulation in the context of daily stress. This study was limited that results of age differences in emotion regulation may or may not resemble patterns of age-related changes in emotion regulation across the adult lifespan. In addition, the study sample consisted of relatively healthy individuals of predominantly the European-American origin. Findings may not be generalizable to individuals who have chronic medical conditions or mental illnesses. Furthermore, findings may have limited generalizability to other cultural subgroups in the United States and to other cultures.

Significance of the Study

Emotion regulation in adulthood has been increasingly studied over the last two decades (Gross, 2008). However, results of emotion regulation in adulthood are conflicting, in part because emotion regulation has been differently defined by different researchers and has been measured in various ways. The present study added to the literature in two different ways. First, this study examined emotion regulation using a dynamical systems approach in a large age-heterogeneous adult lifespan sample. Earlier studies using the dynamical systems approach examined emotion regulation in age-homogeneous samples of preadolescents (Hoeksma, Oosterlaan, Schipper, & Koot, 2007) and older adults (Bisconti, Bergeman, & Boker, 2004; Boker & Bisconti, 2006). The dynamical systems approach was also applied in a study of affect experience in young and middle-aged heterosexual couples (Butner, Diamond, & Hicks, 2007). Second, the present study used daily diary data over a 30-day assessment period. Repeated measurements of emotional experiences allowed the examination of the flow of daily emotional experiences, rather than snap-shot observations of emotions (Bolger, Davis, & Rafaeli, 2003).

Summary

This study was designed to examine age differences in emotion regulation using the dynamical systems approach. The working definition of emotion regulation adopted for this study focused on individuals' tendency to redirect their flow of emotions towards equilibrium in response to daily stressors. This study had three objectives. First, using dynamical systems modeling, I described the self-regulatory pattern of positive and negative affect. Second, I examined how individuals redirected the flow of positive and negative affect in response to daily stressors. In particular, daily stressors were assumed to be associated with unwanted emotional experiences and individuals sought to redirect the flow of emotions towards the equilibrium. Third, I examined the role that individual difference variables and age played in the redirection of the flow of positive and negative affect in response to daily stressors.

CHAPTER 2

REVIEW OF THE LITERATURE

Emotion regulation is central to individuals' emotional experience throughout the lifespan. In infants and children, a large body of studies has examined the influence of intrinsic (e.g. temperament) and extrinsic factors (e.g. caregiver support) on the development of emotion regulation (Calkins & Hill, 2007; Eisenberg & Fabes, 2006; Holodynski & Friedlmeier, 2006). Compared to studies in children, studies of emotion regulation in adults have a relatively short history. Findings revealed that adults exert some degree of influence in most emotions they experience and express (Gross, 1998; Gross & Thompson, 2007; Koole, 2009). Studies also found individual differences and contextual effects on emotion regulation in adults (John & Gross, 2007; Shaver & Mikulincer, 2007). Furthermore, recent theories postulate that emotion regulation continues to develop throughout the adult lifespan (Carstensen, Fung, & Charles, 2003; Carstensen, Pasupathi, Mayr, & Nesselroade, 2000; Labouvie-Vief & González, 2004; Labouvie-Vief & Medler, 2002).

In the following, I will first review the pertinent literature on emotion regulation in adults, with a particular emphasis on the conceptualization of emotion regulation as a self-regulatory process. Second, I will review the contextual effects on emotion regulation. Third, I will give a review on the recent interest in emotion regulation in the lifespan development literature. Fourth, four theoretical perspectives on emotion regulation are presented and discussed. These theories include the Broaden-and-Build

Theory, the Dynamic Affect Model, the Socioemotional Selectivity Theory, and the Dynamic Integration Model. Fifth, I will review the contextual and individual variables examined in the present study, namely, daily stressors, neuroticism, self-concept incoherence, and age. Finally, I will discuss the advantage of using the daily diary method in the examination of emotion regulation.

Emotion Regulation

Despite the recent growth of research in emotion regulation in adults, the term "emotion regulation" is ambiguous and is differently used by different researchers (Gross, 1999; Gross & Thompson, 2007). For instance, emotion regulation can mean "regulation by emotions," which refers to how emotions regulate something else, such as thoughts or behaviors. Emotion regulation can also mean "regulation of emotions," which refers to how emotions are themselves regulated (Gross, 1998). In the present study, I used the term "emotion regulation" to mean the "regulation of emotions."

It is also important to note that beyond the general emphasis on the modulation of emotion-related experiences over time and across situations, researchers define and measure emotion regulation in markedly different ways (Diamond & Aspinwall, 2003). A common definition of emotion regulation is the experience of a high level of positive affect and a low level of negative affect (Charles & Carstensen, 2007; Gross, 1998). Erber and Erber (2000), however, questioned the assumption that individuals are only hedonistically motivated in how they manage their emotional experiences. Despite the importance of hedonic needs, the hedonistic approach does not account for the full range of emotional experiences. For instance, when strong situational norms call for appropriate emotional responding (e.g., when individuals attend a funeral), individuals may down-regulate their positive affect and up-regulate their negative affect (Koole, 2009).

Some studies of emotion regulation have addressed a wider range of emotional experiences than simply focusing on hedonistic needs. Carstensen and colleagues (2000) examined poignancy – the co-occurrence of positive and negative affect. Instead of focusing on a high level of positive affect and a low level of negative affect, poignancy refers to the experience of both positive and negative affect at the same time. However, these studies of emotion regulation share a common problem, namely, that the modulation in emotional experiences is not explicitly examined. The levels and the co-occurrence of positive and negative affect measure the state of emotional experiences, not the modulation of emotion, either, the change from one state to the next state of emotional experiences. The examination of the levels and co-occurrence of positive and negative affect may at best be indirect measures of emotion regulation.

According to Koole (2009), emotion regulation takes place only when an unwanted emotionally charged state occurs (e.g., the experience of negative affect in response to a stressor) and the study of emotion regulation is to examine the temporal unfolding of emotional responses from a less desirable to a more desirable emotional state. Individuals regulate the experience of emotions to increase, maintain, or decrease their initial emotional states, in the attempt to bring it closer to the emotional state that they desire (Gross, 1998, 2001). For instance, Carstensen and colleagues (2000) operationalized emotion regulation as the maintenance of positive affect to be higher than individuals' idiosyncratic means and the maintenance of negative affect to be lower than individuals' idiosyncratic means. These authors studied the probabilities of four conditions: (a) maintaining high positive states from one measurement occasion to the next; (b) maintaining low negative states from one measurement occasion to the next; (c) moving from low positive states to high positive states; and (d) moving from high negative states go low negative states. Studies that take into account the temporal component of emotional experiences, such as the stability and change in emotional states, seem to give more valid measures of emotion regulation, compared to studies that measure the levels and co-occurrence of emotional experiences.

To study the temporal unfolding of emotional responses, Koole (2009) made a distinction between emotional sensitivity and emotion regulation. When individuals encounter an emotion-eliciting situation, individuals' primary emotional response (first emotional reaction) and secondary emotional response (subsequent emotional reaction) may differ in valence and intensity. The primary emotional response – how individuals first react to an emotion-eliciting situation – may be termed emotional sensitivity. In other words, emotional sensitivity refers to the onset of an emotional response. In contrast, emotion regulation concerns the management of emotional experiences, such as the primary emotional response. Thus, the secondary emotional response may be termed emotion regulation and refers to the offset of an emotional response (Koole, 2009). Koole (2009) also noted that emotional sensitivity and emotion regulation are fundamentally distinct emotional experiences and may display different developmental trajectories.

Emotion Regulation as a Self-Regulating Process

One way to study emotion regulation and take into account the temporal unfolding of emotional experiences is to conceptualize emotion regulation as a self-regulating process (Boker & Bisconti, 2006; Boker & Nesselroade, 2002; Carver, 2004;

Diamond & Aspinwall, 2003). Self-regulation refers to a specific kind of change to bring a certain state in accord with a desired standard (Forgas, Baumeister, & Tice, 2009). Self-regulating processes are prevalent in human behaviors, ranging from the maintenance of body temperature to goal-oriented behaviors (Forgas, et al., 2009). For instance, body temperature is regulated to be within certain upper and lower thresholds and fluctuates around the equilibrium at about 98 ^{o}F. In the present study, emotion regulation was conceptualized as a self-regulating process.

A self-regulating process involves the monitoring of the current state of a system and where information of the current state is used to adjust future levels of the system (Boker & Nesselroade, 2002; Carver & Scheier, 2003). The cruise control system in vehicles is an everyday example of a self-regulatory system. The function of a cruise control system is to maintain the constant speed of a vehicle. A cruise control system works by monitoring the current speed of the vehicle. Comparing the current speed to the set speed, the cruise control system accelerates the vehicle when the current speed is below the set speed. In contrast, the cruise control system decelerates the vehicle when the current speed is above the set speed. Thus, the vehicle speed is maintained at the set speed within certain upper and lower thresholds. In the present study, I conceptualized emotion regulation in terms of a self-regulating system. Similar to a cruise control system, it was assumed that individuals' positive and negative affect fluctuate around their own equilibrium. It was also assumed that individuals monitor their positive and negative affect and try to maintain their positive and negative affect at the equilibrium, such that excessive departure from the equilibrium is avoided.

I examined the instantaneous flow of positive and negative affect in an adult lifespan sample for 30 consecutive days. I used dynamical systems model to capture the ebb and flow of daily positive and negative affect. Specifically, I modeled the pattern of the flow of daily positive and negative affect using the damped oscillator model (Boker & Bisconti, 2006) and the coupled oscillators model (Boker & Laurenceau, 2006). A damped oscillator model can be used to capture the changes in one self-regulating system (Boker & Bisconti, 2006; Boker & Nesselroade, 2002). In contrast, a coupled oscillators model can be used to capture the changes in two self-regulating systems, such that changes in one system may influence changes in the other system. Details of modeling the temporal pattern of positive and negative affect will be discussed in more detail in the Method chapter.

Emotional Regulation and the Context

The context in which emotion regulation takes place needs to be taken into account because individuals engage in emotion regulation in response to environmental cues and by drawing on certain resources (Gross, 1999). Contextual variables include both environmental resources that enable emotion regulation and environmental demands that challenge individuals' abilities to regulate their emotions. Individuals elicit context-appropriate emotional responses, as a result of the perceived demands and the resources available from the environment (Gross, 1999; Koole, 2009). In a laboratory study, compared to the control group, individuals instructed to suppress their emotions during film viewing were able to inhibit their facial and somatic expressions of emotions. In addition, individuals in the suppression and control groups already showed different physiological activities during the instructional period before film viewing. This showed that individuals prepared themselves to inhibit their emotional expressions in accord to environmental demands (Gross & Levenson, 1997).

The examination of contextual variables in adults' emotion regulation, however, is complicated by the fact that adults tend to have a certain extent of control over the selection and modification of their immediate naturalistic environments. Contextual and individual difference variables may not be easily teased apart in studies of emotion regulation in natural settings, as opposed to laboratory studies, because individuals select and modify their environments to fit their personal needs and goals. For instance, evidence showed that stressful events have an impact on emotional experiences in both natural and laboratory settings (Zautra, Reich, Davis, Potter, & Nicolson, 2000). Whereas the stressful condition in the laboratory was manipulated by experimenters and randomly assigned to participants, stressful conditions in natural settings were in part manipulated by individuals themselves. Specifically, individuals may differ in how they are able to avoid stressful situations (Almeida, 2005). When a stress-eliciting event happens, individuals may also differ in their appraisal of the situation, which in part depends on their psychological resources. Therefore, self-report of stressful events in naturalistic studies represents a product of contextual variables and individuals' resilience and vulnerability factors (Almeida, 2005).

To empirically tease out the contextual variable (i.e., stressors) in the stress process in natural settings, Almeida (2005) noted that the within-person approach used in daily stress research allows the separation of the relatively stable personality and environmental variables from stressors, the time-varying contextual variable. Stressors are contextual variables that elicit stress. In contrast, stress is the psychological and physiological responses that individuals experience in reaction to stressors. Thus, stress is defined by the stimulus-response relationship, not the stimulus or response alone (Lazarus, 1993; Lazarus & Folkman, 1984). Using the within-person approach where stressors are measured repeatedly over time, daily stress research enables researchers to rule out stable personality and environmental variables as alternative explanations for the effect of stressors on well-being (Almeida, 2005). Daily stress research also enables the examination of the effect of stressors on changes in individuals' emotional lives over time. This present study adopted the within-person approach and examined the effect of the contextual variable, daily stressors, on emotion regulation in the natural setting.

Taking the perspective that emotion regulation is a self-regulating process, the working definition of emotion regulation adopted for this study was the modulation of the spontaneous flow of positive and negative affect, such that positive and negative affect are redirected towards equilibrium and excessive departure from equilibrium is avoided. Emotion regulation was operationalized as the tendency of individuals' affect to return towards equilibrium. In addition, emotion regulation was studied in the context of daily stressors. It was assumed that daily stressors are usually associated with an undesirable emotional state. That is, daily stressful events were assumed to diminish a person's level of positive affect and to increase the level of negative affect. Thus, emotion regulation was examined in terms of the redirection of the flow of positive and negative affect in response to daily stressors.

Emotion Regulation and Lifespan Development

Emotion regulation has increasingly become a topic of interest in adult development and aging (Carstensen, et al., 2000; Gross, 1998; Labouvie-Vief, 2003). As discussed earlier, indirect evidence measuring the levels of positive and negative affect indicates that emotion regulation may improve with age (Carstensen, et al., 2000; Charles, Reynolds, & Gatz, 2001). However, few studies have directly examined age differences in the modulation of affect. One exception is Carstensen and colleagues' (2000) study that found older adults showed better emotion regulation than young and middle-aged adults, as measured by the greater stability of high positive affect and low negative affect. It is particularly perplexing that compared to young adults, older adults generally report better emotional experience as measured by higher positive affect and lower negative affect (Charles, et al., 2001; Mroczek, 2001), even though older adults are at a higher risk for the development of health problems and the loss of loved ones. Recent studies in adult development and aging seek to identify risk and resilience factors in emotional functioning across the adult lifespan (Almeida & Horn, 2004; Ong, Bergeman, Bisconti, & Wallace, 2006; Zautra, et al., 2000). For instance, Kessler and Staudinger (2009) found that compared to young and middle-aged adults, older adults reported better perceived emotion regulation under conditions of difficulties. Perceived emotion regulation is also found to be a resilience factor in the maintenance of emotional functioning in old age. Thus, it is important to examine age differences in emotion regulation. In particular, direct evidence from the examination of the modulation of emotions, rather than perceived emotion regulation, is needed to verify age differences in emotion regulation.

Theoretical Perspectives on Emotion Regulation

Several theoretical perspectives have incorporated individual difference variables and stress in research on emotion regulation in adults. Some of these theories incorporate the lifespan approach and are particularly important in the speculation of the development of emotion regulation across the adult lifespan. These theoretical perspectives are: the Broaden-and-Build Theory, the Dynamic Affect Model, the Socioemotional Selectivity Theory, and the Dynamic Integration Theory. It is important to note that the definitions of emotion regulation used in these theories largely focus on the levels of positive and negative affect, rather than the modulation of positive and negative affect over time.

Broaden-and-Build Theory. The Broaden-and-Build Theory postulates that positive and negative affect have distinct but complementary adaptive functions (Fredrickson, 1998, 2001). The proper balancing of positive and negative affect is thus essential to enable adaptive functioning and emotional well-being. Specifically, the Broaden-and-Build Theory conceives positive affect as being more than a marker of human flourishing. Indeed, positive affect is thought to produce flourishing by broadening individuals' thought-action repertoires. Positive emotional experiences expand individuals' range of cognitions and behaviors, which enable individuals to build on their physical, intellectual, and social resources (Tugade & Fredrickson, 2004). In turn, the building-up of their enduring personal resources enables individuals to better cope with future stress and challenges.

In contrast, negative affect serves a different function. Negative affect narrows individuals' momentary thought-action repertoires, which may be beneficial at times of threat (Fredrickson & Joiner, 2002; Tugade & Fredrickson, 2004, 2007). In a life-threatening situation, the narrowed range of cognitions and behaviors channels individuals to a quick and specific action for direct and immediate benefits (i.e., fight-or-flight response). However, despite the benefits that negative affect may bring, the cardiovascular and immunological reactivity associated with negative affect can be damaging to health (Fredrickson, Mancuso, Branigan, & Tugade, 2000). Therefore, the regulation of negative affect is necessary to maintain and optimize overall functioning. In particular, positive affect is demonstrated to undo the potentially health-damaging cardiovascular reactivity following negative affect (Fredrickson, et al., 2000). Hence, effective regulation of positive and negative affect is essential to optimize individuals' health and well-being (Fredrickson, 2000). Furthermore, empirical findings have shown that individuals differ in their ability to effectively regulate positive and negative affect in the face of stressful situations. For example, individuals who tend to have higher overall positive emotionality are also better able to bounce back from negative emotional experiences (Tugade, Fredrickson, & Barrett, 2004).

In summary, the Broaden-and-Build Theory is mainly concerned with the level of positive and negative affect that individuals experience. Optimal emotion regulation is conceptualized as the maintenance of a high level of positive affect and a low level of negative affect. This theory focuses on how much positive and negative affect individuals have and elaborates on the effects of positive affect on physical and psychological well-being. In contrast, the Dynamic Affect Model, the second theory that guides the present study, focuses on the structure of emotional experiences and whether that structure varies under different contextual circumstances.

Dynamic Affect Model. According to the Dynamic Affect Model (Reich, Zautra, & Davis, 2003; Zautra, Potter, & Reich, 1998; Zautra, et al., 2000), emotion regulation is by definition influenced by contextual factors. In particular, the degree of association between positive and negative affect is a function of the level of stress that individuals experience. When individuals experience a low or average level of stress, positive affect and negative affect are relatively independent systems. Under stressful situations, however, individuals' psychological resources, such as cognitive resources, are taxed. Individuals need to identify and implement an adaptive response to meet the demands from their environment. Because the maintenance of two separate affect systems requires more cognitive resources, the separate affect systems are merged to simplify response options at times of stress, hence resulting in a greater inter-relatedness of positive and negative affect (Zautra, Potter, & Reich, 1998).

Findings from previous studies have supported the Dynamic Affect Model. It has been found that both life stressors (e.g. disability and bereavement in older adults) and daily stressors (e.g. daily pain level in women with arthritis) have an effect on the degree of association between positive and negative affect. Specifically, a higher level of stress has consistently been shown to be associated with a higher negative correlation between positive and negative affect (Zautra, et al., 2000; Zautra, Smith, Affleck, & Tennen, 2001). That is, under conditions of stress, positive and negative affect are not independent anymore but show a pattern of inverse correlation.

In addition to the within-person variable (i.e. stressors), individual differences have been identified in the degree of association between positive and negative affect in response to stress (Tennen, Affleck, & Zautra, 2006; Zautra, et al., 2001). Individuals differ in their abilities to maintain two separate affect systems at times of stress. In particular, a study of women with fibromyalgia found that formerly depressed and never-depressed individuals differed in the degree of association between positive and negative affect in response to daily pain (Tennen, et al., 2006). Compared to individuals without a depression history, formerly depressed individuals showed a more highly negative association between positive and negative affect on more painful days. This means that non-depressed individuals were better able to maintain the two independent systems of positive and negative affect. In addition, a study of women with arthritis found that individuals with greater mood clarity showed less overlap in their ratings of positive and negative affect (Zautra, et al., 2001). In other words, individuals who believe that they are clear about how they feel are more likely to maintain the independence of positive and negative affect. Therefore, these findings showed that individual differences such as depression history and mood clarity predict individuals' maintenance of two independent affect systems in response to stressful events. Other individual difference variables, such as neuroticism, which is a personality characteristic related to emotional instability, may also predict the co-dependence of positive and negative affect.

Both the Broaden-and-Build Theory and Dynamic Affect Theory address individual differences in emotion regulation. Dynamic Affect Theory, in particular, addresses the varying affect structure under different contextual conditions, such as varying stress and pain levels. However, these two theories do not address potential developmental changes in emotion regulation across the adult lifespan. The Socioemotional Selectivity Theory, the third theory that guides the present study, focuses on the developmental trajectory of emotion regulation.

Socioemotional Selectivity Theory. The Socioemotional Selectivity Theory focuses on the developmental changes in social goals across the adult lifespan (Carstensen, et al., 2003; Carstensen, Isaacowitz, & Charles, 1999). With increasing age, individuals set different priorities in terms of social goals because they are aware that their time left in life is increasingly limited. Social goals involve the motivation of getting to know and getting along with people. Social goals may be categorized into two broad priorities, namely, knowledge acquisition and emotion regulation. In young adulthood, knowledge acquisition takes priority over emotion regulation because young adults are motivated to learn for their successful adaptation and functioning in the future. In contrast, emotion regulation takes priority over knowledge acquisition in older adults and more generally, in individuals with limited future time perspective. As individuals age, they set different priorities because they perceive their time in life is increasingly limited. Older adults are aware of their increasingly shorter future and realize that the emotional satisfaction and meaning from interpersonal and close relationships have priority over the possible gain in knowledge in the future (Carstensen, et al., 1999). Thus, emotion regulation is expected to improve across the adult lifespan when individuals have increasingly limited time. Individuals are expected to increasingly seek to pursue satisfaction and meaning in their social contact as they age.

