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The Relationship Between Cognitive Flexibility and Rumination: From Laboratory to Daily Life

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THE RELATIONSHIP BETWEEN COGNITIVE FLEXIBILITY AND RUMINATION: FROM LABORATORY TO DAILY LIFE

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ABSTRACT

THE RELATIONSHIP BETWEEN COGNITIVE FLEXIBILITY AND RUMINATION: FROM LABORATORY TO DAILY LIFE

By

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Cognitive flexibility has been considered one of the risk factors for anxiety. People with high levels of anxiety tend to stick to more maladaptive strategies such as rumination. The interaction between cognitive flexibility and rumination may help explain the contribution of cognitive flexibility to the development of anxiety. This study investigated the relationship between cognitive flexibility and rumination. Each individual's level of cognitive flexibility, anxiety, and rumination were measured through questionnaires and computer tasks. Daily changes in emotion and rumination were assessed using the experience sampling method. The results showed interesting relationship between rumination (both trait and momentary) and cognitive flexibility (self-report and task-based). Furthermore, it was cognitive flexibility but not trait rumination that predicted the mean momentary rumination.

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INTRODUCTION

Imagine that it is final exam week in graduate school. While you are preparing for your final exams your car breaks down and needs an expensive part to fix it. You now need to work extra hours, plan when you will study, and find a way to make it to your job and school until your car can be fixed. These situations are all too common and place a great amount of pressure on individuals in their daily lives. In these situations, individuals become stressed and overwhelmed. Managing these situations and finding solutions to them requires knowing the demand of each situation and using flexible coping strategies. In the literature, the ability of an individual to adapt to the changing demands of the environment in social, emotional, or academic realms is called cognitive flexibility (Stange et al., 2017). Anxiety has been associated with a lower level of cognitive flexibility (Whitmer & Gotlib, 2012). One possible way that cognitive flexibility contributes to the development of anxiety is by the influence it has on an individual's ability to regulate his or her unpleasant feelings. When people are anxious, they often try to use emotion regulation strategies to adjust their moods. However, it has been shown that people with elevated levels of anxiety tend to utilize more maladaptive strategies, such as rumination. Rumination is defined as the repeated focus on the same negative event or affect and has been considered a maladaptive emotion regulation strategy, leading to longer and more severe instances of negative mood (Whitmer & Gotlib, 2012). Since anxiety impacts an astounding 40 million Americans each year (Anxiety and Depression Association of America, [ADAA], n.d.) investigating how cognitive risk factors (such as cognitive flexibility) impact the development and maintenance of anxiety is worthwhile. Exploring the interaction between

cognitive flexibility and maladaptive emotion regulation (such as rumination), and the role of their interaction in anxiety, will help better understand the underlying mechanisms and develop potential treatment. However, research with regard to the relationship between cognitive flexibility and rumination is still scarce. The aim of the current study is to investigate the relationship between cognitive flexibility and rumination in both laboratory and realistic settings and the role their relationship plays with anxiety.

LITERATURE REVIEW

Anxiety

Anxiety is a normal adaptation that has functioned throughout time to help individuals sustain life and avoid potential threats (Park & Moghaddam, 2017). Although anxiety has been a helpful tool in such scenarios, it can grow out of control and become maladaptive. Anxiety disorders are the most prevalent of psychiatric disorders and have a very high burden of illness (Bandelow et al., 2017). According to Park & Moghaddam (2017), in addition to disrupting goal-directed behaviors and cognitive processes, anxiety causes aversive and unpleasant feelings that lead individuals to avoid potential threats in their immediate environments. When anxiety symptoms are not managed, they can worsen and prevent individuals from performing activities that sustain daily life and are considered to be maladaptive (Park & Moghaddam, 2017).

When a person is unable to control the anxiety, it can lead to anxiety disorders. Generalized Anxiety Disorder (GAD) is one of the disorders that can result from unmanaged anxiety (Stein & Sareen, 2015). Symptoms of prolonged or chronic anxiety can manifest to form physical symptoms such as headaches, muscle tension, gastrointestinal distress, and insomnia (Stein & Sareen, 2015).