Empirical evidence has provided partial support for the Socioemotional Selectivity Theory. Individuals tend to prioritize emotion regulation goals over knowledge acquisition goals when they perceive that they have a limited amount of time left (Carstensen & Fredrickson, 1998). However, only a small number of studies have shown that the awareness of limited time leads to better emotional experiences and especially to better emotion regulation (Kessler & Staudinger, 2009). Indeed, studies have found that older adults tended to report higher positive and lower negative affect compared to young and middle-aged adults. Older adults also reported greater stability in maintaining higher positive affect and lower negative affect (Carstensen, et al., 2000).

Nevertheless, a recent study found that when future time perspective was directly measured, the awareness of limited time did not predict the levels of positive and negative affect (Kessler & Staudinger, 2009). Instead, perceived emotion regulation was a statistically significant predictor of emotional functioning.

In conclusion, the Socioemotional Selectivity Theory postulates that emotion regulation improves with age because individuals are increasingly motivated to prioritize their emotional goals over knowledge acquisition goals when they perceive that their time is limited (Carstensen, et al., 2003; Carstensen, et al., 1999). However, the Socioemotional Selectivity Theory is limited to address what emotion regulation means and what modes of emotion regulation are activated. Studies in support of this theory by far tend to associate better emotion regulation with high level of positive affect and low level of negative affect (Charles, et al., 2001). The Dynamic Integration Theory, the next theory that I will review, gives a more detailed account of two broad modes of emotion regulation by describing their functions and cognitive elements.

Dynamic Integration Theory. The Dynamic Integration Theory proposes that effective emotion regulation involves two relatively independent modes: affect optimization and affect complexity (Labouvie-Vief, 2003; Labouvie-Vief & Medler, 2002). Affect optimization refers to individuals' ability to maximize positive affect and dampen negative affect. In the face of losses and decline, affect optimization is an automatic and relatively effortless response. Older adults often display a remarkable capacity to optimize their emotional experiences by maximizing positive and minimizing negative affect (Labouvie-Vief & Medler, 2002). Affect complexity, on the other hand, is the ability to coordinate positive and negative affect into flexible and complex cognitive structures. It involves the coordination and synchronization of feelings in the present with past and future feelings. The hallmark of affect complexity according to Labouvie-Vief (2003) is that it involves elaborate cognitive processing and requires considerable cognitive resources. In other words, affect complexity is integrally linked to individuals' general cognitive processing capacities (Labouvie-Vief & Medler, 2002).

Individuals' growth and decline in cognitive capacities across the adult lifespan potentially alters the degree of complexity of their emotional structures and experiences. As individuals grow up through adolescence into middle-age, their cognitive skills become more mature and they are able to experience more complex emotions. The growth of affect complexity, however, abates in late middle adulthood and a significant decline may occur thereafter (Labouvie-Vief, 2003). Across the adult lifespan, both affect optimization and affect complexity are dynamically linked and are complementary criteria of effective emotion regulation.

Empirical findings have supported the differentiation and independence of affect optimization and affect complexity. In a cross-sectional study, these two emotion regulation strategies emerged as two independent dimensions in principal components analyses (Labouvie-Vief & Medler, 2002). Moreover, results from longitudinal analyses have supported the hypothesized developmental trend in affect optimization and affect complexity (Labouvie-Vief, Diehl, Jain, & Zhang, 2007). Generally, affect optimization has been shown to increase from young adulthood to middle-age with a subsequent leveling-off. In contrast, affect complexity has been shown to increase from young adulthood to middle-age and to decline thereafter (Labouvie-Vief, et al., 2007; Labouvie-Vief & Medler, 2002).

Concluding remarks. These four theories and related empirical studies have painted the picture of emotion regulation in adulthood fairly broadly. Both individual and contextual factors influence emotion regulation and it is also reasonable to assume that emotion regulation changes with age. However, each of these four theories has its strengths and limitations. The Broaden-and-Build Theory (Fredrickson, 1998, 2001) and the Dynamic Affect Model (Zautra, et al., 1998) each focus on a distinct aspect of emotional experience and take into account both individual and contextual factors in emotion regulation. However, these two theories do not incorporate any aspect of developmental reasoning and do not address how emotion regulation may change at different stages of the lifespan. In contrast, the Socioemotional Selectivity Theory (Carstensen, et al., 1999) and the Dynamic Integration Theory (Labouvie-Vief, 2003) have a lifespan focus but these two theories are limited in the explanation of possible individual differences in how emotion regulation may change with age. Furthermore, instead of seeing emotion regulation as a unidimensional construct, emotion regulation may be conceptualized in different modes or along different dimensions. For example, the Dynamic Integration Theory (Labouvie-Vief, 2003) proposes the distinction between two modes of emotion regulation, namely affect optimization and affect differentiation (Labouvie-Vief, 2003; Labouvie-Vief, et al., 2007). Thus, it is important to draw on the strengths of each of these theories in order to give a more complete picture of how emotion regulation is achieved in adults and how emotion regulation may change across the adult lifespan.

A major drawback of these theories is that the definitions of emotion regulation do not focus on the modulation of positive and negative affect explicitly. Instead, empirical studies drawing from these theories largely examined the state of emotional experience such as the affect level and the degree of association between positive and negative affect. The present study built on these theories and examined the effects of individual difference variables, contextual variables, and age on emotion regulation. This study is innovative in that the dynamical systems approach was applied to capture the modulation of positive and negative affect in the context of daily stress. Emotion regulation was operationalized as the tendency for affect to return towards equilibrium in response to daily stressors. The first research question addressed whether positive and negative affect showed a pattern of self-regulation.

The Current Study

Overall, this study was guided by Almeida's (2005) model of daily stress processes (see Figure 2.1). This model incorporates contextual variables, individual difference variables, and age into a conceptualization of daily stress that can account for the substantial individual differences that are observed in stress and coping research. It is important to examine the influence of these factors on emotion regulation. For contextual variables, I examined the effects of daily stressors on emotion regulation. For individual difference variables, I examined the effect of neuroticism and self-concept incoherence, on emotion regulation. I also tested whether individuals of different ages differed in how they regulated their emotions. The daily diary method (Bolger, et al., 2003) was used to examine the effect of time-invariant individual difference variables and time-varying contextual variables on emotion regulation.

The role of daily stressors. Stress is a ubiquitous part of contemporary life. In the history of scientific stress research there has been a movement from studying stress

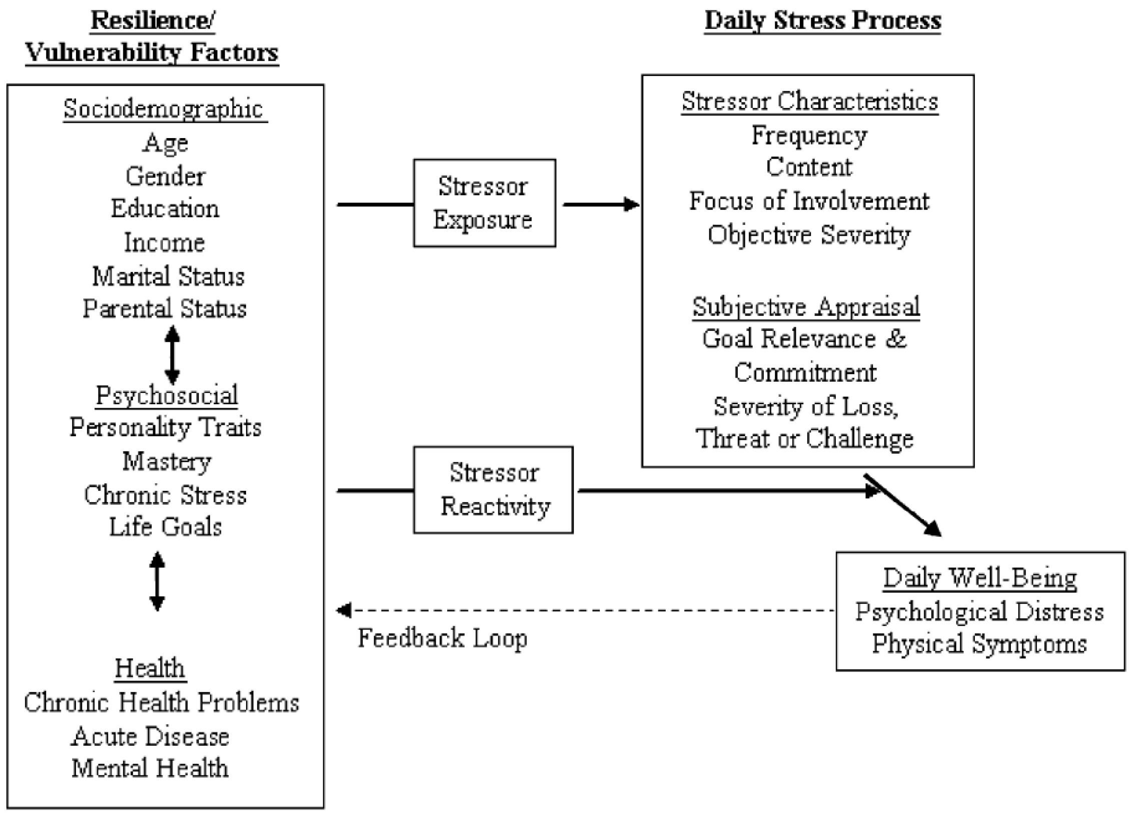


Figure 2.1. Almeida's (2005) model of daily stress process.

and coping in the laboratory to studying these constructs in real life settings (Lazarus, 1993; Lazarus & Folkman, 1984). Stress is the response to environmental demands, i.e. stressors, that individuals perceive as taxing their resources or threatening their well-being (Cohen, Kessler, & Gordon, 1995; Lazarus & Folkman, 1984). In particular, daily stressors are defined as unexpected challenges that disrupt day-to-day living (Almeida, 2005). Daily stressors cause tangible interruptions in everyday life that may be detrimental to individuals' emotional experience and health in the long run (Almeida, 2005; Almeida, Wethington, & Kessler, 2002; Bolger & Schilling, 1991; DeLongis, Folkman, & Lazarus, 1988). Compared to major life stressors, daily stressors may seem to be minor disturbances. However, daily stressors occur more frequently than life stressors and may pile up over days to create persistent irritation and distress (Almeida, et al., 2002; Lazarus & Folkman, 1984). Empirical evidence shows that daily stressors have a negative effect on emotion regulation (Mroczek & Almeida, 2004; Stawski, Sliwinski, Almeida, & Smyth, 2008; Zautra, et al., 2000). For example, daily stressors concerning relationships and work increase individuals' experience of negative affect (Mroczek & Almeida, 2004).

In addition, evidence shows that individuals differ in their exposure to daily stressors and responses to stressors (Almeida, 2005; Almeida & Horn, 2004; Bolger & Zuckerman, 1995; Folkman, Lazarus, Pimley, & Novacek, 1987; Larsen & Prizmic, 2008; Mroczek & Almeida, 2004). Older adults are less frequently exposed to daily stressors, compared to young and middle-aged adults (Almeida & Horn, 2004; Folkman, Lazarus, Pimley, & Novacek, 1987; Stawski, et al., 2008). Adults of different ages also tend to experience stressors from different domains. For instance, older adults report more stressors in the health domain than young and middle-aged adults (Hay & Diehl, 2010). In terms of responses to stressors, individuals higher in neuroticism tend to react more negatively to daily stressors (Mroczek & Almeida, 2004). In other words, more neurotic individuals are prone to poorer emotion regulation and react more negatively to daily stressors, compared to their less neurotic counterparts. Taken together, the examination of emotion regulation benefits from the understanding of individual differences in the interplay between daily stressors and daily affect. The second research question addressed whether and how daily stressors were associated with emotion regulation.

The role of neuroticism. Personality has been widely examined as an individual factor to predict behaviors and other psychological outcomes. In particular, personality traits are the psychological properties individuals possess that explain individual differences in their consistent patterns of thoughts, feelings, and behaviors (Allport, 1937; Cattell, 1965; Goldberg, 1981; McCrae & Costa, 1995, 2003). The Big Five Theory of personality (McCrae & Costa, 1995, 2003), for example, postulates that individuals differ in five basic personality traits, namely, Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness and that these five personality traits account to a large extent for how individuals behave.

Personality traits are important because they determine to a good extent how individuals perceive and experience the world around them. Empirical evidence consistently shows that neuroticism plays an important role in explaining individual differences in how people manage stress (Bolger & Schilling, 1991; Gross, 1998, 1999). Specifically, neuroticism accounts for individuals' tendency of adopting different strategies of emotion regulation (John & Gross, 2004). Individuals low in neuroticism, for example, were more likely to positively reappraise their emotional experiences than individuals high in neuroticism. Furthermore, reappraisal – changing the way how one thinks about the emotional events – was a healthy emotion regulation strategy that was associated with a decrease in both the expression and experience of negative emotions (John & Gross, 2004). Thus, neuroticism is generally associated with the ineffective use of emotion regulation strategies.

In addition, neuroticism may lead to poor emotion regulation through three mechanisms, namely stress exposure, stress reactivity, and a mechanism unrelated to environmental events (Bolger & Schilling, 1991). First, neuroticism may increase individuals' exposure to stressful situations. Using a daily diary design, Bolger and Schilling (1991) found that individuals higher in neuroticism reported a greater number of daily stressful events across a six-week period. Thus, neuroticism was associated with a higher level of daily stress, which may have an impact on emotion regulation. Second, neuroticism was found to be associated with stress reactivity (Bolger & Schilling, 1991). Findings showed that individuals higher in neuroticism became more distressed than individuals lower in neuroticism when stressful events occurred (Bolger & Schilling, 1991). Thus, neuroticism tends to be associated with ineffective management of emotions in dealing with stressful situations. Third, neuroticism was shown to lead to distress directly, even in the absence of environmental stressors. Findings showed that about 60% of the neuroticism-distress relationship was not mediated by daily stress (Bolger & Schilling, 1991). In other words, neuroticism has a substantial direct effect on emotional experiences, which is not explained by the variation in daily stress. Taken together, neuroticism appears to be a risk factor in emotion regulation via different mechanisms, including stress exposure, stress reactivity, and a direct effect on distress. The third research question of this study was to examine whether and how neuroticism was associated with emotion regulation.

The role of self-concept incoherence. Another personal risk or resilience factor may be the representations that individuals hold about themselves. In particular, how such representations are structurally organized may affect whether the self-concept serves an adaptive or maladaptive function. Although concepts and terminologies associated with the self-concept are plentiful and diverse, in this study, the terms "self-concept" and "self-representations" are used interchangeably to denote the attributes and characteristics of the self that the individual is able to consciously acknowledge (Diehl, 2006; Harter, 1999). As several theorists have pointed out (Campbell, et al., 1996; Higgins, 1996; Markus & Wurf, 1987), a person's self-concept consists of a collection of general and context-specific representations about his or her traits, beliefs, values, and memories about the self. Self-representations serve the adaptive function of self-regulation to meet the demands of the physical and social environment (Higgins, 1996; Markus & Wurf, 1987). Self- representations are important for understanding the self as an adaptive resource in adult development because individuals organize and reorganize their self-knowledge in the face of age-related challenges (Diehl & Hay, 2007; Greve & Wentura, 2003). In particular, individuals' self-representations are increasingly conceptualized as a knowledge structure that serves as a psychological resource for coping with life stress and developmental challenges in adulthood (Brandtstädter & Greve, 1994; Diehl & Hay, 2007; Higgins, 1996). Thus, this study examined whether an incoherent self-concept poses a risk factor with regard to emotion regulation in response to daily stressors.

Specifically, the structural organization of a person's self-representations influences how self-relevant information is processed and may moderate important psychological outcomes (Diehl & Hay, 2007). The basic assumption is that different structural organizations of self-representations are associated with different ways of processing self-relevant information and, in turn, with different adaptive or maladaptive behaviors. For instance, self-concept incoherence has been found to be associated with stress and coping in adulthood (Block, 1961; Diehl, 2006; Diehl & Hay, 2007). Self-concept incoherence is defined as an individual's tendency to have self-representations that are very different across social roles and contexts (Donahue, Robins, Roberts, & John, 1993). Thus, self-concept incoherence is an indicator of having a divided and fragmented sense of self.

From a developmental perspective, individuals show an increasing differentiation into role-specific multiple selves from childhood through adolescence and young adulthood (Diehl & Hay, 2007; Harter, 2006a, 2006b). It is thus a developmental task that adults need to coordinate their multiple selves into a coherent sense of self. Empirical findings have suggested that self-concept incoherence in middle adulthood is associated with poorer adjustment 30 years ago (Donahue, et al., 1993). In particular, in a sample of middle-aged women, self-concept incoherence was positively correlated with concurrent maladjustment and a long-term history of maladjustment (Donahue, et al., 1993). Using cross-sectional data, women with higher self-concept incoherence at age 52 reported higher neuroticism and lower well-being. In addition, using longitudinal data, women with greater self-concept incoherence at age 52 had a history of maladjustment and emotional distress throughout their adulthood. Compared to women with lower self-concept incoherence at age 52, women with higher self-concept incoherence displayed higher levels of neuroticism, anxiety, and depression in their early 20s. Higher self-concept incoherence was also associated with role dissatisfaction, more frequent role changes, and a less stable relationship history, such as divorce. This pattern of maladjustment remained through ages 27, 43, and 52 for these women with a more divided sense of self (Donahue, et al., 1993). In addition, greater self-concept incoherence has been shown to be associated with higher average negative affect and greater vulnerability to daily stressors (Diehl & Hay, 2007).

In a cross-sectional study using a lifespan sample, a curvilinear association between age and self-concept incoherence was found (Diehl, Hastings, & Stanton, 2001). In general, for both young and older adults, a higher level of self-concept incoherence was associated with lower psychological well-being. The effect of self-concept incoherence on psychological well-being, however, was moderated by age. Specifically, the negative association between self-concept incoherence and well-being was significantly stronger in older adults than in young adults (Diehl, et al., 2001). Thus, self-concept incoherence appears to be a risk factor with regard to psychological well-being with a stronger negative effect on older adults. Moreover, these findings also suggest that self-concept incoherence may represent a risk factor when individuals are confronted with daily stress. Thus, the fourth research question addressed whether and how self-concept incoherence was associated with emotion regulation.

The role of age. The role that age plays in emotion regulation remains somewhat ambiguous and not well understood. On the one hand, age is associated with age-related losses such as cognitive decline, health problems, and changes in social network. With increasing age, these age-related losses may lead to more stress and in turn, may also erode individuals' coping resources, thus leading to poorer emotion regulation. On the other hand, age tends to be associated with life experiences and less frequent stressful events (Almeida & Horn, 2004; Stawski, et al., 2008), which may be associated with better emotion regulation. Consistent with the Socioemotional Selectivity Theory (Carstensen, et al., 2003; Carstensen, et al., 1999), emotion regulation is expected to improve with age because as individuals grow older, emotion regulation takes priority over knowledge acquisition. Individuals increasingly gain satisfaction in their social interactions and forego the possible gain in knowledge. Empirical findings have generally supported the positive association between age and emotion regulation. For example, in a longitudinal study (Charles, et al., 2001), individuals increasingly reported higher positive affect over 23 years. This suggests, at least in part, that emotion regulation improves as people grow older. In addition, results from two daily diary studies (Neupert, Almeida, & Charles, 2007; Stawski, et al., 2008) showed that emotion regulation was better in older adults than in middle-aged and young adults. Both studies found that compared to young adults, older adults reacted to daily stressors less negatively. Furthermore, compared to young and middled-aged adults, older adults showed that they experienced longer lasting positive affect and more fleeting negative affect (Carstensen, et al., 2000). Taken together, age appears to be associated with better emotion regulation.

Consistent with previous findings, the fifth research question was to examine whether and how age was associated with emotion regulation.

Advantages of the Daily Diary Method

Compared to traditional cross-sectional designs, the present study capitalizes on the advantages of the daily diary design for studying the processes of emotion regulation. The daily diary design has several strengths (Bolger et al., 2003). First, emotion regulation is by definition a process of change. That is, emotion regulation is a process that unfolds over time and is motivated by individuals' desire to change from one emotional state to another. Thus, in the context of daily diary studies, the repeated measures of daily affect and stressors allow (a) the examination of within-person variations over time and (b) the examination of individual differences in their within-person variations in daily affect and stressors (Almeida, 2005; Almeida, Wethington, & Kessler, 2002; Bolger, et al., 2003).

Second, compared to laboratory studies, information obtained by daily diary studies better approximates individuals' real-life experiences (Almeida, 2005; Bolger, et al., 2003). Findings from the examination of naturally occurring stressful events and the accompanying affective experiences provide greater ecological validity than findings from studies that artificially create stress and induce affective experiences in the laboratory.

Third, daily diary studies purportedly allow more accurate assessment of stressors and affective experiences because this research design reduces retrospective recollection bias (Bolger, et al., 2003). Compared to conventional research methods that ask participants to retrospectively recall their experiences over weeks, months, or years, the daily diary method enhances the accuracy of individuals' account of experiences by minimizing the reliance on the participants' memory of their experiences over a longer period of time. Thus, a daily diary study of affect and stress is appropriate to examine individual and contextual differences in emotion regulation.

Fourth, in terms of stress research, daily diary studies also permit the examination of accumulative processes (Bolger, et al., 2003). The repeated measurement of daily stressors allows the examination of how emotional experiences unfold from one state to the next. It also allows the examination of how individuals may differ in their adaptation to stress over time. Thus, the daily diary method was adopted in the present study to capture the ebb and flow of positive and negative affect as they unfold in the context of daily stressful events.

Summary

Review of the literature indicates that research on emotion regulation can contribute to understanding how emotional functioning is maintained in adulthood. Several theoretical perspectives have provided a promising conceptual framework for further research on the contextual effect and individual differences on the development of emotion regulation across the adult lifespan.

Several major issues have been identified that need further research. First, emotion regulation is by definition a process of change in affective experience. Statements on the development of emotion regulation need to be based on direct measures of emotion regulation that capture the temporal pattern of emotional changes, rather than indirect static measures of emotional experiences. However, with a few exceptions (Bisconti, et al., 2004; Carstensen, et al., 2000), assessment of emotion regulation tends to focus on the state of emotional experiences, instead of the modulation of affect over time. Second, research on emotion regulation needs to take into account the context in which emotional experiences unfold. Individuals engage in emotion regulation in response to environmental demands and may or may not apply situation-appropriate emotional responses. However, except for some laboratory studies (Gross & Levenson, 1997), the contextual effects on emotion regulation have not been examined. In contrast, naturalistic studies that take into account contextual effects of daily stressors focused only on emotional states, and not the modulation of emotional experiences (Zautra, Affleck, Tennen, Reich, & Davis, 2005). Third, effects of individual difference variables, such as personality, have been identified in everyday emotional experiences (Bolger & Schilling, 1991). However, it is unsure whether these individual differences also have impact on emotion regulation, measured in terms of the modulation of emotions. Thus, it is important to examine the interplay of individual difference variables and contextual factors on emotion regulation.

The present study built on the past studies and examined emotion regulation as a self-regulating process using the dynamical systems approach (Boker & Nesselroade, 2002). I examined the effect of daily stressors on emotion regulation. Individual differences in emotion regulation in terms of neuroticism and self-concept incoherence were examined. I also examined age differences in emotion regulation.

CHAPTER 3

STATEMENT OF OBJECTIVES

The present study used a daily diary design to examine emotion regulation for 30 consecutive days. The objectives of this study were threefold: (a) To examine the self-regulatory pattern of positive and negative affect; (b) to examine the effect of daily stressors on emotion regulation; and (c) to examine individual and age differences in emotion regulation. These objectives are described below in more detail.

Self-Regulation of Positive and Negative Affect

The first study objective was to determine whether positive and negative affect showed a systematic pattern of self-regulation. Dynamical systems modeling was applied to summarize the affect time series of the 30-day assessment period. Emotion regulation was conceptualized as the tendency for daily positive and negative affect to return towards individuals' equilibrium. I expected that the self-regulatory pattern of positive and negative affect would be captured using the damped oscillator model. I also expected that the coupled oscillators model would capture the regulatory effect of positive affect on negative affect, and vice versa.

Daily Stressors

The second study objective focused on the examination of the effect of daily stressors on emotion regulation. Based on prior research findings (Almeida, 2005; Bolger & Schilling, 1991), I expected that daily stressors would show an effect on emotion regulation. Prior studies reported that daily stressors were associated with an increase in negative affect (Neupert, Almeida, & Charles, 2007). However, research did not give any guidance which direction the effect of daily stressors would be, i.e. whether affect would move towards or away from equilibrium. Therefore, I did not hypothesize any specific direction of the effect of daily stressors on emotion regulation. I hypothesized that daily stressors were associated with the tendency for affect to return towards equilibrium.

Hypothesis 1: Daily stressors are associated with emotion regulation, the tendency for affect to return towards equilibrium.

Individual and Age Differences in Emotion Regulation

The third objective concerned the examination of individual and age differences in emotion regulation. For individual differences, I examined the effects of neuroticism and self-concept incoherence on the tendency for affect to return towards equilibrium in response to daily stressors. I hypothesized that the effect of daily stressors on emotion regulation was stronger in individuals higher in neuroticism and self-concept incoherence. I also examined the interaction effect of self-concept incoherence and age on emotion regulation. I hypothesized that self-concept incoherence had a stronger effect on the effect of daily stressors in older adults than in young adults.

Hypothesis 2: The effect of daily stressors on emotion regulation is stronger in individuals higher in neuroticism.

Hypothesis 3: The effect of daily stressors on emotion regulation is stronger in individuals higher in self-concept incoherence.

Hypothesis 4: Self-concept incoherence and age has an interaction effect on the effect of daily stressors on emotion regulation. Compared to young adults, self-concept incoherence has a stronger effect on the effect of daily stressors in emotion regulation in older adults.

I also examined the effect of age on emotion regulation. Drawing on results from previous studies (Carstensen, et al., 2000; Charles, et al., 2001), I expected that age would show a positive effect on emotion regulation. Specifically, compared to young adults, the effect of daily stressors on emotion regulation was expected to be weaker in older adults.

Hypothesis 5: Age has a positive effect on emotion regulation. The effect of daily stressors on emotion regulation is weaker in older adults than in young adults.

CHAPTER 4

METHOD

The study methods are presented in the following five sections. First, I will describe the context and research design of the present study. Second, a description of the study sample will be provided. The third section presents a description of the testing procedures and the fourth section provides a description of the measures used in the study. Finally, the statistical techniques used in this study will be described.

Design

The present study was part of a larger project on the examination of daily stress experiences across the adult lifespan. Using a daily diary design, participants recorded their daily stressors and affect for 30 consecutive days. The daily diary design has several advantages. The first strength is its ability to characterize temporal dynamics (Affleck, Zautra, Tennen, & Armeli, 1999; Bolger, et al., 2003). The daily diary design allows the examination of within-person and between-person variability of ongoing psychological processes as the processes unfold over time. Second, daily diary data are collected as the psychological processes unfold in real-life settings rather than laboratory settings, thus providing greater ecological validity. Compared to laboratory studies, findings from daily diary studies may be more readily generalized to natural settings. Third, the daily diary design minimizes the biases introduced by retrospective reporting (Bolger, et al., 2003). Stress and affect experiences are recorded as they occur, thus reducing inaccuracy as a result of recall bias over a relatively long period of time.

The daily diary design also has its limitations. First, observational studies of within-person processes as they occur naturally may have limited internal validity. That is, conclusions of causal relationships between different variables in observational studies may be compromised because the variables in question are not subject to manipulation as in controlled experiments. Thus, examinations of causal effects are limited in daily diary studies (Bolger, et al., 2003). Second, participants are observed over a relatively long period of time in daily diary studies. This requires relatively more time commitment from participants and may lead to several problems in participant recruitment and retention. First, the greater time commitment may pose more burdens on participants, which, in turn, may lead to poorer participant compliance. Second, the greater time commitment may result in a highly selected group of participants. Consequently, findings from daily diary studies may not be readily generalizable to other populations. Third, compared to conventional experimental studies, the time commitment required from participants in daily diary studies may lead to more missing data and attrition, if no proper precautions are taken to carefully monitor participants.

Despite these limitations, the daily diary method allows the examination of within-person changes over time, and individual differences in these within-person changes. Therefore, the daily diary method is well-suited for the purpose of the current study in the examination of within-person daily emotional experiences, and individual differences in these within-person changes of emotions.

Participants

The sample consisted of 120 men and 119 women ranging in age from 18 to 89 years (*M* = 49.6 years, *SD* = 19.6 years). Participants were recruited from a tri-county area (Alachua, Columbia, and Marion County) in North Central Florida using a mix of sampling procedures (i.e., 25% through random digit dialing, 25% through letters of invitation to alumni of a major university in Florida, 45% through newspaper advertisements and flyers, and 5% through a retirement community). Because the focus of the study was on healthy, community residing adults, individuals were screened out for any major sensory impairments, concurrent depression, or history of mental illness and substance abuse (e.g., alcoholism or drug addiction). Participants also had to be physically able to come to the testing location, and have adequate cognitive ability to complete the study protocol. The study's eligibility criteria were established during a screening interview.

To ensure an even distribution of age, participants were recruited from three age groups: young adults (*n* = 81; age range 18-39 years), middle-aged adults (*n* = 81; age range 40-59 years), and older adults (*n* = 77; age 60 or older). Gender was evenly distributed within each age group. Eighty-eight percent of the participants were Caucasian, 9% were African American, and 3% were Hispanic. All participants spoke English as their primary language. On average, participants reported 16.3 years of education (*SD* = 2.9 years) and 62% had a college degree or higher. The median reported income was $35,000 – $50,000. Most of the young adults (72.8%) were single, whereas most middle-aged (65.4%) and older adults (62.3%) were married. The young adults were approximately evenly divided between those who were employed (full- or part-time) and those who were students, whereas the majority of the middle-aged adults were employed and the majority of the older adults were retired. Participants described themselves as being in good health (*M* = 5.20, *SD* = .83; 1 = *very poor*; 6 = *very good*) and being satisfied with their lives (*M* = 4.64, *SD* = .72; 1 = *extremely unhappy*; 6 = *extremely happy*). The three age groups did not differ from each other in subjective health, F (2, 236) = .23, $p > .05$, and life satisfaction F (2, 236) = 2.37, $p > .05$. In contrast, the three age groups differed from each other in mean positive affect, F (2, 236) = 5.71, $p < .01$, and mean negative affect, F (2, 236) = 12.98, $p < .001$, across the 30-day assessment period. Using Tukey's Honest Significant Differences test with 95% family-wise confidence level, results indicated that young adults had a significantly lower level of positive affect compared to middle-aged (*M* difference = 2.48, $p < .05$) and older adults (*M* difference = 3.32, $p < .01$). Similarly, results showed that young adults had a significantly higher level of negative affect than middle-aged (*M* difference = 1.40, $p < .01$) and older adults (*M* difference = 2.02, $p < .001$). The three age groups also differed in their within-person variability in daily positive and negative affect. The standard deviation was calculated for each individual's daily positive and negative affect. Using Tukey's Honest Significant Differences test with 95% family-wise confidence level, results indicated that older adults (*SD* = 4.37) showed less within-person variability than young adults (*SD* = 5.34) in daily positive affect ($p < .01$). Compared to young adults (*SD* = 3.26), both middle-aged (*SD* = 2.53) and older adults (*SD* = 2.00) also showed less within-person variability in daily negative affect ($p < .01$ and $p < .001$ respectively). Additional information is presented in Table 4.1.

Procedure

Participants first attended a 2 to 3 hour individual baseline session. Most participants completed the session at the Adult Development and Aging laboratory on the campus of the University of Florida. A subset of older adults (*n* = 16) completed their

Table 4.1

Means and Standard Deviations of Affect, Subjective Health, and Life Satisfaction

	Young adults (n = 81)		Middle-aged adults (n = 81)		Older adults (n = 77)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Mean positive affect	25.24	6.21	27.71	6.28	28.56	6.84
Mean negative affect	13.96	2.89	12.56	2.37	11.94	2.38
Subjective health	5.15	.76	5.23	.86	5.21	.89
Life satisfaction	4.59	.74	4.54	.78	4.78	.62

Note. M represents mean and *SD* represents standard deviation.

testing at the retirement community in which they resided. The day following the baseline session, participants began 30 consecutive daily assessments, consisting of an evening phone interview and a diary. Both baseline sessions and daily phone interviews were conducted by trained research assistants. The daily diaries were self-administered and participants completed diaries each evening at approximately the same time. Participants were instructed to mail the diaries in pre-paid envelopes the day immediately following completion. Through close monitoring during data collection, including monitoring of the time elapsed from diary completion to receipt of diaries, checking postal date stamps, cross-checking information provided in the diaries with information obtained during daily interviews, and following up with all participants who did not return their diaries in a regular and timely manner, we determined that participants who failed to complete the majority of their dairies often failed to follow the study protocol when they filled out diaries. That is, these individuals either completed their diaries late and/or completed multiple diaries on the same day.

Thus, to ensure that the sample consisted of participants who followed the prescribed study protocol and provided daily data in the correct manner, only participants who completed a minimum of 24 interviews and 24 diaries (80%) in the 30-day period were included in the final sample. As a result, 43 participants were excluded from analyses due to insufficient daily data. In addition, one participant was excluded because of missing data on a key measure used in this study. The final sample included 239 participants.

Participants who were excluded were compared to those in the final sample on a number of baseline measures. In comparison to the final sample, participants who did not complete the study protocol were younger, $F(1, 282) = 8.10$, and rated themselves in poorer health, $F(1, 282) = 8.10$, both p's $< .01$. They also exhibited scores indicative of poorer psychological well-being (PWB) on a number of measures assessing positive and negative dimensions of PWB, including the Center for Epidemiological Studies Depression Scale (Radloff, 1977), $F(1, 282) = 13.60$, $p < .001$, the negative affect subscale of the Positive Affect and Negative Affect Scale (Watson, Clark, & Tellegen, 1988), $F(1, 282) = 11.00$, $p < .001$, and the Self-Acceptance and Purpose in Life subscales of the Scales of Psychological Well-being (Ryff, 1995), $F(1, 282) = 5.10$ and $F(1, 282) = 4.10$, both p's $< .05$, respectively. Participants who were excluded, however, did not differ from those in the final sample on the average number of stressors they experienced per day.

The 239 participants were in the study for a total of 6,941 days (an average of 29 days of data per person, $SD = 1.44$ days, range = 23 to 30 days). Given the analytic strategy (see below), the first- and second-order derivatives of the time series of positive and negative affect were estimated using the 6,941 days of data. The estimation of the first- and second-order derivatives of the affect time series resulted in 5,625 days of data. Only days with complete data on all measures of interest were included in the analyses. Thus, the presented analyses were based on 5,467 days of data.

Measures

Measures administered during the baseline session assessed a variety of sociodemographic and personal information, including participants' self-concept incoherence and selected personality traits. Daily phone interviews assessed positive and stressful events participants experienced that day. Measures included in the daily diaries assessed physical, emotional, and cognitive states participants experienced on a day-to-day basis.

Positive and negative affect. Each day, participants completed the Positive Affect and Negative Affect Schedule (PANAS; Watson, et al., 1988). The positive and negative affect subscales each consists of 10 items that describe affect states such as feeling cheerful or relaxed, and angry or distressed. Positive Affect (PA) reflects the extent to which a person feels enthusiastic, active, and alert. High PA is indicative of a high energy level, full concentration, and pleasurable engagement, whereas low PA is indicative of sadness and lethargy. In contrast, negative affect (NA) is a general dimension of aversive mood states such as anger, contempt, disgust, guilt, fear, and nervousness, with low NA being a state of calmness and serenity.

Respondents indicated how often they had experienced these affective states during the past 24 hours on a 5-point scale (1 = *very slightly or not at all*; 5 = *extremely*). Daily subscale scores range from 10 to 50. The PANAS has high internal consistency and test-retest reliability (Watson, et al., 1988). In this study, I estimated the internal consistency coefficients on the 5^{th}, 15^{th}, and 25^{th} day of measurement. For positive affect, Cronbach's α = .92, .93, and .94, respectively. For negative affect, the resulting coefficients were respectively .84, .87, and .89. To capture reliability in the longitudinal sequence, R_{Λ} was calculated (Laenen, Alonso, Molenberghs, & Vangeneugden, 2009). R_{Λ} was .98 for positive affect and .96 for negative affect across the 30-day scores.

Neuroticism. Neuroticism was assessed using the Neuroticism subscale of the NEO Five-Factor Inventory (Costa & McCrae, 1992; NEO-FFI). The Neuroticism subscale consists of 12 items which are rated on a 5-point scale (0 = *Strongly disagree* to

4 = *Strongly agree*). Higher scores indicate higher neuroticism. Neuroticism is a personality trait characterized by emotional instability and experiences of negative emotional states. Individuals who score high on neuroticism tend to experience higher levels of negative emotions and have frequent mood swings. In contrast, individuals who score low on neuroticism tend to experience low levels of negative emotions and are emotionally stable. The reliability and validity of this scale have been established in various studies (Costa & McCrae, 1992; McCrae & Costa, 2003). The internal consistency of the scale was high in the present study (Cronbach's α = .85).

Self-concept incoherence. Participants' level of self-concept incoherence was assessed using Block's (1961) self-concept differentiation (SCD) index. Self-concept incoherence refers to the degree of coherence in individuals' beliefs of who they are in different social roles. Individuals who score high in terms of self-concept incoherence tend to view themselves acting and thinking very differently across social roles. In contrast, individuals with low self-concept incoherence tend to report that they act and think relatively consistently across social roles. Participants rated on an 8-point scale (1 = *extremely uncharacteristic*; 8 = *extremely characteristic*) how characteristic 40 self-attributes were of their true self and of themselves in four social roles: with their family, spouse or significant other, a close friend, and colleagues. Each participant's set of ratings were correlated and the resulting 5 × 5 correlation matrix was subjected to a *within-person* principal components analysis. The first principal component extracted represents the variance shared across the five self-representations. The SCD index was calculated by subtracting the shared variance from 1.00. Thus, the SCD index represents the proportion of variance that is not shared by the five self-representations and higher scores indicate greater self-concept incoherence. The reliability and criterion validity of this index have been established in a number of studies (Diehl, et al., 2001; Donahue, et al., 1993).

Daily stressors. Each day during their phone interviews, participants completed the *Daily Inventory of Stressful Events* (DISE; Almeida, Wethington, & Kessler, 2002). The DISE is a semi-structured interview used to measure stressor exposure in everyday life. Stressors are events that tax a person's coping resources and challenge the person's adaptation. The DISE was developed on a nationally representative sample of adults aged 25 to 74 years. The DISE consists of seven stem questions assessing the occurrence of stressors, including having or avoiding arguments, as well as stressors that occur in various domains of life (e.g., at work/school/volunteering, in personal health). The number of stressful events participants experienced each day was summed to create an index of daily stressors. Scores can range from 0 to 7, with higher scores indicating a greater number of stressors. Participants also rated each daily stressor in terms of its stressfulness on a 4-point scale (1 = *not at all stressful*; 4 = *very stressful*).

Participants reported experiencing no stressors on 45% of the days and 1 or more stressors on 55% of the days. The median number of stressors experienced per day was 1; the mean number of stressors experienced per day was 0.75 (*SD* = 0.82; range: 0 – 6). The correlation between number of stressors and stress intensity was .94, indicating high collinearity between these two variables. Stress intensity was used as the variable of interest. Stress intensity was calculated by summing the intensity ratings of each daily stressor reported.

Statistical Analyses

Dynamical systems modeling (Boker & Bisconti, 2006; Boker & Laurenceau, 2006; Boker & Nesselroade, 2002) was used to test the specific research hypotheses. Dynamical systems modeling is well-suited to answer questions about self-regulating systems, such as emotion regulation. Self-regulation is defined as a "process by which a phenomenon maintains equilibrium by responding to information about change in the phenomenon's state" (Boker & Laurenceau, 2006, p. 195). An example of a self-regulating system is the maintenance of vehicle speed at a desired set point using a cruise control system. A cruise control system regulates the speed by accelerating the vehicle when the current speed is below the lower threshold and decelerates the vehicle when the speed is above the upper threshold. Thus, the vehicle speed remains within the lower and upper thresholds, fluctuating around the desired speed. Similarly, emotion regulation is conceptualized as a self-regulating system in this study. It is assumed that individuals have a desired set point of positive and negative affect. Individuals also monitor their current emotional states and engage in emotion regulation to bring their current emotional states closer to the desired equilibrium.

Using dynamical systems modeling, a self-regulatory system can be estimated as a *damped oscillator* (Boker & Laurenceau, 2006; Boker & Nesselroade, 2002; Nesselroade, 2002). Figure 4.1 gives a visualization of an oscillator. For a damped oscillator, the weight oscillates around equilibrium and the amplitude of oscillation gradually reduces. Eventually, the weight comes to rest at equilibrium. In contrast, an undamped oscillator swings around equilibrium and the weight does not come to a rest. The motion of an oscillator can be represented using a mathematical model in terms of

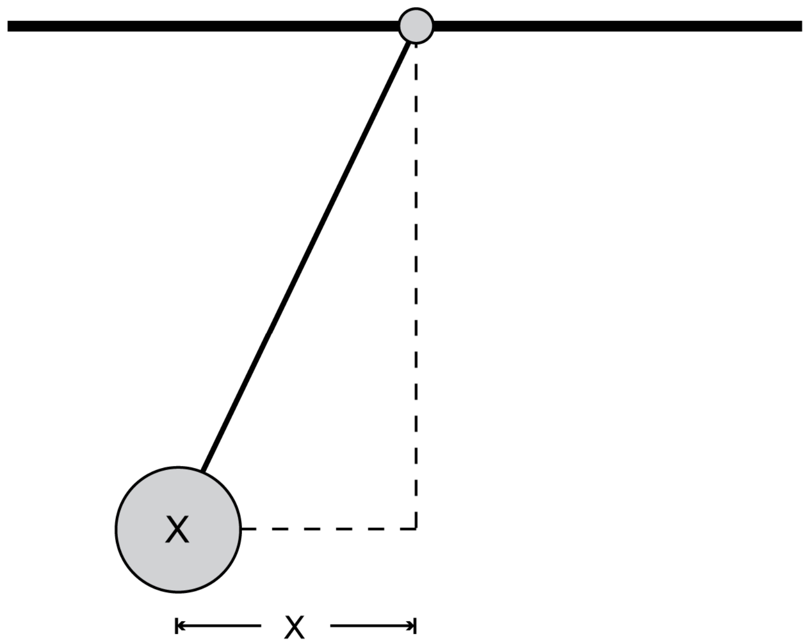


Figure 4.1. Damped oscillator model.

the displacement of the weight. Displacement is the difference between the current position of the weight from its initial position (i.e., the value for the distance “x” in Figure 4.1). Displacement is a vector and has both magnitude and direction.