Social Anxiety Disorder (SAD) is another possible diagnosis for mismanaged anxiety. The symptoms of SAD become active in social situations and tend to be emotional, physical, or both (Stein & Stein, 2008). When a person with SAD is in a social setting he or she may appear to be shy, quiet, and withdrawn. According to Stein & Stein (2008), when someone with SAD is experiencing anxiety symptoms in these situations, he or she may feel discomfort that is overt

(blushing, sweating, shaking) or covert (fear, racing heart, trouble concentrating). Due to SAD pertaining to social situations, symptoms may differ depending on the culture of the person experiencing the symptoms (Hofmann et al., 2010).

Individuals who have anxiety may choose to seek treatment by a medical doctor or other professional if they have high levels of distress (Brandelow et al., 2017). Medical treatments include tricyclic antidepressants and benzodiazepines. Non-drug treatments, such as cognitive behavioral therapy (CBT), are also popular among those who have anxiety (Brandelow et al., 2017). CBT is sometimes used in conjunction with medication to manage the symptoms of anxiety (Brandelow et al., 2017). Kodal et al. (2018) found that CBT was an effective form of long-term treatment for anxiety disorders in youth and encouraged more implementation of this form of treatment in mental health clinics.

Although there are existing treatments for anxiety disorders, there is still room for improvement. According to Brandelow et al. (2017), benzodiazepines, which are prescribed for their anxiolytic properties, are no longer first in line when it comes to treating anxiety due to adverse effects on the central nervous system (dizziness, fatigue, delayed reaction time). Furthermore, while CBT is a relatively safe form of treatment, research comparing CBT to a placebo group showed that CBT is moderately effective, but more effective treatments are still needed (Carpenter et al., 2018).

Cognitive Flexibility

Cognitive Flexibility and Anxiety

Cognitive flexibility is defined as the ability of an individual to adapt to the changing demands of the immediate environment, extending to social, academic, and emotional realms of life (Stange et al., 2017). Cognitive flexibility allows people to move through life's problems and

unexpected situations with more ease, as it brings forth solutions to problems that are experienced. Poor management of anxiety symptoms can lead to a decrease in a person's cognitive flexibility and the ability to adapt to goal-directed behaviors (Wilson et al., 2018). It has been suggested that deficits in cognitive flexibility are also associated with elevated anxiety and worry (Twivy et al., 2020).

The more anxious or inflexible a person becomes, the more likely he or she may be to use maladaptive emotion regulation strategies, such as rumination, to alleviate mood. In fact, inflexible cognition could be the reason why people turn to maladaptive emotion regulation strategies. As a person becomes unable to navigate unexpected obstacles in life, or adapt to situational demands, he or she will experience more unpleasant emotions (Stange et al., 2017).

Measuring Cognitive Flexibility

Cognitive flexibility can be measured in various ways through use of questionnaires and behavioral measures. Questionnaires measure how people react in general while behavioral measures allow researchers to observe behavior in the lab during specific tasks. The Cognitive Flexibility Scale (CFS) is typically used when gathering self-report data on cognitive flexibility levels. The validity of this 12-item Likert scale was tested by Martin and Rubin in 1995, and again by Martin and Anderson in 1998. Both studies offered support for the validity of the CFS compared to alternative cognitive flexibility measures. When completing the CFS, participants are instructed to provide responses to statements, such as "I seldom have choices when deciding how to behave," with responses ranging from strongly agree to strongly disagree (Martin & Rubin, 1995).

In addition to the CFS, the Cognitive Flexibility Inventory (CFI) was created in order to assess the type of cognitive flexibility needed for individuals to successfully challenge

maladaptive tendencies with more adaptive ones (Dennis & Wal, 2010). The CFI is a 50-item, 7-point Likert scale, which is significantly longer than the CFS. Dennis and Wal (2010) argued that the CFS was created to measure three aspects of cognitive flexibility: awareness of communication alternatives, willingness to adapt to the situation, and self-efficacy in being flexible. However, it does not appear to have a multiple factor structure, which was the motivation for creating the CFI.

Aside from questionnaires, behavioral measures in the laboratory are often used with tasks to assess cognitive flexibility levels. There are different paradigms that permit researchers to observe particular behaviors of interest. Task switching paradigms, such as the Wisconsin Card Sorting Task (WCST) and the Internal Shifting Task (IST), have been widely used to assess cognitive flexibility within the laboratory.