Figure 4.2 gives the trajectory plots of the displacement of (a) a damped oscillator and (b) an undamped oscillator. As shown in Figure 4.2, the displacement of the weight has the same sign when the weight is on one side of equilibrium. Displacement equals zero when the weight’s position is at equilibrium. The displacement of the weight changes sign when the weight moves from one side to the other side of equilibrium.

For a damped oscillator (Figure 4.2a), the amplitude of the displacement trajectory reduces over time. In contrast, the amplitude of the displacement trajectory of an undamped oscillator remains the same over time (Figure 4.2b). The damped oscillator can be represented using the following model:

$$\ddot{x}_t = \eta \; x_t + \zeta \; \dot{x}_t \tag{1}$$

x_t is the displacement of the weight at time *t*, $\dot{x}_t$ and $\ddot{x}_t$ are respectively the first- and second-order derivative of x with respect to time. Thus, $\dot{x}_t$ is the velocity of the weight at time *t* and $\ddot{x}_t$ is the acceleration at time *t*. η is the frequency coefficient and is a negative value. η represents the curvature of the trajectory. ζ is the damping coefficient and determines how quickly the weight comes to rest. ζ is a negative value for damped oscillators. When ζ equals zero, the oscillator is undamped.

In addition, because η is a negative constant, the displacement and the second-order derivative are always in opposite directions, except when displacement equals zero. The implication of the negative sign of η is that, when the weight is on one side of

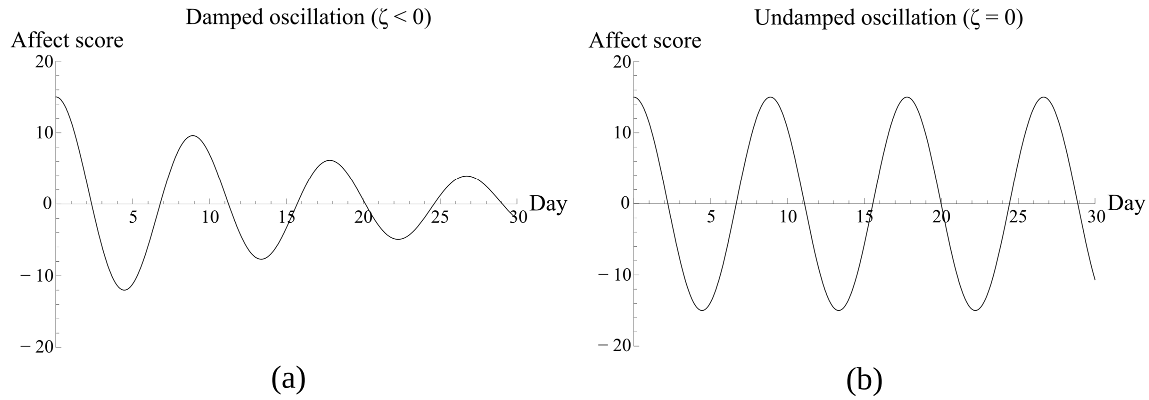


Figure 4.2. Trajectory plots of the displacement of damped and undamped oscillators.

equilibrium, the weight always decelerates and tends to move back towards the other side of equilibrium. Moreover, the tendency to move back towards the other side increases with increased displacement. This means that when the weight is farther away from equilibrium, the weight has a higher tendency to move back to the other side. The oscillation period λ can be calculated using the following formula:

$$\lambda = \frac{2\pi}{\sqrt{-\eta}} \tag{2}$$

To model real-world data where there is always uncertainty and error, a residual term can be added to Equation 1 to include this uncertainty and error in the model.

$$\ddot{x}_t = \eta \; x_t + \zeta \; \dot{x}_t + e_t \tag{3}$$

In Equation 3, e_t is the residual term which meets ordinary least squares regression assumptions. That is, the residuals are independent, normally distributed, with a mean of zero, and a constant standard deviation. Later in this chapter, I will introduce the application of mixed-effects modeling where these assumptions can be partially relaxed.

In the present study, positive and negative affect were conceptualized as two self-regulating systems coupled together. Coupled self-regulating systems consist of individual self-regulatory systems, such that changes in one system influence changes in the other. Figure 4.3 shows an example of a coupled oscillators model. Weights X and Y are linked by a spring. Each weight oscillates around its own equilibrium. At the same time, changes in X influence changes in Y, and vice versa. The coupled oscillators model can be represented by the following equations:

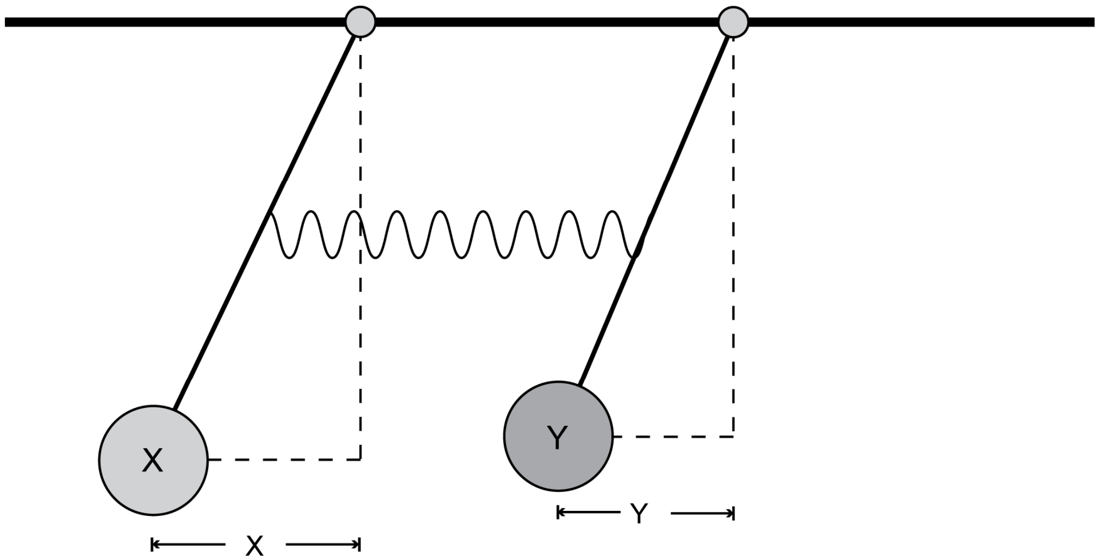


Figure 4.3. Coupled oscillators model.

$$\ddot{x}_t = \eta_x x_t + \zeta_x \dot{x}_t + \gamma_x(\eta_y y_t + \zeta_y \dot{y}_t) + e_{xt} \quad (4)$$

$$\ddot{y}_t = \eta_y y_t + \zeta_y \dot{y}_t + \gamma_y(\eta_x x_t + \zeta_x \dot{x}_t) + e_{yt} \quad (5)$$

In Equation 4, η_x and ζ_x are respectively the frequency and damping coefficients for weight X. In contrast, η_y and ζ_y are respectively the frequency and damping coefficients for weight Y. γ_x is the coupling strength for X. In Equation 5, γ_y is the coupling strength for Y. The coupling strength is the effect of one system on the other. The presence of γ_x and γ_y in Equations 4 and 5 allows the two oscillators to have a mutual effect on each other. At the same time, the presence of γ_x and γ_y allow the possibility of an asymmetrically coupled system. In a symmetrically coupled system, $\gamma_x = \gamma_y$. That is, the effect of X on Y is the same as the effect of Y on X. In contrast, in an asymmetrically coupled system, $\gamma_x \neq \gamma_y$. That is, the effect of X on Y may be larger or smaller than the effect of Y on X. e_{xt} and e_{yt} are residual terms.

This coupled oscillators model is limited, such that X and Y have a proportional regulating effect on each other, as represented by the coupling strength γ_x and γ_y. That is, the effect of one system on the other is proportional to the system's own self-regulating effect. A coupled oscillators model with this constraint relaxed can be specified by the following equations:

$$\ddot{x}_t = \eta_x x_t + \zeta_x \dot{x}_t + \eta_{yx} y_t + \zeta_{yx} \dot{y}_t + e_{xt} \quad (6)$$

$$\ddot{y}_t = \eta_y y_t + \zeta_y \dot{y}_t + \eta_{xy} x_t + \zeta_{xy} \dot{x}_t + e_{yt} \quad (7)$$

In the coupled oscillators model as represented by Equations 6 and 7, the regulating effect of one system on itself is not constrained to be proportional to its regulating effect on the other system. Comparing Equations 4 and 6, η_{yx} does not need to be proportional to η_y and ζ_{yx} does not need to be proportional to ζ_y. Similarly, comparing Equations 5 and 7, η_{xy} is not constrained to be proportional to η_x and ζ_{xy} is not constrained to be proportional to ζ_x. The coupled oscillators model represented by Equations 6 and 7 is more general than the model represented by Equations 4 and 5. The systems self-regulate themselves and they have a mutual effect on each other. However, one system's effect on the other is not constrained to be proportional to the self-regulating effect on the system itself.

In the current study, positive and negative affect were conceptualized as coupled self-regulating systems as represented in Equations 6 and 7. This means that positive and negative affect each self-regulate their own levels. In addition, the regulation of positive affect was assumed to have an influence on the regulation of negative affect, and vice versa. Using differential equation modeling (Boker & Laurenceau, 2006), the dynamical systems of positive and negative affect were estimated and evaluated. First, Local Linear Approximation (Boker & Laurenceau, 2006; Boker & Nesselroade, 2002) was used to convert the time series of positive and negative affect into first- and second-order derivatives. Second, using mixed-effects modeling, the frequency and damping coefficients were estimated by fitting the first- and second-order derivatives of positive and negative affect separately into the damped oscillator model (Equation 3). Third, using mixed-effects modeling, the first- and second-order derivatives of positive and negative affect were fitted into the coupled oscillators model as represented in Equations 6 and 7.

Local Linear Approximation. Local Linear Approximation was used to convert each individual's positive and negative affect time series into first- and second-order derivatives (Boker & Nesselroade, 2002). The first-order derivative is the *velocity* of affect at time *t*. The second-order derivative is the *rate of change* in affect at time *t*. The linear trend from each individual's affect time series was removed. The removal of linear trend from the affect time series allowed the examination of within-person variability of positive and negative affect around equilibrium. This was done by performing an ordinary least squares regression to each individual's affect time series. The detrended time series of positive and negative affect, i.e., the residuals of the regression models, were used for further analyses. Only information on the fluctuation of affect around equilibrium was retained in the residuals.

To model the dynamics of the evolving self-regulation of affect over time, the ordered sequence of the residuals needed to be retained. In other words, the way x_1 leads x_2 and x_2 to x_3 and so on needed to be captured. The ordered sequence of the residuals of the detrended affect time series can be retained using state-space embedding.

State-space embedding. The time-ordered nature of data can be captured by creating an embedded state-space matrix (Boker & Bisconti, 2006; Boker & Nesselroade, 2002). For example, data of a 30-day detrended time series can be represented in a vector of x = { $x_1, x_2, x_3, ..., x_{30}$ }. Using state-space embedding, the residuals of the detrended affect time series was transformed into a state-space matrix X of embedding dimension *d* = 3. Figure 4.4 shows an example of the embedded state-space matrix X of two different values of the time-delay constant, τ .

X has an embedding dimension *d* = 3, as indicated by the three columns of the matrix. Each row of X has three observations and can be presented as a point in a three-dimensional space. The time-ordered nature of the time series is preserved in each row of

$$X = \begin{bmatrix} x_1 & x_3 & x_5 \\ x_2 & x_4 & x_6 \\ x_3 & x_5 & x_7 \\ x_4 & x_6 & x_8 \\ \vdots & \vdots & \vdots \\ x_{24} & x_{26} & x_{28} \\ x_{25} & x_{27} & x_{29} \\ x_{26} & x_{28} & x_{30} \end{bmatrix}$$

$\tau = 2$

(a)

$$X = \begin{bmatrix} x_1 & x_5 & x_9 \\ x_2 & x_6 & x_{10} \\ x_3 & x_7 & x_{11} \\ x_4 & x_8 & x_{12} \\ \vdots & \vdots & \vdots \\ x_{20} & x_{24} & x_{28} \\ x_{21} & x_{25} & x_{29} \\ x_{22} & x_{26} & x_{30} \end{bmatrix}$$

$\tau = 4$

(b)

Figure 4.4. Examples of state-space matrix.

the matrix. The time-delay constant τ is the number of observations to skip forward to obtain the next observation in the same row. The appropriate value of τ needs to be determined by comparing the model fit of the mixed-effects model using the derivatives calculated based on various values of τ. Below I will first describe how the first- and second-order derivatives based on different values of τ were estimated using Local Linear Approximation. I will then describe how the appropriate value of τ was selected.

Estimating first- and second-order derivatives. Here I illustrate how the first- and second-order derivatives of a time series were estimated using Local Linear Approximation. Figure 4.5 shows a 3-point segment of a time series.

The first-order derivative at x_2 was estimated as the mean of the two nearby slopes (Boker & Nesselroade, 2002), i.e., $(b_2 + b_1)/2$. That is:

$$\dot{x}_2 = \left[\frac{(x_2 - x_1)}{\tau} + \frac{(x_3 - x_2)}{\tau} \right] / 2$$

$$= \frac{x_3 - x_1}{2\tau}$$

Furthermore, the second-order derivative at x_2 was estimated as the difference in slope with respect to time (Boker & Nesselroade, 2002), i.e., $(b_2 – b_1)/t$. That is:

$$\ddot{x}_2 = \left[\frac{(x_3 - x_2)}{\tau} - \frac{(x_2 - x_1)}{\tau} \right] / \tau$$

$$= (x_3 + x_1 - 2x_2) / \tau^2$$

Thus, in the time-delay embedded state-space matrix X, the first- and second-order derivatives for the kth row of the matrix were calculated as:

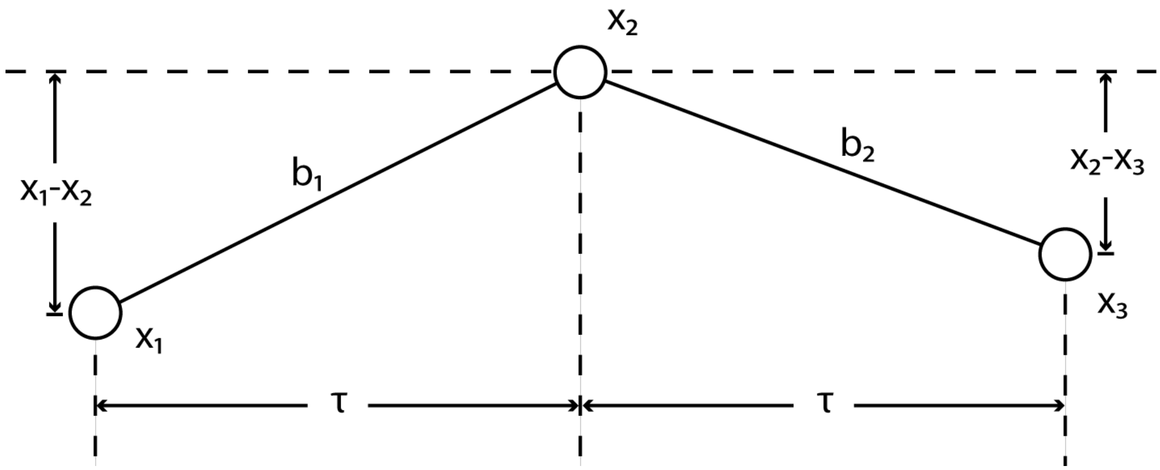


Figure 4.5. Visualization of the estimation of first- and second-order derivatives of a time series using Local Linear Approximation.

$$\dot{x}_k = (x_{k3} - x_{k1}) / 2\tau \quad (8)$$

$$\ddot{x}_k = (x_{k3} + x_{k1} - 2x_{k2}) / \tau^2 \quad (9)$$

$\dot{x}_k$ and $\ddot{x}_k$ are respectively the first- and second-order derivatives for the k^th row of the embedded state-space matrix. x_{k1} is the first element and x_{k3} is the third element in the k^th row. τ is the time-delayed constant used in the construction of the embedded state-space matrix. Thus, $\dot{x}_k$ and $\ddot{x}_k$ are the first- and second-order derivatives at time $k+\tau$.

Take τ = 2 as an example (Figure 4.4a), $\dot{x}_1 = (x_5 - x_1)/(2\times 2)$ and $\ddot{x}_1 = (x_5 + x_1 - 2x_3)/2^2$ in row k = 1. $\dot{x}_1$ and $\ddot{x}_1$ are the first- and second-order derivatives on day 3.

Choosing the value of τ***.*** To choose an appropriate value of τ, model fit comparison was performed in mixed-effects models using the derivatives calculated based on values of τ = {1, 2, … 8}. Larger values of τ were not considered because larger values tend to obscure the estimate of η, the frequency coefficient (Boker & Laurenceau, 2006). For each individual, the first- and second-order derivatives of the affect time series were calculated based on different values of τ. For each value of τ, the first- and second-order derivatives were fitted in the damped oscillator model using mixed-effects modeling:

Level 1: (10)

$$\ddot{x}_{ij} = \eta_{ix} x_{ij} + \zeta_{ix} \dot{x}_{ij} + e_{ij}$$

Level 2:

$$\eta_{ix} = c_{00} + u_{oi}$$

$$\zeta_{ix} = c_{10} + u_{1i}$$

x is one of the two variables: positive affect or negative affect. $\ddot{x}_{ij}$, $\dot{x}_{ij}$, and x_{ij}, are respectively the second-order derivative, the first-order derivative, and the displacement from equilibrium of individual *i*'s affect time series at time *j*. η_{ix} is the frequency coefficient and ζ_{ix} represents the damping effect. c_{00} and c_{10} are respectively the fixed effects for the random coefficients of η_{ix} and ζ_{ix}. e_{ij} is the within-person level error, with the assumption $e_{ij} \sim N(0, \sigma_e^2)$. That is, the within-person level error is normally distributed with mean equals zero and variance equals σ_e^2. Unlike the assumptions in ordinary least squares regression in Equation 2, the within-person level error, e_{ij}, in Equation 10 is not assumed to be independent. u_{oi} and u_{1i} are the between-person level errors. In this model, each individual's frequency and damping coefficients are allowed to vary randomly.

To choose the most appropriate value of τ, the model fit of the mixed-effects models of the derivatives of positive and negative affect was inspected (Boker & Laurenceau, 2006). r^2 was calculated for each individual's data using the following formula:

$$r^2 = 1 - \frac{\sigma^2(e_{ij})}{\sigma^2(\ddot{x}_{ij})} \tag{11}$$

$\sigma^2(e_{ij})$ is the residual variance of an individual's data around its own regression line. $\sigma^2(\ddot{x}_{ij})$ is the variance of an individual's second-order derivative. The mean explained variance (r^2) over 239 individuals' data and the lower 95% confidence interval of the explained variance were inspected for each value of τ = {1, 2, … 8}.

The appropriate value of τ was determined based on several criteria (Boker & Laurenceau, 2006). First, the fitted model using the appropriate value of τ should show a relatively high mean explained variance, indicating reasonable fit to the data. Second, τ should be relatively small because larger values of τ would tend to misrepresent short-term variations in the trajectory. In addition, larger values of τ result in a dataset of first- and second-order derivatives of fewer data points. Take τ = 1 as an example, the first- and second-order derivatives on day 1 and day 30 cannot be calculated because there is no data on day 0 and day 31. This means that in a 30-day dataset, taking τ = 1 results in a dataset of derivatives of 28 days. In general, depending on the value of τ, the resulting dataset of derivatives will have $30-\tau\times 2$ days of data for each individual. It is also noted that choosing an inappropriate value of τ will result in biased estimates of damping and frequency parameters (Boker & Laurenceau, 2006; Boker & Nesselroade, 2002). Sensitivity analysis was conducted to examine differences in results using different values of the time-delay constant, τ (Butner, Amazeen, & Mulvey, 2005).

Coupled oscillators model. When the appropriate value of τ was chosen, mixed-effects modeling was used to estimate the coefficients of the coupled oscillators model (Boker & Laurenceau, 2006). In this model, positive and negative affect self-regulate themselves and also regulate each other. The following coupled oscillators model was tested.

Level 1: (12)

$$\ddot{x}_{ij} = \eta_{ix} x_{ij} + \zeta_{ix} \dot{x}_{ij} + \eta_{iy} y_{ij} + \zeta_{iy} \dot{y}_{ij} + e_{ij}$$

Level 2:

$$\eta_{ix} = c_{00} + u_{0i}$$

$$\zeta_{ix} = c_{10} + u_{1i}$$

$$\eta_{iy} = c_{20} + u_{2i}$$

$$\zeta_{iy} = c_{30} + u_{3i}$$

x and y are one of the two variables: positive affect and negative affect. $\ddot{x}_{ij}$, $\dot{x}_{ij}$, and x_{ij}, are respectively the second-order derivative, the first-order derivative, and the displacement from equilibrium of individual *i*'s affect time series at time *j*. $\dot{y}_{ij}$ and y_{ij} are respectively the first-order derivative and displacement of individual *i*'s other affect time series at time *j*. η_{ix} and ζ_{ix} are respectively the frequency and damping coefficients of the self-regulation of affect respectively. η_{iy} and ζ_{iy} are the regulatory effects from the other affect. c_{00}, c_{10}, c_{20}, and c_{30} are the fixed effects for the random coefficients of η_{ix}, ζ_{ix}, η_{iy}, and ζ_{iy}, respectively. e_{ij} is the within-person level error, with the assumption $e_{ij} \sim N(0, \sigma_e^2)$. u_{oi}, u_{1i}, u_{2i}, and u_{3i} are the between-person level errors. In this model, each individual's frequency and damping coefficients of affect self-regulation, and the regulatory effects from the other affect are allowed to vary randomly.

Additional variables were added to the models to predict the regulation of positive and negative affect. To test the hypothesis whether daily stressors had an effect on emotion regulation, daily stressor was added in the level-1 model. To test the hypotheses whether emotion regulation showed individual and age differences, time-invariant variables including neuroticism, self-concept incoherence, and age were added in the level-2 model. Control variables were also entered into the models, including physical symptoms, gender, and mean positive and negative affect. The within-person variable physical symptoms was entered in the model because physical pain showed a negative effect on emotional experiences (Zautra, Johnson, & Davis, 2005; Zautra, et al., 2001). Previous studies also showed that physical symptoms were associated with daily stressors (Almeida, et al., 2002). Therefore, daily physical symptoms was added as a control variable in the level-1 model. Furthermore, gender was included as a control variable because men and women might experience different patterns of daily stressors (Almeida, et al., 2002). Mean positive and negative affect were also controlled because a tendency to experience positive affect seemed to be a protective factor to cope with stress (Ong, Bergeman, Bisconti, & Wallace, 2006; Tugade & Fredrickson, 2004). Thus, gender, and mean positive and negative affect scores were entered in the level-2 model as control variables. Analyses were performed using the nlme package in R (Pinheiro & Bates, 2000; R Development Core Team, 2009). Full Maximum Likelihood estimation was used to estimate model parameters.

CHAPTER 5

RESULTS

Results of this study are reported in four sections. First, descriptive findings regarding positive and negative affect, and daily stressors are presented. Second, I will present results from exploratory analyses of time series plots and random intercept models of positive and negative affect. The third section presents results of dynamical systems modeling that addressed the first research question concerning whether positive and negative affect showed a pattern of self-regulation. Next, I present results that addressed the second research question, examining the effect of daily stressors on emotion regulation. I then report results addressing research questions three to five. Specifically, I tested whether individuals differed in emotion regulation in response to daily stressors. Three individual difference variables were examined, including neuroticism, self-concept incoherence, and age. Control variables including physical symptoms, gender, and mean positive and negative affect were also examined. Finally, the last section reports results of the sensitivity analysis to examine the extent of differences in estimates using different values of the time-delay constant, τ.

Descriptive Findings

Across the 30-day assessment period, the mean daily positive affect was 27.17 (range = 10-50; *SD* = 8.33) and the mean daily negative affect was 12.82 (range = 10-42; *SD* = 3.99). The mean daily stress intensity was 1.54 (range = 0-14; *SD* = 1.83). Table 5.1 presents the descriptive statistics across age groups. The three age groups differed in

Table 5.1

Means and Standard Deviations of Affect, Daily Stressors, and Personality Variables

	Young adults		Middle-aged adults		Older adults	
	M	*SD*	*M*	*SD*	*M*	*SD*
Daily stressors	1.58	1.79	1.58	1.84	1.46	1.86
Neuroticism	16.06	7.40	15.79	7.67	12.16	8.34
Self-concept incoherence	.19	.10	.16	.10	.14	.11

Note. M represents mean and *SD* represents standard deviation.

neuroticism, $F(2, 236) = 6.11$, $p < .01$, and self-concept incoherence, $F(2, 236) = 5.41$, $p < .01$. Using Tukey's Honest Significant Differences test with 95% family-wise confidence level, results indicated that older adults reported a significantly lower level of neuroticism, compared to middle-aged (*M* difference = 3.63, $p < .05$) and young adults (*M* difference = 3.90, $p < .01$). For self-concept incoherence, older adults also scored significantly lower than young adults (*M* difference = .05, $p < .01$).

Exploratory Analyses

Time series plots of positive and negative affect for each participant were inspected. Figure 5.1 shows the scores of positive and negative affect of one randomly selected participant from each age group. The time series plots indicated that individuals might have a preferred equilibrium value for each affect score. In addition, individuals' positive and negative affect scores seemed to have regulatory effects on each other, as indicated by observations that positive and negative affect appeared to be further removed from equilibrium at the same time. For instance, in the young adult's affect time series, positive and negative affect scores were further away from equilibrium on days 22 and 24. Similarly, both affect scores were further away from equilibrium in the middle-aged adult's time series on days 10 and 15. Given these preliminary findings from the plotted data, it seemed reasonable to test a coupled oscillators model that positive affect and negative affect regulate each other and self-regulate themselves.

Next, a random intercept model grouped by individual was fitted to positive affect and negative affect separately. This model allowed the examination of the between- and within-person variance of the positive and negative affect time series:

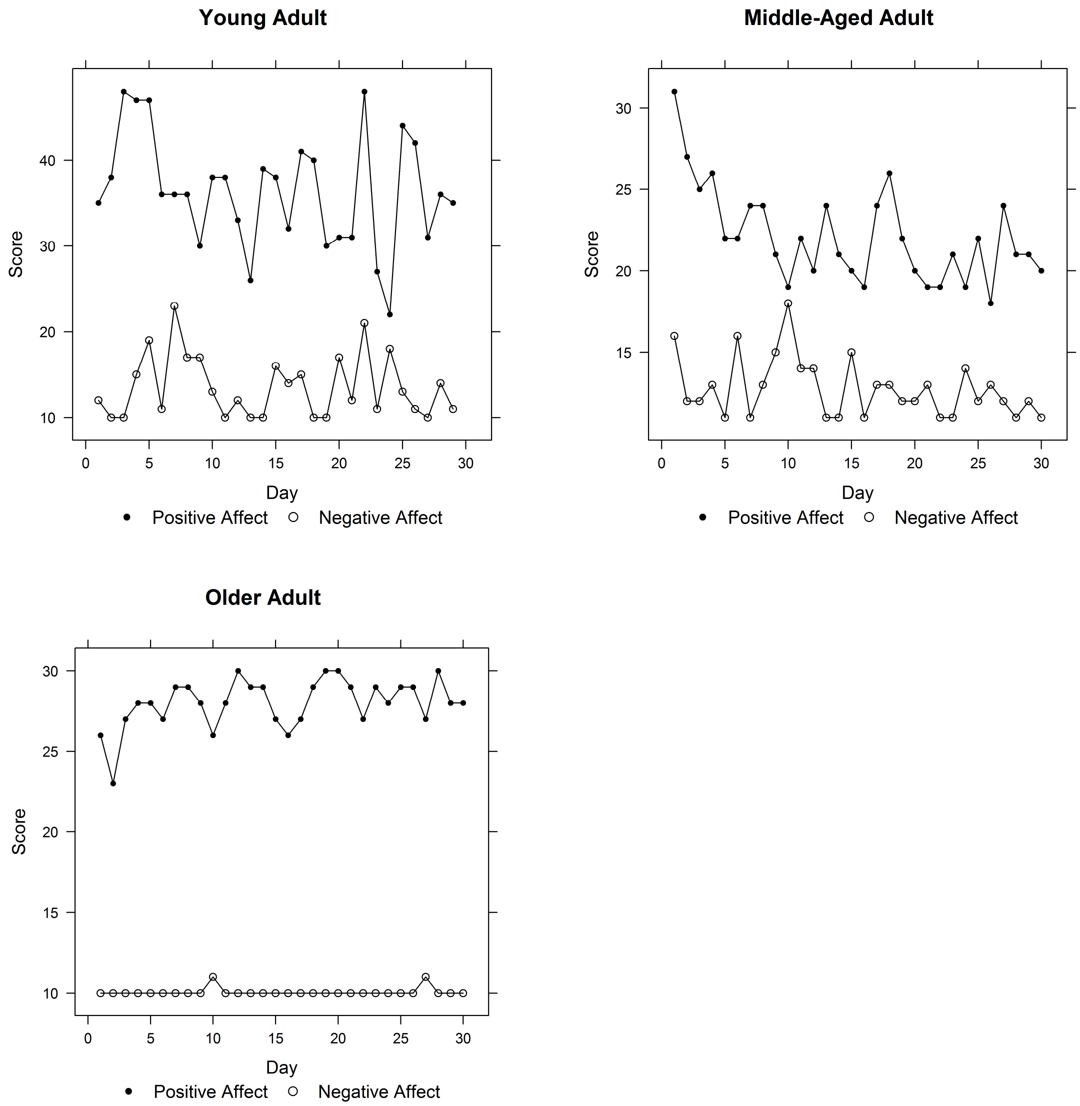


Figure 5.1. Time series of daily positive and negative affects for one randomly selected individual from each age group.

$$x_{ij} = b_i + e_{ij}$$

$$b_i = c_0 + u_i$$

x_{ij} is one of the two variables, positive affect or negative affect, for individual *i* on day *j*. b_i is the intercept for individual *i* and c_0 is the group mean for intercept across all occasions and individuals. e_{ij} is the within-person error and u_i is the between-person error.

Table 5.2 shows the between-person variance, σ_0^2, and the within-person variance, σ_e^2, for positive and negative affect. The between-person variability indicates that individuals differed in their equilibrium values in positive and negative affect. The proportions of within-person variability of positive and negative affect were calculated using the following formula:

$$\frac{\sigma_e^2}{\sigma_0^2 + \sigma_e^2}$$

The substantial amount of within-person variability for both positive affect (39%) and negative affect (57%) suggested that within individuals, affect scores varied across the 30-day assessment period.

In addition, the corresponding fixed intercept models were compared to the random intercept models, separately for positive and negative affect. The fixed intercept model is the ordinary least squares regression model assuming independence in the data points. It also assumes that individuals have the same equilibrium value, i.e. intercept. In contrast, the random intercept model relaxes the assumption of independence. That is, the random intercept model allows that responses within individuals are dependent on each

Table 5.2

Intercept-Only Mixed-Effects Models Grouped by Individual

Variable	Intercept	*SE*	σ_0^2	σ_e^2
Positive affect	27.15***	.42	42.04	27.21
Negative affect	12.83***	.17	6.88	9.07

Note. *SE* represents standard error. σ_0^2 is the between-person variance and σ_e^2 is the within-person variance.
*** $p < .001$.

other. Individuals' equilibrium values are also allowed to vary in the random intercept models. The Likelihood Ratio Test indicated that the random intercept models fit significantly better. For positive affect, Deviance = 5,542.36, $df = 1$, $p < .001$; for negative affect, Deviance = 3,152.63, $df = 1$, $p < .001$. Thus, these results suggested that there was substantial within-person variability in the positive and negative affect time series. This indicates that it was reasonable to examine whether the within-person variability of positive and negative affect behaved as a self-regulatory system.

Dynamical Systems Modeling

Using Local Linear Approximation, the linear trend from each individual's affect time series was removed by fitting an ordinary least squares regression in each individual's affect time series. Time-delay embedded state-space matrices were created, using the residuals of the detrended positive and negative affect time series. For each individual's affect time series, eight time-delayed embedded state-space matrices were created using various values of the time-delay constant, $\tau = \{1, 2, \ldots 8\}$. The first- and second-order derivatives of each individual's detrended positive and negative time series were calculated using Equations 8 and 9 as described in the Method chapter for various values of τ. To choose an appropriate value of τ, mixed-effects models of damped oscillator models were examined, using the estimated first- and second-order derivatives of positive and negative affect. Model fit comparisons were performed to choose the most appropriate value of τ (Boker & Laurenceau, 2006; Boker & Nesselroade, 2002).

Figure 5.2 shows the mean explained variance (r^2) of the models fitted (thicker lines) and the lower 95% confidence interval (thinner lines) of the explained variance plotted against the values of τ. The horizontal line at $r^2 = 0.656$ was the expected value

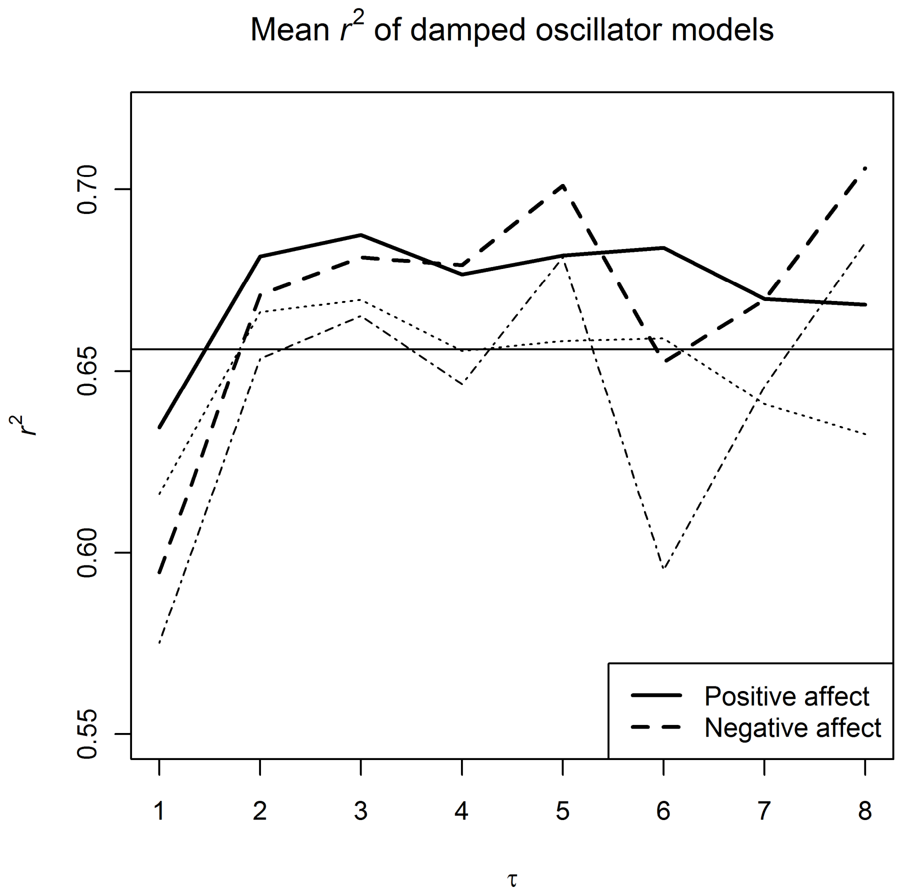


Figure 5.2. Mean explained within-individual variance (r^2) of damped oscillator models of positive and negative affect.

of r^2 for uncorrelated measurement error. Results supported the rejection of the hypothesis that the intraindividual variability in the detrended positive and negative affect time series was solely measurement error when $\tau \geq 3$. However, two observations suggested that $\tau = 2$ was the most appropriate value for the estimation of first- and second-order derivatives. First, the largest gain in the expected value of r^2 occurred between $\tau = 1$ and $\tau = 2$. Second, the expected value of r^2 for both positive and negative affect were close to their peak values at $\tau = 2$. In addition, previous studies showed that at the minimum value of τ, when r^2 first nears the maximum value, gives the minimum bias in the estimates of the frequency coefficients (Boker & Bisconti, 2006; Boker & Laurenceau, 2006). Furthermore, a smaller value of τ allows for the examination of shorter cycles. Thus $\tau = 2$, when the expected value of r^2 first neared its peak value, was selected as the most appropriate value for the calculation of the first- and second-order derivatives. Further analyses were based on the derivatives of the affect time series using $\tau = 2$. Sensitivity analysis was performed to examine the differences in estimates using different values of τ. Results of the sensitivity analysis are presented in the last section of this chapter.

Damped oscillator models. Using the derivatives calculated for $\tau = 2$, the following mixed-effects model was fitted for both the second-order derivatives of positive and negative affect.

Level 1:

$$\ddot{x} = \eta_{ix} x_{ij} + \zeta_{ix} \dot{x}_{ij} + e_{ij}$$

Level 2:

$$\eta_{ix} = c_{00} + u_{oi}$$

$$\zeta_{ix} = c_{10} + u_{1i}$$

Table 5.3 shows the results of the mixed-effects models for the damped oscillator model of positive affect, using τ = 2. Three models were fitted with different random effects estimated. Across Models 1 to 3, the frequency coefficient (η_{ix}) was significantly different from zero, suggesting that positive affect showed a pattern of oscillation in the 30-day period. In addition, the significant coefficient of η_{ix} indicated that the displacement of positive affect from equilibrium was negatively proportional to the curvature of the trajectory. This means that the farther positive affect was away from equilibrium, the greater attraction it had to return to equilibrium. Figure 5.3a shows the pattern of oscillation using the estimated fixed effects. The frequency coefficient, η_{ix}, can be converted to the period metric using the following equation:

$$\lambda = \frac{2\pi}{\sqrt{-\eta}}$$

Converting to the frequency coefficient (η_{ix}) to the period metric, the cycle of oscillation was 8.98 days. The significant damping coefficient (ζ_{ix}) indicated that there was evidence of damping in the trajectory of positive affect. This means that the fluctuations of positive affect from equilibrium decreased over time. Comparing Models 1 through 3, results from the Likelihood Ratio Tests suggested that retaining the random effect of τ_{11} did not improve the model fit (Models 1 vs. 2, Deviance = 0.00, *df* = 2, *p* > .05; Models 1 vs. 3, Deviance = 153.15, *df* = 2, *p* < .001). Therefore, Model 2 was selected as the best fitting model among the damped oscillator models of positive affect.

Table 5.3

Mixed-Effects Models Predicting Second Derivatives of Positive Affect (Damped Oscillator Model)

	Parameters	Model 1	Model 2	Model 3
Fixed effects				
pad	c_{00}	-.49*** (.01)	-.49*** (.01)	-.49*** (.00)
dpad	c_{10}	-.03* (.01)	-.03* (.01)	-.03* (.01)
Random effects				
pad	τ_{00}	.01	.01	--
dpad	τ_{11}	.00	--	.00
Residual	σ^2	2.49	2.49	2.65
Fit indices				
AIC		20,700.48	20,696.48	20,849.63
BIC		20,740.12	20,722.91	20,876.06
Log-Likelihood		-10,344.24	-10,344.24	-10,420.82

Note. Standard errors are in parentheses. pad is the detrended daily positive affect score; dpad is the first-order derivative of positive affect; c_{00} and c_{10} are the fixed effects; τ_{00} and τ_{11} are the level-2 variance-covariance components; σ_{ij}^2 is the level-1 variance; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion. The covariance component, τ_{01}, was estimated but not displayed.
*** $p < .001$. * $p < .05$.

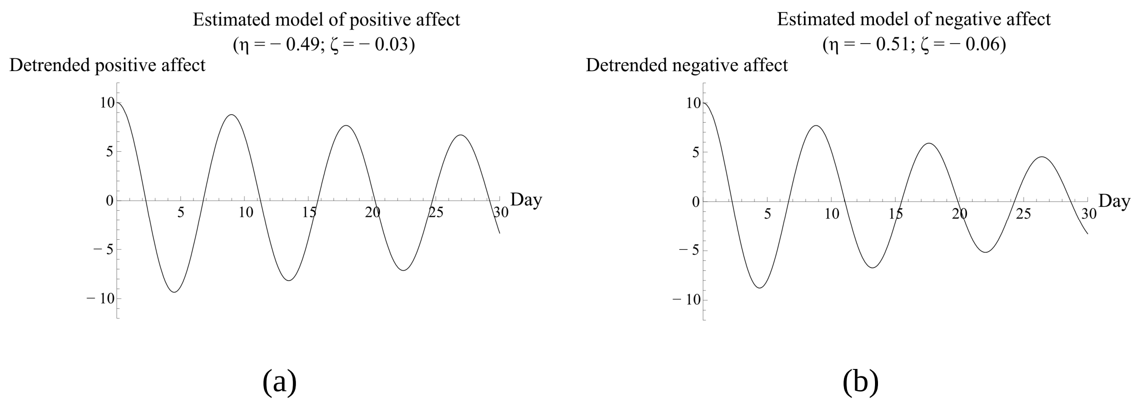


Figure 5.3. Estimated oscillation patterns of positive and negative affect.