The WCST is a task switching paradigm that was developed by Grant & Berg (1948) in order to assess aspects of the reinforcement process in a complex problem-solving situation using stimulus and response cards. Each stimulus card contains one to four figures or shapes (stars, crosses, circles, triangles) that differ in color. Each card could be matched to a response card based on shape, number of shapes, or color. During the task, the participants must guess the matching rule, and the rule changes based on the instruction of the experimenter, or computer program. The WCST is used in research to assess cognitive flexibility, perseverative tendencies, and many other types of neuropsychological facets. For example, Holder et al. (2021) used an emotional version of the WCST (eWCST) to examine shifting with regard to emotional and non-emotional stimuli and its relationship with cognitive restructuring in people with social anxiety. Researchers found that poor shifting or perseverative tendencies during the task predicted decreased ability to produce pleasant alternative thoughts to negative feelings about an

impending speech task. Holder et al. (2021) concluded that the standard version of the WCST is sensitive to capturing mental flexibility that is necessary to produce helpful alternative thinking during cognitive restructuring.

The IST is a working memory task which involves updating and shifting based on internally represented stimuli. Figueroa et al. (2019) used IST to measure cognitive flexibility in a study examining attentional control, rumination, and the recurrence of depression. Each trial presented a single face in the center of a computer screen. Participants were instructed to keep a mental count of the number of faces they saw based on two categories: gender and emotion.

In recent years, eye-tracking technology has been used in conjunction with behavioral measurement. Eye-tracking allows researchers to view the physiological function of choice such as eye movements, fixation points, and attention while the participant completes a task. For instance, Zheng and Church (2021) used eye-tracking to examine what aspects of cognitive flexibility children have difficulty with compared to adults, given how eye gaze changes with age. To do this, researchers implemented a cued task switching paradigm in two groups: children (8-16 years) and adults (18-27 years). During the task, participants were asked to pick which response matched a target based on a cue or rule (such as shape, color, pattern, outer color) that changed or repeated by trial. Performance on the task showed that children spent more time fixating on the cued rule rather than the response choices compared to adults.

Emotion Regulation

Emotion Regulation and Anxiety

The aversive symptoms of anxiety and other negative emotional states can be lessened by utilizing the correct emotion regulation strategies. Emotion regulation aids in maintaining an individual's mental and physical well-being (Braunstein et al., 2017). Strategies to regulate one's

emotional state can be adaptive or maladaptive. Adaptive emotion regulation strategies are those that aid in mitigating the negative effects of anxiety. According to research by Aldao et al. (2014), using adaptive emotion regulation techniques such as reappraisal and acceptance help to alleviate the clinical symptoms of anxiety disorders. Conversely, maladaptive emotion regulation strategies, such as expressive suppression, rumination, and experiential avoidance, work to amplify one's anxiety symptoms and even maintain them (Aldao et al., 2014).

Measuring Emotion Regulation

Emotion regulation strategies can be measured in various ways. Questionnaires such as the Emotion Regulation Questionnaire (ERQ) and Cognitive Emotion Regulation Questionnaire (CERQ) are among the most popularly utilized in emotion regulation research. The ERQ is a 10-item questionnaire developed by Gross and John (2003) that measures two emotion regulation strategies, one that is beneficial and one that is harmful (Ioannidis & Siegling, 2015). Response choices vary from one (strongly disagree) to seven (strongly agree).

The CERQ is a 36-item questionnaire that is comprised of nine cognitive emotion regulation strategies. Each of the nine strategies include four items that refer to what someone thinks after stressful life events. The strategies include self-blame, other-blame, rumination, catastrophizing, putting into perspective, positive refocusing, positive reappraisal, acceptance, and planning (Garnefski & Kraaij, 2007). Participants' answers are measured on a 5-point Likert scale ranging from 1 (almost never) to 5 (almost always) (Garnefski & Kraaij, 2007).

Questionnaires such as the ERQ and CERQ have frequently been used by professionals on clinical samples when evaluating patients. Given that certain medical diagnoses are associated with emotion regulation, Feliu-Soler et al. (2017) used the CERQ to assess emotion regulation in patients with fibromyalgia. According to clinicians, using the CERQ was a sound way for

assessing cognitive emotion regulation in a sample of patients who had a fibromyalgia diagnosis (Feliu-Soler et al., 2017).

Rumination

Rumination is a maladaptive emotion regulation strategy that involves the tendency of individuals to obsess over thoughts or events that are negatively valanced, which worsens the symptoms of anxiety being experienced (Treynor et al., 2003). Those who are anxious may fixate on one particular event that brings them anxiety, but causes them to experience the aversive symptoms over and over again, such as messing up a speech or failing an important test. Rumination can be measured using the Ruminative Response Scale (RRS) which focuses on brooding and reflection, two major components of rumination.

In the past 10 years, little research has been conducted to investigate the neural mechanisms or brain regions behind rumination. However, one study conducted in that time frame used fMRI to identify the neural aspects of rumination. Cooney et al. (2010) found that rumination in depressed individuals led to increased activation in the orbitofrontal cortex, anterior cingulate cortex, and dorsolateral prefrontal cortex. Neural activity during rumination has been shown to activate the amygdala, rostral anterior cingulate cortex, prefrontal cortex, and parahippocampus (Cooney et al., 2010). These areas are important because they are associated with emotional processing and memory (Cooney et al., 2010).

Measuring Rumination

Rumination can be measured by administering questionnaires. The most common questionnaire used in the literature is the Ruminative Response Scale (RRS), a subscale of the Response Style Questionnaire (RSQ). The RRS was developed by Morrow & Nolen-Hoeksema (1991) and provides insight into trait rumination. Trait rumination is described as a theoretical

information processing mode where individuals may consistently fixate on the impact of current events on future experiences. It is a more consistent baseline measure of rumination, not often changing from each moment (Kocsel et al., 2017). The RRS is a scale used to measure one's disposition to repeatedly focus on negative events that exacerbate an anxious state (Treynor et al., 2003). The RRS is made up of 22 questions that measure brooding and reflection, which are two main types of rumination. Answers are reported on a 4-point Likert scale ranging from 1 (almost never) to 4 (almost always).

Aside from the RRS, other questionnaires are used to assess trait rumination in research. The Ruminative Thought Style Questionnaire (RTSQ), developed by Brinker and Dozois (2009), is a 20-item measure which evaluates rumination without focusing directly on depressive symptoms as many other rumination measures have done previously (Kovacs et al., 2021). Another rumination measure is the precursor to the RRS, the RSQ. The RSQ assesses rumination based on 71 questions and on four different subscales: Distracting Response Scale, Problem-Solving Scale, Dangerous Activities Scale, and Ruminative Response Scale (Erdur-Baker & Bugay, 2010). This questionnaire has been effective in measuring rumination, but critiqued for length, which is why Treynor et al. (2003) utilized the RRS.

Rumination can also be measured using different computer tasks in laboratory settings. The tasks commonly induce states of rumination within the subjects. Cooney et al. (2010) utilized a rumination induction task that was modified from previous research by Nolen-Hoeksema and Morrow (1991, 1993). The task consisted of 10 statements from three different conditions: rumination, abstract distraction, and concrete distraction (Cooney et al., 2010). Each of the three conditions and accompanying thought prompts induced different mental states

associated with rumination. The prompts were not inherently positive or negative, allowing for individual interpretation of each participant (Cooney et al., 2010).

Additionally, other laboratory tasks that employ subject driven free-thinking paradigms have been used. This can be observed in previous neuroimaging research by Milazzo et al. (2016) where researchers sought to observe the neural correlates of rumination during a free-thinking task. In this study, researchers guided participants with thought prompts to evoke different mental states including a ruminative mental state. For example, in order to elicit a negative rumination state, researchers instructed participants to think about a time of personal disappointment (Milazzo et al., 2016).

A third way that rumination can be measured is by Experience Sampling Methods (ESM). This method is used by scientists to gather insights into the systematic collection of information about daily life (Van Berkel et al., 2018). Previously, ESM was only available in the form of pagers or pen and paper which was time consuming and limiting in usability. However, the emergence of recent technology has allowed for ESM to be open to users on their smartphones and tablets (Xie et al., 2019). Since becoming more accessible, ESM has been used more often and provides more accurate depiction of day-to-day events in the participants' lives (Van Berkel et al., 2018).

In the literature, ESM is used outside of the laboratory to give researchers the ability to examine momentary rumination and affect. Momentary rumination is described as brief rumination that occurs as the result of events day-to-day. During use, a notification will sound on the user's device, prompting him or her to provide a self-report response. These responses to identical questions are recorded various times per day across multiple days. Collecting data via this method permits researchers to study participants' natural behaviors in their daily life

experiences and environments outside of the laboratory (Van Berkel et al., 2018). While ESM has been used to inspect many facets of human behavior, it is particularly useful for research in momentary rumination. To assess worry and momentary rumination relating to psychosis, Hartley et al. (2017) used ESM questions such as “Rumination means I’m out of control” rated on a scale from 1 (do not agree) to 4 (agree very much).