Figure 5.3b shows the estimated pattern of oscillation of negative affect. Similar to positive affect, the frequency coefficient of η_{ix} of negative affect was significantly different from zero across Models 4 to 6 (Table 5.4). This suggests that negative affect showed a pattern of oscillation and the trajectory had a greater tendency to return towards equilibrium when it was farther away from equilibrium. The oscillation period was 8.80 days. The significant damping coefficient of ζ_{ix} indicated that there was evidence of damping in the trajectory of negative affect. This means that the fluctuations of negative affect decreased over time. Comparing Models 4 through 6, results from the Likelihood Ratio Tests indicated that retaining the random effects of η_{ix} and ζ_{ix} significantly improved the model fit (Models 4 vs. 5, Deviance = 12.41, $df = 2$, $p < .01$; Models 4 vs. 6, Deviance = 138.49, $df = 2$, $p < .001$). Thus, Model 4 was selected as the best fitting model among the damped oscillator models of negative affect.

Coupled oscillators models. To examine the potential coupling effect of the regulation of positive affect and negative affect, the following mixed-effects model was fitted, separately predicting the second-order derivatives of positive and negative affect.

Level 1:

$$\ddot{x}_{ij} = \eta_{ix} x_{ij} + \zeta_{ix} \dot{x}_{ij} + \eta_{iy} y_{ij} + \zeta_{iy} \dot{y}_{ij} + e_{ij}$$

Level 2:

$$\eta_{ix} = c_{00} + u_{0i}$$

$$\zeta_{ix} = c_{10} + u_{1i}$$

$$\eta_{iy} = c_{20} + u_{2i}$$

$$\zeta_{iy} = c_{30} + u_{3i}$$

Table 5.4

Mixed-Effects Models Predicting Second Derivatives of Negative Affect (Damped Oscillator Model)

	Parameters	Model 4	Model 5	Model 6
Fixed effects				
nad	c_{00}	-.51*** (.01)	-.51*** (.01)	-.51*** (.00)
dnad	c_{10}	-.06*** (.01)	-.06*** (.01)	-.06*** (.01)
Random effects				
nad	τ_{00}	.00	.00	--
dnad	τ_{11}	.01	--	.01
Residual	σ^2	.83	.84	.87
Fit indices				
AIC		14,679.34	14,687.75	14,813.83
BIC		14,718.98	14,714.18	14,840.26
Log-Likelihood		-7,333.67	-7,339.88	-7,402.92

Note. Standard errors are in parentheses. nad is the detrended daily negative affect score; dnad is the first-order derivative of negative affect; c_{00} and c_{10} are the fixed effects; τ_{00} and τ_{11} are the level-2 variance-covariance components; σ_{ij}^2 is the level-1 variance; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion. The covariance component, τ_{01}, was estimated but not displayed.
*** $p < .001$.

For the coupled oscillators model predicting the second-order derivative of positive affect, the model would not converge after 50 iterations. A simpler model was fitted, removing the random effects u_{2i}, and u_{3i}. Table 5.5 shows results of the coupled oscillators models predicting the second-order derivative of positive affect (Models 7, 8, and 9). The fixed effects of the frequency (η_{ix}) and damping coefficients (ζ_{ix}) were significantly different from zero. This suggests that positive affect showed a cyclical pattern over the 30-day assessment period. Positive affect also showed intrinsic damping over the 30-day assessment period. This means that the amplitude of fluctuation of positive affect decreased over time. However, the fixed effects of the regulatory effects of negative affect on positive affect (η_{iy} and ζ_{iy}) were not statistically significant. The Likelihood Ratio Test showed that Model 7 fit significantly better than Model 8, Deviance = 152.29, $df = 5$, $p < .001$. However, Model 7 did not fit significantly better than Model 9, Deviance = .00, $df = 5$, $p > .05$. Thus, the more parsimonious model, Model 9, was selected as the best fitting model among the coupled oscillators models of positive affect.

Table 5.6 shows results of the coupled oscillators models, predicting the second-order derivative of negative affect (Models 10, 11, 12, and 13). Similar to positive affect, both the fixed effects of the frequency (η_{ix}) and the damping coefficients (ζ_{ix}) for negative affect were significantly different from zero. This means that negative affect showed a cyclical pattern over the assessment period. In addition, negative affect showed intrinsic damping over the 30-day assessment period. The fixed effects of the regulatory effects of positive affect on negative affect were not significantly different from zero. The Likelihood Ratio Test suggested that Model 10 fit significantly better than Model 11,

Table 5.5

Mixed-Effects Model Predicting Second-Order Derivative of Positive Affect (Coupled Oscillators Model)

	Parameters	Model 7	Model 8	Model 9
Fixed effects				
pad	c_{00}	-.49*** (.01)	-.49*** (.00)	-.49*** (.01)
dpad	c_{10}	-.03* (.01)	-.03* (.01)	-.03* (.01)
nad	c_{20}	-.01*ns* (.01)	-.01*ns* (.01)	-.01*ns* (.01)
dnad	c_{30}	.01*ns* (.02)	.01*ns* (.02)	.01*ns* (.02)
Random effects				
pad	τ_{00}	.01	--	.01
dpad	τ_{11}	.00	.00	--
nad	τ_{22}	--	--	--
dnad	τ_{33}	--	--	--
Residual	σ^2	2.49	2.65	2.49
Fit indices				
AIC		20,709.03	20,851.32	20,699.03
BIC		20,781.7	20.890.96	20,738.67
Log-Likelihood		-10,343.52	-10,419.66	-10,343.52

Note. Standard errors are in parentheses. pad and dpad are respectively the detrended daily positive affect score and the first-order derivative; nad and dnad are respectively the detrended daily negative affect score and the first-order derivative. *SE* = standard error and *df* = degrees of freedom. AIC = Akaike Information Criterion. BIC = Bayesian Information Criterion. The covariance component, τ_{01}, was estimated but not displayed. *** $p < .001$. * $p < .05$. *ns* = not significant.

Table 5.6

Mixed-Effects Model Predicting Second-Order Derivative of Negative Affect (Coupled Oscillators Model)

	Parameters	Model 10	Model 11	Model 12	Model 13
Fixed effects					
nad	c_{00}	-.51*** (.01)	-.51*** (.01)	-.51*** (.00)	-.51*** (.01)
dnad	c_{10}	-.06*** (.01)	-.06*** (01)	-.06*** (.01)	-.06*** (.01)
pad	c_{20}	-.00*ns* (.00)	-.00*ns* (.00)	-.00*ns* (.00)	-.00*ns* (.00)
dpad	c_{30}	-.01*ns* (.01)	-.01*ns* (.01)	-.01*ns* (.01)	-.01*ns* (.01)
Random effects					
nad	τ_{00}	.00	.00	--	.00
dnad	τ_{11}	.01	.01	.01	--
pad	τ_{22}	.00	--	--	--
dpad	τ_{33}	.00	--	--	--
Residual	σ^2	.82	.83	.87	.84
Fit indices					
AIC		14,675.48	14,681.79	14,815.19	14,690.34
BIC		14,774.58	14,734.64	14,854.83	14,729.98
Log-Likelihood		-7,322.74	-7,332.90	-7,401.59	-7,339.17

Note. Standard errors are in parentheses. pad and dpad are respectively the detrended daily positive affect score and the first-order derivative; nad and dnad are respectively the detrended daily negative affect score and the first-order derivative. *SE* = standard error and *df* = degrees of freedom. AIC = Akaike Information Criterion. BIC = Bayesian Information Criterion. The covariance components, τ_{01}, τ_{02}, τ_{03}, τ_{12}, τ_{13}, τ_{23} were estimated but not displayed.

*** $p < .001$. *ns* = not significant.

Deviance = 20.31, *df* = 7, *p* < .01, Model 12, Deviance = 157.71, *df* = 9, *p* < .001, and Model 13, Deviance = 32.86, *df* = 9, *p* < .001. However, using BIC, Models 11 and 13 fit better than Model 10. Models 11 and 13 were more parsimonious than Model 10 and thus were more preferable than Model 10. Using the Likelihood Ratio Test, Model 11 fit significantly better than Model 13, Deviance = 12.55, *df* = 2, *p* < .01. Thus, Model 11 was selected as the best fitting model among the coupled oscillators models of negative affect. The Likelihood Ratio Test was used to compare the best-fitting damped oscillator model and the best-fitting coupled oscillators model, separately for positive and negative affect. For positive affect, the coupled oscillators model (Model 9) did not fit significantly better than the damped oscillator model (Model 2), Deviance = 1.45, *df* = 2, *p* > .05. Similarly, for negative affect, the coupled oscillators model (Model 11) did not fit significantly better than the damped oscillator model (Model 4), Deviance = 1.55, *df* = 2, *p* > .05. Taken together, these results suggested that the regulation of positive and negative affect was not coupled.

Given the lack of support of a coupled oscillators model, further analyses were performed using the best-fitting damped oscillator models of positive and negative affect (Model 2 and Model 4). Specifically, level-1 and level-2 covariates were added to the damped oscillator models, separately predicting the second-order derivative of positive and negative affect.

Damped oscillator models of positive affect with level-1 covariates. Table 5.7 shows results of the first set of damped oscillator models of positive affect, adding the original scores of daily stressors and daily physical symptoms in the level-1 model. Results showed that daily stressors had a statistically significant effect on the regulation

Table 5.7

Mixed-Effects Models Predicting Second-Order Derivative of Positive Affect (Adding Level-1 Covariates)

	Parameters	Model 14	Model 15	Model 16	Model 17
Fixed effects					
pad	c_{00}	-.50*** (.01)	-.50*** (.01)	-.50*** (.01)	-.50*** (.01)
dpad	c_{10}	-.03* (.01)	-.03* (.01)	-.03* (.01)	-.03* (.01)
Daily stressors	c_{20}	-.02* (.01)	-.02* (.01)	-.00*ns* (.01)	-.00*ns* (.01)
Physical symptoms	c_{30}	--	--	-.00* (.00)	-.00* (.00)
Random effects					
pad	τ_{00}	.01	.01	.01	.01
dpad	τ_{11}	--	--	--	--
Daily stressors	τ_{22}	.00	--	.00	--
Physical symptoms	τ_{33}	--	--	.00	--
Residual	σ^2	2.49	2.49	2.48	2.48
Fit indices					
AIC		20,697.78	20,693.78	20,700.14	20,690.14
BIC		20,744.02	20,726.81	20,772.81	20,729.78
Log-Likelihood		-10341.89	-10,341.89	-10,339.07	-10,339.07

Note. Standard errors are in parentheses. pad is the detrended daily positive affect score; dpad is the first-order derivative of positive affect. *SE* = standard error and *df* = degrees of freedom. AIC = Akaike Information Criterion. BIC = Bayesian Information Criterion. The covariance components, τ_{02}, τ_{03}, τ_{23} were estimated but not displayed.

*** $p < .001$. * $p < .05$. *ns* = not significant.

of positive affect (Models 14 and 15). The negative sign of the effect of daily stressors on the second-order derivatives of positive affect means that daily stressors were associated with a faster return of positive affect towards equilibrium when positive affect was above equilibrium. In contrast, when positive affect was below equilibrium, daily stressors were associated with a slower return of positive affect towards equilibrium. Substantively, daily stressors were associated with a faster than usual decrease in positive affect for positive affect to return towards equilibrium from above. Daily stressors were also associated with a slower than usual increase in positive affect for positive affect to return towards equilibrium from below.

However, when physical symptoms was entered into the model, the effect of daily stressors became non-significant (Models 16 and 17). The negative sign of the effect of physical symptoms means that physical symptoms were associated with a faster than usual decrease in positive affect for positive affect to return towards equilibrium from above. In contrast, physical symptoms were associated with a slower than usual increase in positive affect for positive affect to return towards equilibrium from below. The Likelihood Ratio Test showed that Model 17 fit better than Model 14, Deviance = 5.64, $df = 1$, $p < .05$, and Model 15, Deviance = 5.64, $df = 1$, $p < .05$. In addition, Model 16, the more complicated model, did not fit significantly better than Model 17, Deviance = .00, $df = 2$, $p > .05$. Compared to Model 2, where daily stressors and physical symptoms were not introduced into the model, Model 17 fit significantly better, Deviance = 10.35, $df = 2$, $p < .01$. Thus, Model 17 was selected as the best-fitting model among these damped oscillator models of positive affect. Level-2 covariates were then added in Model 17 to predict the regulation of positive affect.

Damped oscillator models of positive affect with level-2 covariates. Level-2 covariates including age, gender, self-concept incoherence, neuroticism, and individuals' mean positive and negative affect across the 30-day assessment, were added into Model 17. These variables were grand mean centered. Table 5.8 shows the taxonomy of the models fitted. Looking at Models 18 through 23, mean positive affect had a significant cross-level interaction effect with daily stressors. The other level-2 covariates did not predict the regulation of positive affect. Substantively, the positive sign of the cross-level interaction effect of daily stressors and mean positive affect on the second-order derivatives of positive affect means that the effect of daily stressors was weaker in individuals who experienced higher positive affect across days. The negative sign of the main effect of daily stressors (although non-significant) suggested that daily stressors were associated with a quicker return of positive affect towards equilibrium from above. However, the significant cross-level interaction effect suggested that the rate of return towards equilibrium from above (i.e. rate of decrease in positive affect) was slower in individuals with generally higher positive affect. In addition, daily stressors were associated with a slower return of positive affect towards equilibrium from below. However, the rate of return to equilibrium from below (i.e. rate of increase in positive affect) was faster in individuals who tended to experience higher positive affect across days.

A more parsimonious model, Model 24, was fitted, retaining only the cross-level interaction between daily stressors and mean positive affect. Using the Likelihood Ratio Test, Models 18 to 24 were compared against Model 17. Model 18 (Deviance = 10.63, $df = 3$, $p < .05$), Model 19 (Deviance = 10.66, $df = 4$, $p < .05$), Model 20 (Deviance = 11.38,

Table 5.8

Mixed-Effects Models Predicting Second-Order Derivative of Positive Affect (Adding Level-2 Covariates)

	Parameters	Model 18	Model 19	Model 20	Model 21	Model 22	Model 23	Model 24
Fixed effects								
pad	c_{00}	-.50*** (.01)	-.50*** (.01)	-.50*** (.01)	-.50*** (.01)	-.50*** (.01)	-.50*** (.01)	-.50*** (.01)
dpad	c_{10}	-.03* (.01)	-.03* (.01)	-.03* (.01)	-.03* (.01)	-.03* (.01)	-.03* (.01)	-.03* (.01)
Daily stressors	c_{20}	-.00*ns* (.01)	-.00*ns* (.01)	-.00*ns* (.01)	-.00*ns* (.01)	-.00*ns* (.01)	-.00*ns* (.01)	-.00*ns* (.01)
Physical symptoms	c_{30}	-.00* (.00)	-.00* (.00)	-.00* (.00)	-.00* (.00)	-.00* (.00)	-.00* (.00)	-.00* (.00)
Daily stressors × age	c_{21}	.00*ns* (.00)	.00*ns* (.00)	.00*ns* (.00)	.00*ns* (.00)	.00*ns* (.00)	.00*ns* (.00)	--
Daily stressors × gender	c_{22}	--	.00*ns* (.02)	.00*ns* (.02)	.00*ns* (.02)	.01*ns* (.02)	.01*ns* (.02)	--
Daily stressors × sci	c_{23}	--	--	-.07*ns* (.09)	-.06*ns* (.09)	-.07*ns* (.09)	-.07*ns* (.09)	--
Daily stressors × neu	c_{24}	--	--	--	-.00*ns* (.00)	-.00*ns* (.00)	-.00*ns* (.00)	--
Daily stressors × mean PA	c_{25}	--	--	--	--	.00* (.00)	.00* (.00)	.00* (.00)
Daily stressors × mean NA	c_{26}	--	--	--	--	.00*ns* (.00)	.00*ns* (.00)	--
Daily stressors × age x sci	c_{27}	--	--	--	--	--	-.00*ns* (.01)	--
Random effects								
dpad	τ_{00}	--	--	--	--	--	--	--
pad	τ_{11}	.01	.01	.01	.01	.01	.01	.01
Residual	σ^2	2.48	2.48	2.48	2.48	2.48	2.48	2.48
Fit indices								
AIC		20,691.85	20,693.82	20,695.11	20,696.98	20,696.69	20,698.68	20,687.66
BIC		20,738.10	20,746.68	20,754,56	20,763.05	20,775.97	20,784.57	20,733.9
Log-Likelihood		-10,338.93	-10,338.91	-10,338.55	-10,338.49	-10,336.35	-10,336.34	-10,336.83

Note. Standard errors are in parentheses. pad is the detrended daily positive affect score; dpad is the first-order derivative of positive affect; sci is self-concept incoherence; neu is neuroticism. Mean PA is the mean positive affect and mean NA is the mean negative affect. *SE* = standard error and *df* = degrees of freedom. AIC = Akaike Information Criterion. BIC = Bayesian Information Criterion.
*** $p < .001$. * $p < .05$. *ns* = not significant.

df = 5, $p < .05$), Model 22 (Deviance = 15.79, *df* = 8, $p < .05$), and Model 24 (Deviance = 14.83, *df* = 3, $p < .01$) fit significantly better than Model 17. In contrast, Model 21 (Deviance = 11.50, *df* = 6, $p > .05$) and Model 23 (Deviance = 15.80, *df* = 9, $p > .05$) did not fit significantly better than Model 17. The better fitting models (Models 18, 19, 20, 22, and 24) were compared against each other using AIC and BIC because they were not nested within each other. Both AIC and BIC indicated that Model 24 was the best-fitting model among these models. Thus, Model 24 was selected as the best-fitting model to predict the regulation of positive affect. Evidence shows that physical symptoms (level-1 covariate) and mean positive affect (level-2 covariate) predict the regulation of positive affect.

Damped oscillator models of negative affect with level-1 covariates. Daily stressors and daily physical symptoms were entered in the level-1 damped oscillator model, predicting the second-order derivative of negative affect. Table 5.9 shows results of the models fitted. The variable daily stressors was first added into the model. The effect of daily stressors on the regulation of negative affect was not statistically significant. The physical symptoms variable was then added into the model and its effect was not statistically significant either. The Likelihood Ratio Test showed that the model fit of Models 25-28 did not differ from each other, Deviance statistics ranged from .00 to .11, $p > .05$. Thus, the most parsimonious model, Model 26, was selected as the best-fitting model among the damped oscillator model with level-1 covariates, predicting the second-order derivative of negative affect. Comparing Model 26 with Model 4, however, the Likelihood Ratio Test showed that Model 26 did not fit significantly better than Model 4, Deviance = 2.16, *df* = 2, $p > .05$. The results thus showed that daily stressors

Table 5.9

Mixed-Effects Models Predicting Second-Order Derivative of Negative Affect (Adding Level-1 Covariates)

	Parameters	Model 25	Model 26	Model 27	Model 28
Fixed effects					
nad	c_{00}	-.52*** (.01)	-.51*** (.01)	-.51*** (.01)	-.51*** (.01)
dnad	c_{10}	-.06*** (.01)	-.06*** (.01)	-.06*** (.01)	-.06*** (.01)
Daily stressors	c_{20}	-.01*ns* (.01)	.00*ns* (.01)	-.01*ns* (.01)	-.01*ns* (.01)
Physical symptoms	c_{30}	--	--	-.00*ns* (.00)	-.00*ns* (.00)
Random effects					
nad	τ_{00}	.00	.00	.00	.00
dnad	τ_{11}	.01	.01	.01	.01
Daily stressors	τ_{22}	.00	--	.00	--
Physical symptoms	τ_{33}	--	--	.00	--
Residual	σ^2	.83	.83	.83	.83
Fit indices					
AIC		14,685.29	14,679.29	14695.18	14,681.18
BIC		14,751.35	14725.53	14,794.28	14734.03
Log-Likelihood		-7332.64	-7332.64	-7332.59	-7332.59

Note. Standard errors are in parentheses. nad is detrended daily negative affect score; dnad is the first-order derivative of negative affect. *SE* = standard error and *df* = degrees of freedom. AIC = Akaike Information Criterion. BIC = Bayesian Information Criterion.

*** $p < .001$. *ns* = not significant.

and physical symptoms did not have any statistically significant effect on the regulation of negative affect. However, to test individual differences in the impact of daily stressors on the regulation of negative affect, daily stressors and physical symptoms were retained in the model for further analyses. Thus, Level-2 covariates were added to Model 28 to predict the second-order derivative of negative affect.

Damped oscillator models of negative affect with level-2 covariates. Table 5.10 shows the models fitted, with level-2 covariates added to predict the regulation of negative affect. No cross-level interaction was statistically significant. In addition, the Likelihood Ratio Test indicated that these models fit the data equally well, Deviance statistics ranged from .05 to 4.56, $p > .05$. Thus, Model 29, the most parsimonious model, was selected as the best damped oscillator model of negative affect with level-2 covariates. Compared to Model 4, Model 29 did not fit significantly better, Deviance = 2.21, $p > .05$. Therefore, the results showed that no level-1 or level-2 covariate significantly predicted the regulation of negative affect.