ESM is a versatile self-report tool as it can be used for many different research topics that aim to explore human behavior. Participants in ESM studies are able to participate without multiple trips to a laboratory to provide responses. This method also fulfills the requirement of obtaining reliable measures of behavioral aspects in daily life. It also minimizes any cognitive biases as it reduces reliance on the participant’s ability to reproduce earlier experiences, as seen in questionnaires (Van Berkel et al., 2018).

As stated above, ESM has granted scientists the ability to assess real-time changes in participants within a study design. However, it is important to note that there are challenges associated with using this method. Using ESM requires the participant to own a device with application abilities and manage multiple interruptions from daily activities to answer questions. This alone can be a considerable burden to those who have jobs, studies, or other commitments (Klasnja et al., 2008). Attrition rates also tend to be elevated with ESM due to the frequent action required on behalf of participants. Response rates often begin at a high percentage and then decrease over the week of required responses (Van Berkel et al., 2018). In order to reduce attrition rates, Barrett and Barrett (2001) suggest higher compensation for the participants. Another option, as stated by Hektner et al. (2007), is to make ESM data collection more intrinsically rewarding for participants.

Cognitive Flexibility and Emotion Regulation

Research over the last several years has identified that the regulation of emotions by cognitions (thoughts) is inextricably linked to daily human life and helps individuals control their emotions during or after the experience of negative events or emotions (Garnefski & Kraaij, 2007). Cognitive flexibility and emotion regulation are related to each other and their interaction may influence the development of anxiety. As previously mentioned, if a person's anxiety is poorly managed, he or she may have impaired cognitive flexibility. The lower the level of cognitive flexibility, the more likely one becomes to use maladaptive emotion regulation strategies such as rumination, expressive suppression, or experiential avoidance (Aldao et al., 2014).

According to research on 1,114 college students in Turkey by Arici-Ozcan et al. (2019), students with higher levels of self-reported distress tolerance possessed higher levels of cognitive flexibility. Furthermore, those who were more cognitively flexible experienced less difficulty with emotion regulation. Lower levels of difficulty with emotion regulation yielded an increase in resilience overall.

Cognitive Flexibility and Rumination

Rumination is one of the three main maladaptive emotion regulation strategies that individuals may use when attempting to cope with negative emotional states. Rumination has been described as perseverating thoughts, which are prolonged thoughts relating to negative aspects of the self (Davis & Nolen-Hoeksema, 2000). Participants who completed the Why Ruminate questionnaire in a study by Watkins & Baracaia (2001) reported that they ruminated because they believed it enhanced their understanding of problem solving compared to low ruminators (Watkins & Baracaia, 2001). People use rumination as a strategy to manage an

emotional experience, and it has been a topic of interest in research (Lanciano et al., 2010). According to Lanciano et al. (2010), an individual's tendency to ruminate is correlated with emotional intelligence. Furthermore, developing emotional intelligence abilities through training can be a tool people use to handle emotional situations (Lanciano et al., 2010).

Cognitive flexibility and rumination have been found to interact. Research by Davis and Nolen-Hoeksema (2000) revealed that while completing task shifting paradigms such as the WCST, participants with elevated levels of rumination made more perseverative errors than nonruminators (Davis & Nolen-Hoeksema, 2000). Ruminators failed to maintain set during the WCST more often than nonruminators, exhibiting impaired cognition. These findings suggest that those who ruminate have a more difficult time adapting to the changing contingencies.

The Current Study

Rationale and Hypotheses

Although research has examined emotion regulation and cognitive flexibility, very few studies have examined cognitive flexibility and momentary rumination. Momentary rumination differs from trait rumination because it changes from moment to moment each day. Since it has been suggested in the literature that cognitive flexibility and rumination interact, it can also be assumed that momentary rumination also has an interaction. For those reasons, further investigation of the relationship between cognitive flexibility and momentary rumination will be a worthwhile contribution of the present study.

Traditionally, previous researchers have used questionnaires at one time point (e.g., in the lab after cognitive tasks) to measure a general tendency of emotion regulation across a period of time (e.g., two weeks). However, experience sampling method (ESM) can detect the fluctuation of emotion regulation in daily life. ESM is a newer self-report measure that allows for

researchers to look into the mental processes of the individuals with more accuracy. It is highly sensitive to changes because it is completed multiple times throughout the day, for a number of consecutive days (Larson & Csikszentmihalyi, 2014). This method permits researchers to examine (a) changes in mood and social interaction; (b) frequency, intensity, and patterns of psychological states; and (c) frequency and pattern of thoughts, which include intensity and quality of thought disturbance (Larson & Csikszentmihalyi, 2014). Such measures provide the observation of rumination levels both pre and post experiment. Therefore, in the current study, the ESM were used to capture the dynamic patterns of momentary rumination in everyday life.

In addition, cognitive flexibility can be measured through physiological changes during cognitive tasks. Such changes reflect the level of cognitive functioning during the task performance. Eye-tracking technology is a non-invasive way to investigate cognitive functioning, and a main component of this technology is fixation duration and pupil dilation (Eckstein et al., 2017). As stated in a recent article by Eckstein et al. (2017), pupil dilation is modulated by the locus coeruleus, which plays a role in the regulation of cognitive functioning and arousal. The same article goes on to discuss how changes in pupil size indicate the difficulty experienced when performing a task. In addition to pupil dilation, measurements of blinking and gaze can provide valuable insight into cognition. Spontaneous blink rate serves as a potential way to measure dopamine activity in the CNS. Dopamine is involved in working memory, learning, and goal directed behaviors (Eckstein et al., 2017). Analyzing and measuring gaze reveals the individual's attentional focus to the task as well as the cognitive strategies being utilized. Eckstein et al. (2017) suggests that pupil dilation, blink rate, and eye gaze provide insight into an individual's mental processes while performing cognitive tasks, which allows for the measurement of cognitive flexibility. The eye-tracker being used in the proposed research is

an Eye-link ELU-Port-Duo eye-tracker. The duration of fixation was collected by the eye tracker.

Research Questions

Research question 1: The current study aimed to test whether there is a relationship between self-reported cognitive flexibility and trait rumination. This was tested by first administering the CFS and RRS. The current study also tested the relationship between task-based cognitive flexibility and trait rumination. Eye-tracking was used to assess task-based cognitive flexibility during a cued task-switching paradigm where the rules changed and required the participants to adapt to the new matching rule with face stimuli..

Research question 2: Next, the relationship between cognitive flexibility and momentary rumination was tested. This was done by first examining the correlation between the CFS and momentary rumination from the ESM app responses. Then, the researchers examined the correlation between the performance on the eye-tracking task and momentary rumination. Further, researchers investigated whether trait rumination, cognitive flexibility, and momentary affect can be used as the predictors for momentary rumination.

Hypotheses

Based on the research questions, there were two main hypotheses for the current research:

Hypothesis 1: There will be a negative correlation between cognitive flexibility and trait as well as momentary rumination.

Hypothesis 2: The level of cognitive flexibility together with momentary affect and trait rumination will predict the level of momentary rumination.

Methods

Participants

A sample of 44 participants were recruited from the community of Marquette as well as Northern Michigan University via recruitment posters and a mass email sent to 20% of all on campus students. The age range of the participants was between 18 and 42 years old. Individuals who participated were required to have corrected or corrected-to-normal vision as well as possess a smart phone capable of downloading and running the ESM app. To be noted, this study was a part of a larger project that investigates the relationship between cognitive flexibility and emotion regulation. To be involved in the current study, participants needed to complete: 1) the CFS and RRS; 2) eye-tracking experiment; and 3) the whole ESM procedure. Therefore, there were only 27 participants, 24 were female and 3 were male (M_{age} = 20.44, SD_{age} = 2.65, range 18-30 years) in the final sample for the current study (see Table 1).

Table 1.

Demographic characteristics (N = 27)

	Mean	SD	Range
Age	20.44	2.65	18-30
Gender (female: male)	24:3		
RRS	52.44	11.13	29-73
Mean_mRum	6.91	2.14	2.46-10.50
CFS	54.37	7.07	41-67

Note: RRS, Ruminative Response Scale; Mean_mRum, Mean momentary rumination; CFS, Cognitive Flexibility Scale.