Sensitivity Analysis

Results of the damped oscillator and coupled oscillators models presented so far were fitted using first- and second-order derivatives calculated for the time-delay constant, $\tau = 2$. Because the choice of the specific value of τ has substantial effects on the estimation of damping and frequency coefficients in the oscillator models (Boker & Nesselroade, 2002; Butner, et al., 2005), a sensitivity analysis was performed to compare results of mixed-effects models using $\tau = 2$ with results of models using $\tau = 3$ and $\tau = 5$. Values of $\tau = 3$ and $\tau = 5$ were selected for the sensitivity analysis for two reasons. First, these two values are relatively small in the range of values of τ (range = 1 – 8)

Table 5.10

Mixed-Effects Models Predicting Second-Order Derivative of Negative Affect (Adding Level-2 Covariates)

	Parameters	Model 29	Model 30	Model 31	Model 32	Model 33	Model 34
Fixed effects							
nad	c_{00}	-.51*** (.01)	-.51*** (.01)	-.51*** (.01)	-.51*** (.01)	-.51*** (.01)	-.51*** (.01)
dnad	c_{10}	-.06*** (.01)	-.06*** (.01)	-.06*** (.01)	-.06*** (.01)	-.06*** (.01)	-.06*** (.01)
Daily stressors	c_{20}	-.01*ns* (.01)	-.01*ns* (.01)	-.01*ns* (.01)	-.01*ns* (.01)	-.01*ns* (.01)	-.01*ns* (.01)
Physical symptoms	c_{30}	-.00*ns* (.00)	-.00*ns* (.00)	-.00*ns* (.00)	-.00*ns* (.00)	-.00*ns* (.00)	-.00*ns* (.00)
Daily stressors × age	c_{21}	.00*ns* (.00)	.00*ns* (.00)	.00*ns* (.00)	.00*ns* (.00)	.00*ns* (.00)	.00*ns* (.00)
Daily stressors × gender	c_{22}	--	.01*ns* (.01)	.01*ns* (.01)	.01*ns* (.01)	.01*ns* (.01)	.01*ns* (.01)
Daily stressors × sci	c_{23}	--	--	.02*ns* (.05)	.03*ns* (.05)	.02*ns* (.05)	.02*ns* (.05)
Daily stressors × neu	c_{24}	--	--	--	-.00*ns* (.00)	-.00*ns* (.00)	-.00*ns* (.00)
Daily stressors × mean PA	c_{25}	--	--	--	--	-.00*ns* (.00)	-.00*ns* (.00)
Daily stressors × mean NA	c_{26}	--	--	--	--	.00*ns* (.00)	.00*ns* (.00)
Daily stressors × age x sci	c_{27}	--	--	--	--	--	.00*ns* (.00)
Random effects							
nad	τ_{00}	.00	.00	.00	.00	.00	.00
dnad	τ_{11}	.01	.01	.01	.01	.01	.01
Residual	σ^2	.83	.83	.83	.83	.83	.83
Fit indices							
AIC		14,683.13	14,684.60	14,686.42	14,687.77	14,690.57	14,690.57
BIC		14,742.59	14,750.66	14,759.09	14,767.05	14,789.67	14,789.67
Log-Likelihood		-7,332.57	-7,332.30	-7,332.21	-7,331.89	-7,330.29	-7,330.29

Note. Standard errors are in parentheses. nad is the detrended daily negative affect score; dnad is the first-order derivative of negative affect. sci is self-concept incoherence; neu is neuroticism. Mean PA is mean positive affect and mean NA is mean negative affect. *SE* = standard error and *df* = degrees of freedom. AIC = Akaike Information Criterion. BIC = Bayesian Information Criterion.
*** $p < .001$. *ns* = not significant.

examined for the goodness of fit in the mixed-effects models of the derivatives of positive and negative affect. Smaller time-delay constants are preferred, allowing the examination of shorter cycles (Boker & Laurenceau, 2006). Second, as shown in Figure 5.2, similar to results using $\tau = 2$, the mean explained variance (r^2) of the damped oscillator models using $\tau = 3$ and $\tau = 5$ was relatively high.

Damped oscillator models of positive and negative affect were fitted for the first- and second-order derivatives calculated using $\tau = 2$, $\tau = 3$, and $\tau = 5$. These derivatives were calculated using the dataset of 239 participants' positive and negative affect across 30 days. Results of the damped oscillator models using different values of τ were compared in two ways. First, I examined the fixed and random effects of the damped oscillator models fitted. Second, using a random sample of 20 individuals from the total sample of 239 participants, I examined the estimated level-1 regression coefficients in the damped oscillator models fitted using different values of τ.

Fixed and random effects. Table 5.11 shows results of the damped oscillator models of positive affect fitted using $\tau = 2$, $\tau = 3$, and $\tau = 5$. For negative affect, results of the models fitted are presented in Table 5.12. It is noted that the model fit indices cannot be used to compare these models because using different values of τ resulted in different numbers of observations in the datasets of first- and second-order derivatives. Instead, the fixed and random effects of the models were examined to see if they were consistent and in the expected directions.

For positive affect, results of Models 35 through 37 showed that the frequency coefficients, η_{ix}, were significantly different from zero and had a negative sign. This means that positive affect showed a pattern of oscillation in the 30-day assessment

Table 5.11

Sensitivity Test of Estimation of Derivatives of Positive Affect

	Parameters	Model 35 (τ = 2)	Model 36 (τ = 3)	Model 37 (τ = 5)
Fixed effects				
pad	c_{00}	-.50*** (.01)	-.23*** (.00)	-.09*** (.00)
dpad	c_{10}	-.03* (.01)	-.03** (.01)	-.02*** (.01)
Random effects				
pad	τ_{00}	.01	.00	.00
dpad	τ_{11}	.00	.00	.00
Residual	σ^2	2.50	.48	.06
Fit indices				
AIC		21,274.86	10,844.04	403.01
BIC		21,314.66	10,983.27	441.02
Log-Likelihood		-10,631.43	-5466.02	-195.51

Note. Standard errors are in parentheses. pad is the detrended daily positive affect score; dpad is the first-order derivative of positive affect. *SE* = standard error and *df* = degrees of freedom. AIC = Akaike Information Criterion. BIC = Bayesian Information Criterion. *** p < .001. ** p < .01. * p < .05. *ns* = not significant.

Table 5.12

Sensitivity Test of Estimation of Derivatives of Negative Affect

	Parameters	Model 38 (τ = 2)	Model 39 (τ = 3)	Model 40 (τ = 5)
Fixed effects				
nad	c_{00}	-.51*** (.01)	-.23*** (.00)	-.09*** (.00)
dnad	c_{10}	-.06*** (.01)	-.03* (.01)	-.03*** (.01)
Random effects				
nad	τ_{00}	.00	.00	.00
dnad	τ_{11}	.01	.01	.01
Residual	σ^2	.83	.16	.02
Fit indices				
AIC		15,113.5	5,301.41	-4,191.47
BIC		15,153.21	5,340.65	-4,153.44
Log-Likelihood		-7,550.75	-2,644.70	2,101.74

Note. Standard errors are in parentheses. nad is the detrended daily negative affect score; dnad is the first-order derivative of negative affect. *SE* = standard error and *df* = degrees of freedom. AIC = Akaike Information Criterion. BIC = Bayesian Information Criterion. *** $p < .001$. * $p < .05$. *ns* = not significant.

period. Results also showed that the damping coefficients, ζ_{ix}, were statistically significant and had a negative sign. This means that the fluctuations of positive affect decreased over the 30-day period. In addition, the random effects across Models 35 through 37 were similar.

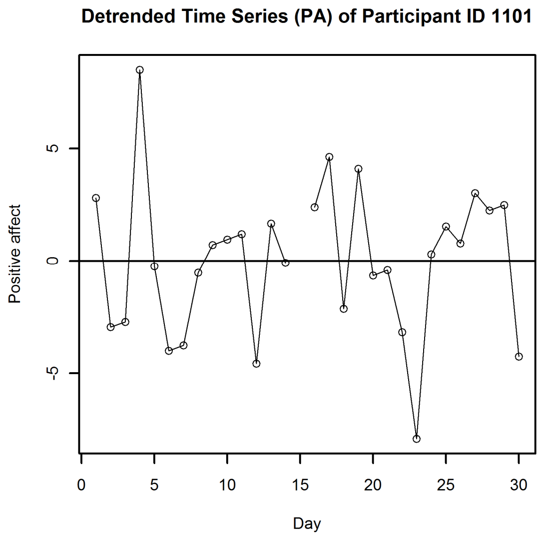
For negative affect, Table 5.12 presents results showing that the frequency coefficients, η_{ix}, and damping coefficients, ζ_{ix}, were statistically significant across Models 38 through 40. This means that negative affect fluctuated around an equilibrium and showed decreasing fluctuation across the 30-day assessment period. Furthermore, these damped oscillator models of negative affect showed similar random effects. In conclusion, these results showed that for both positive and negative affect, the damped oscillator models fitted using different values of τ showed consistent results in terms of the patterns of oscillations.

Estimated level-1 regression coefficients. In order to examine the extent of bias in the damping and frequency coefficients using different values of τ, I examined the estimated level-1 regression coefficients of the damped oscillator models of positive and negative affect (J. Butner, personal communication, February 1, 2010). Estimated level-1 regression coefficients are estimates of parameters in each individual's fitted model. That is, instead of examining fixed effects – the average damping and frequency coefficients of the entire sample – I examined the damping and frequency coefficients of individuals' models. A subset of 20 individuals was randomly selected from the total sample of 239 individuals. In the time series of these 20 selected individuals, their estimated frequency coefficients were converted into the period metric. The estimated period of oscillation of individuals' time series was checked against the period of oscillation in these individuals' plots of detrended affect time series.

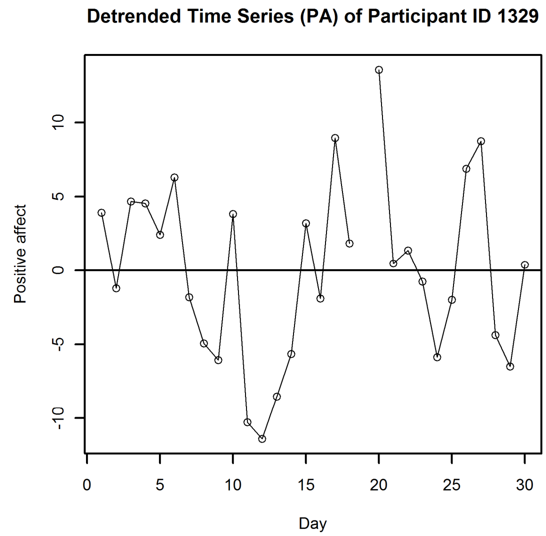
To illustrate, the plots of the detrended affect time series of three individuals, one from each age group, of this subset are presented in Figures 5.4 and 5.5. An examination of the plots of the 20 selected individuals found that the period of oscillation mostly ranged from 5 to 10 days for both positive and negative affect. Next, the frequency coefficients of these 20 individuals' models were converted into the period metric. Using $\tau = 2$, the estimated periods of oscillation in these 20 individuals' time series ranged from 8 to 10 days for positive affect and 8 to 11 days for negative affect. Using $\tau = 3$, the estimated periods of oscillations became a little longer, ranging from 13 to 15 days for positive affect and 12 to 16 days for negative affect. For $\tau = 5$, the estimated periods of oscillations became noticeably longer for both positive (20 to 24 days) and negative affect (21 to 22 days). Thus, the estimated periods of oscillations using $\tau = 2$ were the most consistent with the plots of individual time series. This also suggested that the frequency coefficients calculated using $\tau = 2$ were the least biased, compared to those calculated using $\tau = 3$ and $\tau = 5$. Therefore, results of the sensitivity analysis indicated that for $\tau = 2$, results of the dynamical systems models gave the least biased estimates. Figures 5.6 and 5.7 illustrate how the estimated models using $\tau = 2$ were able to capture individuals' time series of positive affect and negative affect respectively.

Summary

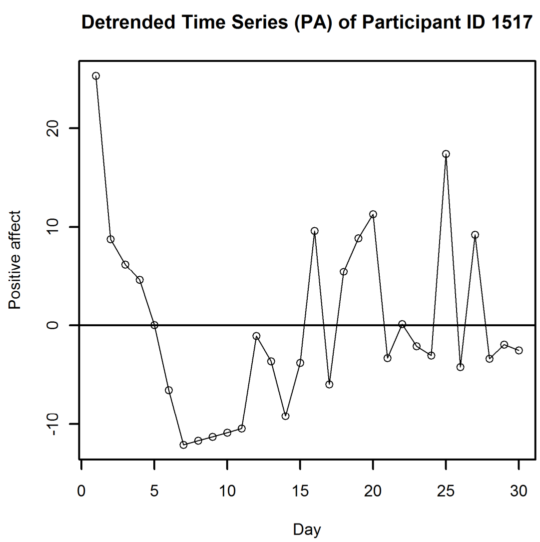
Dynamical systems modeling was used to test the hypothesis that positive affect and negative affect showed a pattern of self-regulation. I also tested the hypothesis that positive and negative affect regulate each other. In addition, daily stressors and individual



(a)



(b)



(c)

Figure 5.4. Plots of positive affect time series of three participants.

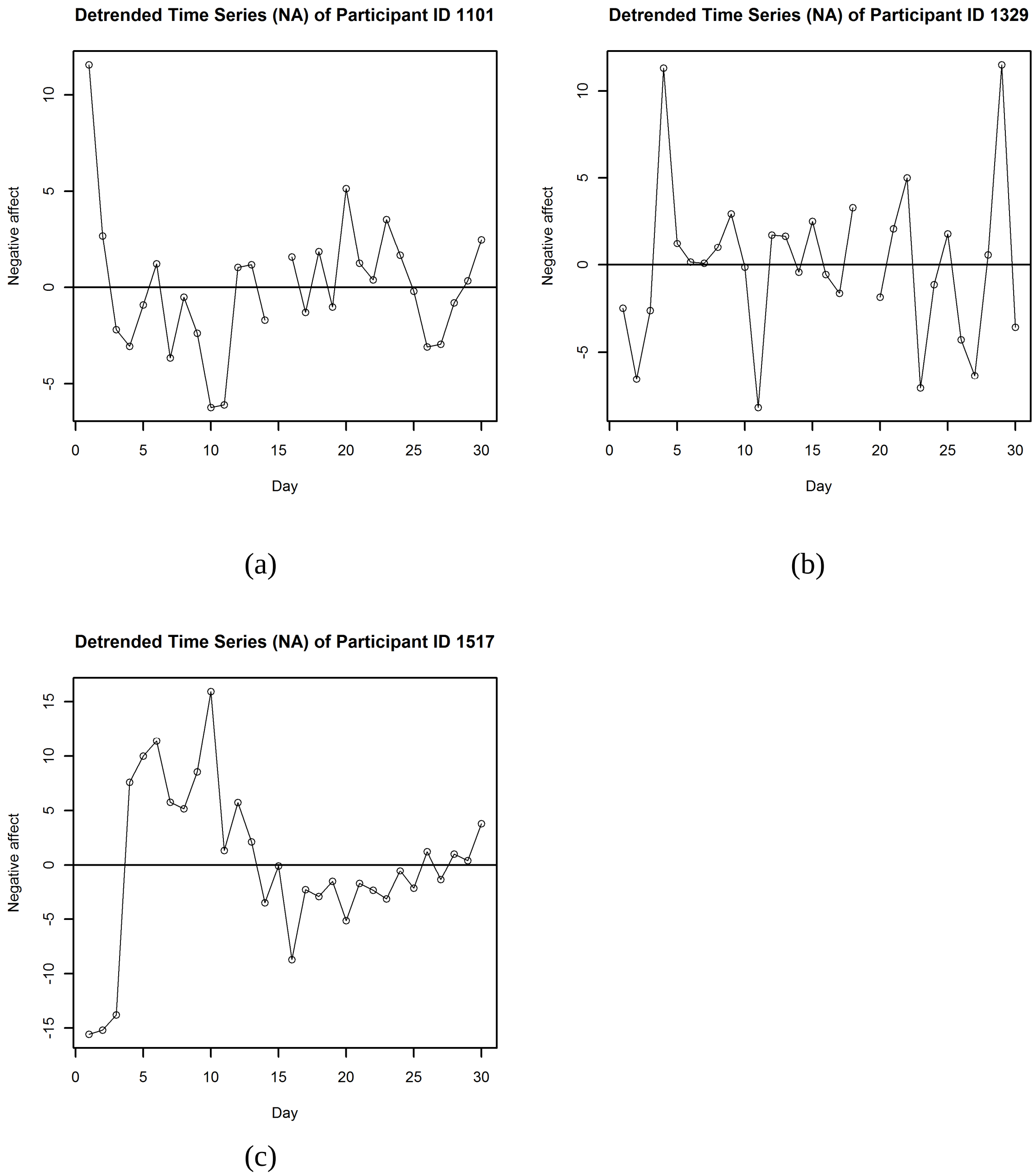
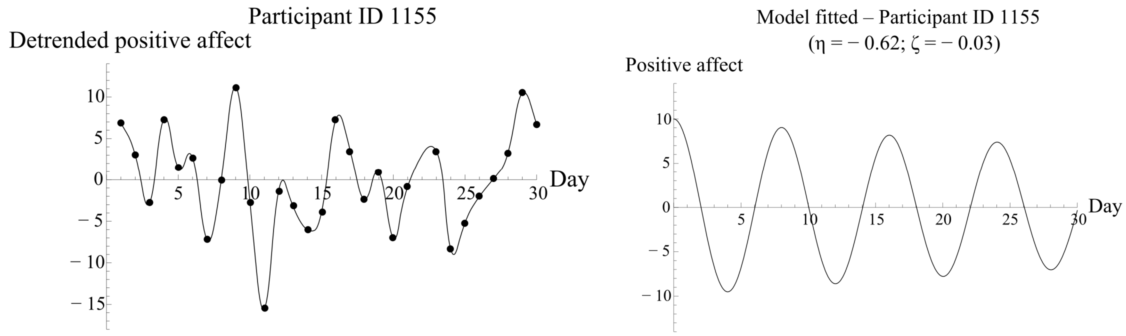
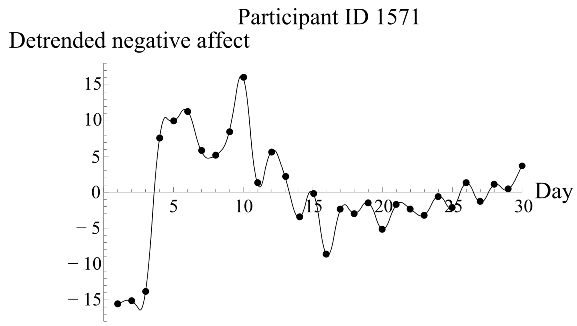


Figure 5.5. Plots of negative affect time series of three participants.

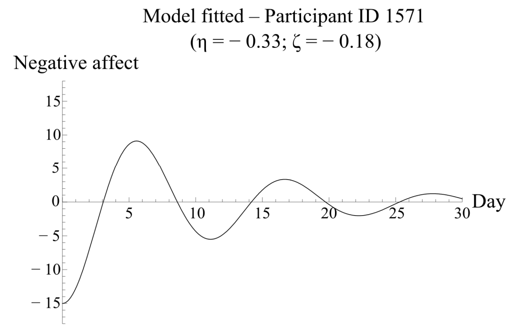


(a) (b)

Figure 5.6. Capturing individuals' times series of positive affect. This 26-year-old woman had a mean positive affect of 29.79 and mean negative affect of 15.00 across 30 days.



(a)



(b)

Figure 5.7. Capturing individuals' times series of negative affect. This 62-year-old man had a mean positive affect of 18.58 and a mean negative affect of 19.89 across 30 days.

difference variables were added into the model to test intra- and inter-individual differences in affect regulation. Results showed that both positive and negative affect showed a pattern of self-regulation. However, in contrast to the hypothesis, positive and negative affect did not regulate each other. In addition, daily stressors and individual difference variables did not predict the regulation of negative affect. For positive affect, daily stressors did not predict the pattern of self-regulation after the control variable physical symptoms was included in the model. The negative sign of the effect of physical symptoms means that physical symptoms were associated with a faster return of positive affect towards equilibrium from above and a slower return of positive affect towards equilibrium from below. Although the regulation of affect from above and from below equilibrium is represented the same mathematically as the second-order derivative, it is noted that the regulation of affect to decrease and return to equilibrium from above – *positive affect reduction* – may be qualitatively different from the regulation of affect to increase and return to equilibrium from below – *positive affect enhancement*. No hypothesized individual difference variable predicted the self-regulation of positive affect. However, the control variable, the mean positive affect, showed a cross-level interaction effect with daily stressors on the regulation of positive affect. The positive sign of the cross-level interaction effect means that controlling the level of daily stressors, individuals with higher mean positive affect tended to have a slower rate of return of positive affect towards equilibrium from above. In contrast, controlling for daily stressors, individuals with higher mean positive affect also tended to have a faster rate of return of positive affect towards equilibrium from below. That is, for individuals who generally showed higher positive affect, the effect of daily stressors on the regulation of positive affect was weaker.