Materials

Questionnaires

Cognitive Flexibility Scale

The Cognitive Flexibility Scale is a 12 item, 6 point Likert scale, and is the most widely used questionnaire to measure an individual's level of cognitive flexibility (Martin & Rubin, 1995). The Cognitive Flexibility Scale consists of 12 statements relating to behaviors, situations, and feelings to measure the cognitive characteristics relating to level of flexibility. Martin and Rubin (1995) tested the validity of the Cognitive Flexibility Scale compared to others, such as the Communication Flexibility Scale (Martin & Rubin, 1994), Rigidity of Attitudes Regarding Personal Habits Scale (Meresko et al., 1954), Interaction Involvement Scale (Cegala, 1981), Self-Monitoring Scale (Snyder, 1974), and Unwillingness to Communicate Scale (Burgoon, 1976). The results supported the Cognitive Flexibility Scale in showing internal reliability, as well as construct and concurrent validity.

Ruminative Response Scale

The Ruminative Response Scale (RRS) is a 22 item, 4-point Likert scale. It measures the tendency of individuals to obsess over thoughts and events that are negative in context, therefore contributing to one's level of anxiety (Treynor et al., 2003). According to research conducted by Treynor et al. (2003), there are two distinct types of rumination: brooding and reflection. Brooding refers to the negative appraisal of one's status compared to another, otherwise known as self-criticism. Reflection refers to the attempts made to problem solve by using one's own thoughts to overcome an obstacle or difficulty (Brose et al., 2020).

Depression Anxiety Stress Scale

The Depression Anxiety Stress Scale (DASS) was used to measure each participant's level of depression, anxiety, and stress (Lovibond & Lovibond, 1995). The DASS is comprised of 42 questions, yielding self-report data, and was administered by researchers prior to the ESM and then once more 2 months after ESM completion. According to work by Brown et al. (1997), the DASS has been shown to have very good internal consistency as well as temporal stability.

Experience Sampling Method

ESM was delivered by use of a smartphone app called Paco. After the participant downloaded and signed into the Paco app, he or she was prompted four times each day to answer a series of questions that measured momentary affect and emotion regulation. Participants were instructed to answer the questions as soon as they received the notification from the ESM app. The app is programed to send participants a reminder 15 minutes after the first notification if the response was not registered. The notification disappears after 30 minutes, and if there is no participant response, then that time point was marked as missing data. ESM has been used both short and long-term. Short-term ESM is quick and permits data to be collected from participants with a lower attrition rate. It is important to note that long-term ESM yields more accurate data, but the attrition rate is likely to be higher than that of short-term ESM. After considering both the risks and benefits of long and short-term ESM, it was decided that it would be most efficient to use ESM four times each day, for seven consecutive days.

During each ESM assessment, participants were asked to respond to questions relating to their emotional states such as "how anxious do you feel at the moment?" on a 7-point scale, with 1 indicating not at all, and 7 indicating very much. The momentary usage of rumination was also measured with a 7-point scale. For example, participants were asked whether they used

rumination to regulate their emotional states with questions like “since the last beep, have you ruminated about something in the past?”, and “since the last beep, have you thought about something in the future a lot?”

Eye-tracking task: Cued Task Switching Paradigm

The behavioral task was created on the basis of research conducted by Bauer et al. (2017) and Zheng and Church (2021). In this task, four cues and response choices were presented on the screen for 1500 ms (see Fig.1). Participants were instructed that the cues represented the four matching rules they could use for their response (i.e., inner color of the color bar, outer color of the color bar, sex of the face stimuli, and emotion of the face stimuli) and that one of the cues would be outlined with red for each trial. In the valid cue block, the red cue predicted the rule for the current trial with 100% accuracy, whereas in the invalid cue block, the predictive accuracy was only 50%. A 500 ms delay period occurred where the red frame disappeared, but participants were still able to freely look at all of the cues and response choices. Then, a target was presented below the response choice. Participants were asked to indicate which response choice matched with the target by pressing left or right button on the response box as quickly and accurately as possible. For each of the response choices and target stimuli, there was a face stimulus with a color bar on the bottom. The face stimuli were combined with sex (i.e., female vs. male) and emotional (angry vs. neutral) features. The color bar also contained two features: inner color (i.e., blue vs. green) and outer color (with a black outline vs. without a black outline). In half of the trials, the rule was either different from previous trials (switch trial) or the same as previous trials (repeat trial). To be noted, the current study was a sub-project of a larger research project which investigated the relationship between cognitive flexibility and emotion regulation.

Therefore, the invalid (i.e., neutral) condition was the main focus to remain in accordance with the purpose of the current study.