CHAPTER 6

DISCUSSION

The discussion consists of three parts. The first part provides a summary of the main findings addressing each of the five research questions in the study. Second, findings are discussed in regard to four major issues in the field of emotion regulation in adulthood. The first issue concerns the conceptualization and measurement of emotion regulation. Second, the current approaches employed in the study of the effect of daily stressors on emotion regulation are discussed. The third issue concerns the association between personality characteristics and emotion regulation. Finally, the development of emotion regulation in adulthood is discussed. The third part discusses the limitations of the study. The discussion will close with implications of the findings and what further research needs to be done to address questions regarding emotion regulation in adulthood.

Main Findings

This study applied dynamical systems modeling in the examination of the systematic patterns of the regulation of daily positive and negative affect. Addressing the first research question, findings showed that positive and negative affect showed a pattern of self-regulation but the two affect systems did not regulate each other. These findings advance current understanding of emotion regulation in adults in two ways. First, consistent with the study hypothesis, results indicated that positive and negative affect showed a pattern of self-regulation such that the affect level was regulated to avoid excessive departure from the equilibrium. Contrary to the study hypothesis, however, the regulation of positive and negative affect was not coupled. Specifically, changes in positive affect did not have any statistically significant effect on the regulation of negative affect, and vice versa.

Second, although this was not the primary objective of the study, the findings underscored the role of positive emotionality in emotion regulation. In part addressing the second research question, results showed that the effect of daily stressors on the regulation of positive affect was moderated by the mean positive affect across the 30-day assessment period. For individuals who experienced higher positive affect in general, the effect of daily stressors on the regulation of positive affect was weaker. Specifically, when positive affect was above equilibrium, positive affect reduction associated with daily stressors was slower in individuals with higher positive affect in general. In other words, individuals with higher positive affect in general were better able to regulate their daily positive affect to stay above equilibrium in response to daily stressors. In addition, individuals who experienced higher positive affect in general showed faster positive affect enhancement in response to daily stressors. That is, they were better able to regulate their positive affect to increase and return towards equilibrium from below in response to daily stressors.

Contrary to the study hypothesis, the effect of daily stressors on the regulation of negative affect was not statistically significant. To address research questions three to five, neuroticism, self-concept incoherence, and age did not predict the regulation of positive and negative affect as hypothesized.

Conceptualization and Measurement of Emotion Regulation

Results of this study suggest that the application of dynamical systems modeling is promising in research on emotion regulation (Boker & Nesselroade, 2002). Although emotion regulation is by definition concerned with the process of emotional changes, emotion regulation has been largely conceptualized and measured in terms of the level of emotional experiences. Most studies by far used multilevel modeling to model daily levels of emotions and did not take into account the temporal sequence of emotions. In contrast, the application of dynamical systems modeling in repeated measurements of daily emotions allows for the understanding of emotion regulation in terms of changes in emotional experiences from one observation to the next.

The findings revealed that positive and negative affect showed a systematic pattern of self-regulation, such that positive and negative affect oscillated around individuals' own equilibrium and excessive departure from the equilibrium was avoided. This is consistent with findings that individuals differed in their average levels of positive and negative affect over time, as indicated by the substantive amount of between-person variance in the repeated measures of daily affect (Cranford, et al., 2006; Nezlek & Kuppens, 2008). This finding is also consistent with the conceptualization of emotion regulation as a self-regulatory process (Carver, 2004). As such, individuals change their emotions in accord to certain standards. One standard of emotion regulation is individuals' preferred equilibrium such that emotion is regulated to lie within certain thresholds around the equilibrium.

Findings showed that positive and negative affect showed a cyclical pattern of oscillation, with a period of about eight days. Although the estimated period of oscillation using Local Linear Approximation may be biased (Boker & Nesselroade, 2002), this finding is consistent with pervious findings of the cyclicity of emotional experiences (Ram, et al., 2005) where daily emotions showed a pattern of weekly cycles. Studies of emotion regulation, however, mostly have not included the examination of the cyclicity of emotional experiences (e.g. Ong, et al., 2006; Sliwinski, Almeida, Smyth, & Stawski, 2009). The cyclical pattern of emotional experiences has implications on studies of intra-individual variability of emotional experiences. Specifically, the within-person variability in emotions may come from two sources: (a) cycles of emotional experiences and (b) the effect of time-varying variables such as daily stressors and physical pain. To speak of the effect of time-varying variables on daily emotional experiences (e.g. stress reactivity), the variability associated with the cyclicity of emotional experiences needs to be teased out from the total within-person variability of emotional experiences. The application of dynamical systems modeling enables the separation of these two sources of within-person variability of emotional experiences. Thus, dynamical systems modeling enables the examination of emotional cycles and the effect of time-varying variables on daily emotions.

The finding of the significant damping effect of emotion regulation, however, was unexpected. Although a previous study found a significant damping effect in the emotional well-being of recently bereaved widows (Bisconti, et al., 2004), participants in the present study were not selected based on any recent experience of major life events. Individuals in this study were not expected to experience more initial within-person variability in positive and negative affect in the 30-day assessment period. Possible reasons of this initial spike of positive and negative affect include reactance as a result of study participation and the development of a habitual response style over the period of study (Bolger, et al., 2003). Reactance refers to participants' heightened awareness of their emotional experiences at the beginning of study participation. In contrast, a habitual response style refers to participants' tendency to become less careful in their daily reports of emotional experiences. Although study participation may have an unintended effect on participants' self-report of emotional experiences, the application of dynamical systems modeling enables the separation of the damping effect from the other effects of interest, such as daily stressors.

Separate systems of emotion regulation. Results of the coupled oscillators model suggested that the regulation of positive affect and negative affect are two separate systems. The regulation of one affect was not associated with the regulation of the other affect. This is consistent with the conceptualization of the two affect systems as independent systems (Watson, et al., 1988). Findings did not support the proposition of the Broaden-and-Build Theory (Fredrickson, 1998) that positive affect has an effect on the regulation of negative affect. One reason for this inconsistent finding is that previous studies did not take into account the affect cycles in the examination of the effect of positive affect on negative affect. However, findings of this study are in partial support for the Broaden-and-Build Theory that positive emotionality has a protective effect on emotion regulation. Specifically, mean positive affect showed a buffering effect on the regulation of positive affect against the effect of daily stressors. Individuals who experienced higher positive affect in general showed a slower rate of positive affect reduction from above equilibrium in response to daily stressors. They also showed a faster rate of positive affect enhancement from below equilibrium in response to daily stressors. However, the protective effect of positive emotionality seemed to be limited to the regulation of positive affect only. Positive emotionality did not appear to have any buffering effect to the regulation of negative affect against the effect of daily stressors.

Daily Stressors and Emotion Regulation

Results suggested that daily stressors did not have any effect on the regulation of negative affect. These results are inconsistent with previous research showing that daily stressors had an impact on daily negative affect (Neupert, et al., 2007; Sliwinski, et al., 2009). Three reasons may account for this inconsistency. First, previous studies did not separate the effect of affect cycles from the total within-person variability in daily affect. The examination of the effect of daily stressors on emotion regulation needs to separate the effect of daily stressors from effects of other time-varying variables, such as affect cycles, in the total within-person variability in affect. The importance of considering the cyclicity of emotional experiences in naturalistic studies of emotional experiences was discussed in the previous section. Second, previous studies examined the level of negative affect, not the regulation of negative affect, either, the tendency for negative affect to return towards equilibrium. Although daily stressors may increase negative affect, daily stressors may or may not change individuals' tendency to regulate their negative affect to return towards equilibrium. Third, there might not be a substantial amount of within-person variability in negative affect to be explained. Consistent with previous studies (Carstensen, et al., 2000; Ong, et al., 2006), individuals tended to report more positive affect than negative affect. Negative affect also showed less within-person variability than positive affect. Therefore, there might not be much within-person variability in negative affect to explain, after taking into account the effects of cyclicity and damping.

Findings provided partial support to the Dynamic Affect Model (Zautra, 2003), such that emotion regulation is dependent on the context. Daily stressors were associated with a quicker return of positive affect towards equilibrium from above. In contrast, daily stressors were associated with a slower return of positive affect from below equilibrium. However, when the control variable physical symptoms was entered into the model, the effect of daily stressors on the regulation of positive affect became non-significant. This indicated that compared to daily stressors, physical symptoms accounted for more variance in the regulation of positive affect.

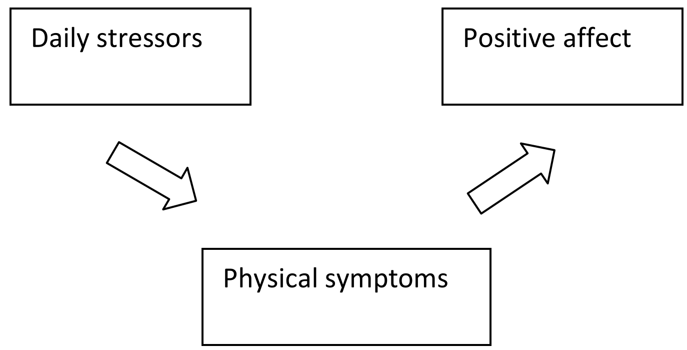
Two possible reasons may explain this result. First, the assessment of physical symptoms in this study did not distinguish between the chronic or acute nature of physical symptoms. In contrast, previous studies particularly examined the physical pain level of women with chronic health problems such as arthritis (Zautra, Johnson, et al., 2005). It is possible that the chronic nature of physical symptoms, e.g. the years of experience of backache, makes physical symptoms more important in emotion regulation. Conversely, it is also possible that the acute nature of physical symptoms, e.g. getting a flu, makes the effect of physical symptoms more dramatic and thus have a stronger effect than daily stressors as measured by minor interruptions of daily routines. Furthermore, previous studies suggested that different types of physical symptoms (e.g. pain, respiratory symptoms, and gastrointestinal distress) were differentially associated with negative affect (Charles & Almeida, 2006). It is currently unclear how the chronic versus acute nature and the different types of physical symptoms may have differential effects on emotion regulation.

The second possible reason concerns the mechanism of stress reactivity. Stress reactivity in everyday life has been measured in two ways: (a) psychological reactivity (e.g. changes in positive and negative affect) and (b) physiological reactivity (e.g. changes in physical symptoms and blood pressure), in response to daily stressors (Hay & Diehl, 2010; Uchino, Berg, Smith, Pearce, & Skinner, 2006; Uchino, Holt-Lunstad, Bloor, & Campo, 2005). Previous studies also separately examined the effects of daily stressors and physical pain on everyday emotions (Sliwinski, et al., 2009; Zautra, Johnson, et al., 2005). In studies examining the association between daily stressors and everyday affect, physical symptoms are either conceptualized as a kind of stressor that taxes individuals' cognitive and psychological resources (Zautra, et al., 2000), or as an outcome variable in response to daily stressors (Hay & Diehl, 2010; Uchino, et al., 2006). The present study, however, examined the effect of daily stressors while controlling for physical symptoms.

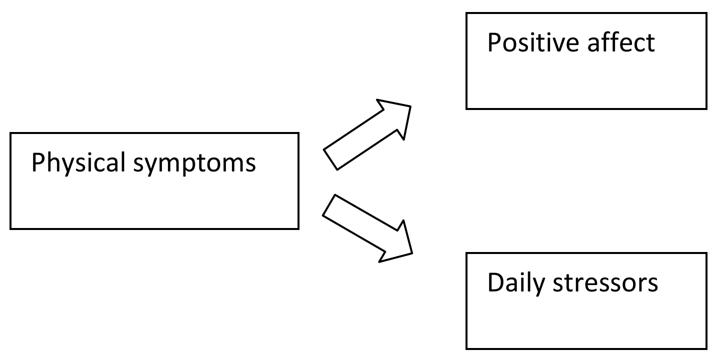
Although both psychological reactivity and physiological reactivity have been used to measure stress reactivity, past research showed that psychological reactivity and physiological reactivity do not couple in response to daily stressors (Uchino, et al., 2006). That is, individuals who report higher psychological reactivity may or may not report higher physiological reactivity in response to daily stressors. To illustrate, mixed results have been found regarding age differences in psychological reactivity in terms of negative affect. Some studies found that compared to young adults, older adults showed greater stress reactivity associated with the occurrence of daily stressors (Mroczek &

Almeida, 2004; Sliwinski, et al., 2009). In contrast, some studies found that older adults reported less increase in negative affect in response to daily stressors than young adults (Uchino, et al., 2006). General statements of age differences in stress reactivity are further complicated by the finding that daily stressors had a greater effect on cardiovascular reactivity in older adults than young adults, although older adults reported less increase in negative affect (Uchino, et al., 2006; Uchino, et al., 2005). Findings from these studies showed that in response to stressors, reactivity in different domains may be in different directions. In addition, reactivity in different domains may differ in different age groups.

Results of this study suggested two possible models of stress reactivity (Figure 6.1). First, physical symptoms may be a mediator in the association between daily stressors and positive affect (Figure 6.1a). Second, physical symptoms may be a confounding variable that causes changes in both positive affect and daily stressors (Figure 6.2b). These two models are statistically equivalent and the selection of a better model needs to be based on theoretical reasoning. A closer examination of the conceptualization and measurement of daily stressors suggests that the confounding variable model (Figure 6.1b) is theoretically unlikely. Physical symptoms may be conceptualized as a kind of daily stressors (Zautra, Affleck, et al., 2005) and are expected to be associated with daily stressors. Evidence shows that daily stressors may lead to physical symptoms (Uchino, et al., 2006). However, physical symptoms are not expected to cause daily stressors, a contextual variable. The direction of the effect of physical symptoms on daily stressors in the confounding variable model cannot be supported by theoretical reasoning. Therefore, the mediation model of stress reactivity is more



(a)



(b)

Figure 6.1. Models of stress reactivity.

theoretically likely. Future research is needed to decipher the complicated link between affect, physical symptoms, and stressors.

Neuroticism, Self-Concept Incoherence, and Emotion Regulation

Contrary to hypotheses, neuroticism and self-concept incoherence were not associated with the regulation of positive and negative affect. These findings are inconsistent with findings that neuroticism and self-concept incoherence were associated with stress reactivity (Bolger & Schilling, 1991; Hay & Diehl, 2010). One reason is that there is not much individual difference in the effect of daily stressors on emotion regulation. Both the fixed effect and random effect of daily stressors were small. There may not be enough power to detect any effect of individual differences on stress reactivity.

Adult Development of Emotion Regulation

The Socioemotional Selectivity Theory and Dynamic Integration Theory postulate that developmental changes in emotion regulation occur in adulthood. Contrary to my hypothesis, findings of this study did not support these theories and age was not associated with the regulation of positive and negative affect. This finding is inconsistent with findings from several self-report, experimental, and intensive longitudinal studies. Self-report studies found that older adults regulate their emotions better than young adults (Gross, et al., 1997; Kessler & Staudinger, 2009). Experimental studies also found that older adults were better able to inhibit their emotions in terms of their subjective emotional intensity and the frequency of the use of emotion words (Magai, et al., 2006). For intensive longitudinal studies, previous findings indicated age difference in stress reactivity (Uchino, et al., 2005).

There are three possible reasons for this inconsistency in findings. First, as I have already noted, this study adopted a different measure of emotion regulation, focusing on the tendency for affect to return towards equilibrium. However, for the previous self-report and experimental studies, results were based on measurements of emotion regulation in terms of between-group differences of emotional experiences and not within-person processes of emotional changes in naturalistic settings. For the intensive longitudinal studies, results were based on the level of daily affect or cardiovascular activities (e.g. blood pressure). Although older adults may believe that they regulate their emotions well and have higher general positive affect than other age groups, they may be no better than adults of other ages in regulating their daily emotions to return towards equilibrium in response to stressors.

Second, mixed results have been reported with regard to the age differences in the effect of stressors on daily emotions. Some studies found an increase in stress reactivity with age (Mroczek & Almeida, 2004) and others found no age differences (Röcke, Li, & Smith, 2009). Thus, it may well be that the direction of age differences in stress reactivity may depend on the measured domains, e.g. affect or physiological changes (Uchino, et al., 2005). Age differences in stress reactivity are further complicated by findings from a recent study suggesting that stress reactivity depends on the type of stressors (Hay & Diehl, 2010). In the present study, however, the variable of interest was stress intensity and not the number of stressors. It is possible that stress intensity may in part take into account the differential effect of the different types of stressors. Considering the complicated mechanism of stress reactivity, it remains unclear whether adults of different ages regulate their emotions better or worse in response to stressors.

Third, age differences in within-person variability of daily affect may play a role in the age differences in emotion regulation. In the present study, results showed that older adults had less within-person variability than young and middle-aged adults in positive and negative affect. This is consistent with previous findings that compared to young adults, older adults experienced less within-person variability in everyday emotions (Röcke, et al., 2009). For individuals who have lower within-person variability of daily affect (i.e., their affect tends to stay closer to their equilibrium), they may not have a high need to regulate their affect to equilibrium because they can tolerate the experienced deviations, compared to individuals with higher within-person variability of daily affect. Thus, the magnitude of the within-person variability may moderate the effect of daily stressors on emotion regulation. Future research may examine age differences in emotion regulation controlling for within-person variability in daily emotions.

Limitations

This study shows that dynamical systems modeling is useful in the study of the regulation of everyday emotions. However, there are a number of limitations. First, the daily diary design requires substantially more time commitment on the participants, compared to conventional research designs. Given their commitment and motivation, the study sample may not be representative to community-residing individuals of all ages. It is not known whether this sample had more or less variability in their daily emotions compared to population samples.

Second, the sample consisted of a relatively homogeneous group of healthy individuals of predominantly the European-American origin. Findings of this study may have limited generalizability to individuals who have physical or mental health conditions. In addition, findings may not be readily generalizable to other cultural subgroups in the United States and in other cultures. In particular, previous findings showed that some cultural subgroups (e.g. racial/ethnic minorities, and gay, lesbian, and bisexual individuals) reported stress exposure related to their disadvantaged social statuses (Banks, Kohn-Wood, & Spencer, 2006; Meyer, Schwartz, & Frost, 2008). Findings of the present study might have underestimated the effect of stressors related to social statuses.

Third, due to the limitation of assessment that thousands or even hundreds of measurement occasions are rarely obtained in most psychological studies, dynamical systems modeling of daily affect requires analysis of the estimated first- and second-order derivatives, instead of the observed affect scores (Boker & Nesselroade, 2002). Findings thus depend on the accuracy of the estimated derivatives. The present study used Local Linear Approximation to estimate the derivatives and sensitivity analyses were performed to test the possible bias in the estimated coefficients. Recent development in the application of dynamical systems modeling suggested that General Local Linear Approximation may overcome some weaknesses in Local Linear Approximation. For instance, results using General Local Linear Approximation showed reduced standard error and increased individual differences in periods (Boker, Deboeck, Edler, & Keel, 2010). Future studies may use different estimation methods to obtain first- and second-order derivatives of the affect time series and determine the possible bias in the estimates of coefficients.

Fourth, related to the limited number of measurement occasions, the one-day measurement interval of stressors and affect adopted in this study might have underestimated the effect of stressors on emotions, compared to other studies using the ecological momentary assessment of multiple assessments daily. For instance, the effect of stressors might be reduced when individuals reported their affect and stressors by the end of the day. Individuals might report less stress intensity than they would, if they were to report their affect and stressors earlier during the day. Individuals might also differ in how quickly the effect of stressors was reduced. Thus, findings of this study might have underestimated the effect of stressors on emotion regulation.

Implications and Future Research

A major contribution of this study is that emotion regulation in everyday life was studied in terms of a self-regulatory process and not the level of daily affect. The conceptualization of emotion regulation as a self-regulatory process is in line with the definition of emotion regulation as the moderation of emotional experiences. Results showed that dynamical systems modeling can be applied to empirical data successfully. This study also advances the use of dynamical systems modeling by adding level-1 covariates in the multilevel models. This is important because both within-person and between-person differences are expected to have effects on emotion regulation. The application of dynamical systems modeling in studies of everyday emotional experiences may open up new ways of answering old questions. In particular, emotion regulation can be operationalized as the tendency of affect changes and not the level of affect states. The coupling of regulatory systems, e.g. emotion and cognition, can also be examined. In addition, dynamical systems modeling may enable better identification of intra- and inter-individual differences, and age differences in emotion regulation by teasing out method effects, such as reactance, from other effects of interests.

This study offers insights for future research. The increasing availability of electronic data collection of everyday experiences means that researchers are now better equipped to study the ebb and flow of emotional experiences over time (Khan, Markopoulos, & Eggen, 2009). Statistical softwares also make intensive measurement methods (Walls & Schafer, 2006) increasingly available. Future research should examine everyday emotions in shorter time intervals, i.e. within-day assessment, provided that electronic data collection effectively minimizes the burden on participants. The availability of everyday emotions in shorter time intervals enables better understanding of how emotions unfold over time, e.g. within a day. Future research should also explore the possibility of other ways in which everyday emotions may be regulated. Currently, the hedonistic approach is influential in the field of emotion regulation in adulthood. Instead of regulating emotions to return towards equilibrium, the goal of emotion regulation may seek to regulate positive affect to stay above equilibrium and regulate negative affect to stay below equilibrium (Carstensen, et al., 2000). Future research using dynamical systems modeling may assist in the understanding of the underlying principles of emotion regulation.

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