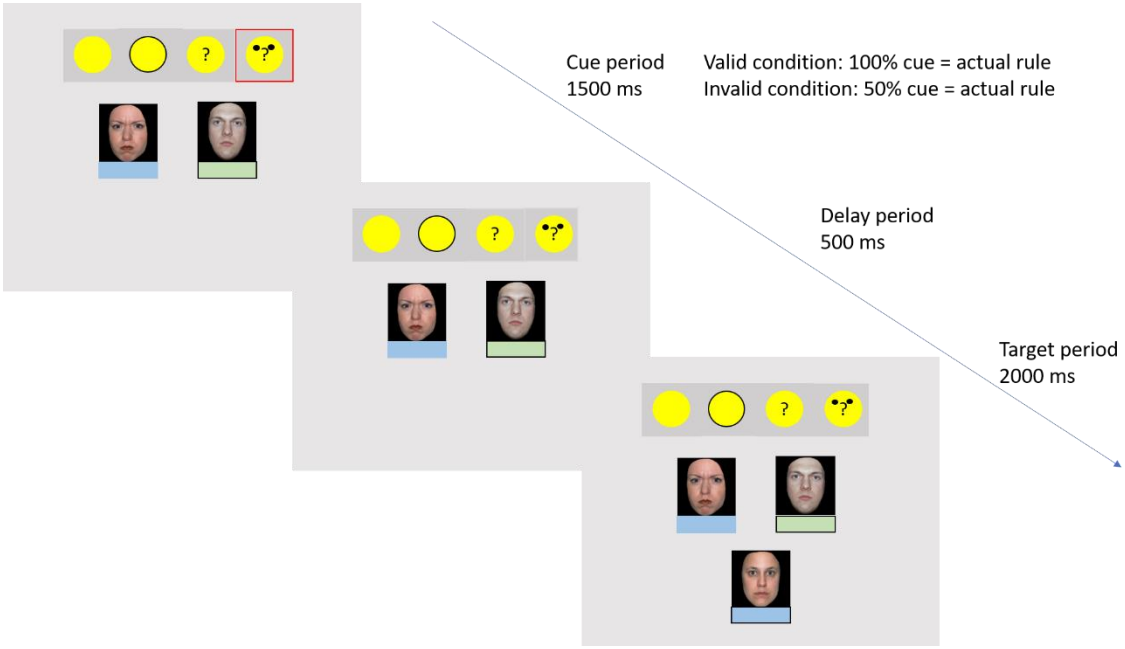


Figure 1. Cued Task Switching paradigm. In this task, four cues and two response choices were first presented on the screen for 1500 ms. The cues represent the four matching rules that they can use for their response (i.e., inner color of the color bar, outer color of the color bar, sex of the face stimuli, and emotion of the face stimuli) and one of the cues was outlined with red for each trial. In the valid cue block, the red cue predicted the rule for the current trial with 100% accuracy whereas in the invalid (or neutral) cue block, the predictive accuracy was only 50%. Next, there was a 500 ms delay period where the red frame disappeared but participants still freely looked at all the cues and response choices. Then, a target was presented below the response choice. Participants were asked to indicate which response choice matched with the target by pressing left or right button as quickly and accurately as possible.

Apparatus for Eye-tracking

Eye-link (2000 Hz EyeLink Portable Duo, SR Research) eye-tracking equipment was utilized to record gaze behavior at a sampling rate of 1000 Hz. Consistent with previous

research, a threshold of ≥100ms was used to define visual fixations. Stimulus presentation and eye movement recording were controlled by E-prime3.

Procedure

The entire study consisted of one in-person session at the eye-tracking lab, one week of ESM sessions using the ESM app, and then one follow-up session with an online survey (see Fig.2). At the beginning of the lab session, participants were asked if they were wearing contacts, instructed to read and sign the consent form and the Covid-19 protocol form. The lab session was held in Weston Hall room 1133 at Northern Michigan University in the eye-tracking room. During the lab session, participants completed the cognitive flexibility measurement on a desktop computer followed by the questionnaires. The eye-tracker was placed in front of the participant to collect the psychophysiological data, such as changes in attention and fixation during the task, a chin rest was also used to help ensure stable and accurate measurement. At the conclusion of the lab session, participants received guidance on how to download the ESM app onto their smart phones. During ESM sessions, participants were prompted to use the app four times per day, for seven consecutive days, in order to gather data on affective state and momentary rumination. Each ESM session was approximately 1-2 minutes long. Finally, two months after the last ESM session, participants were asked to fill out the DASS and RRS online as a follow up measure. After full completion of the study, each participant was debriefed and received a monetary reward of $30.

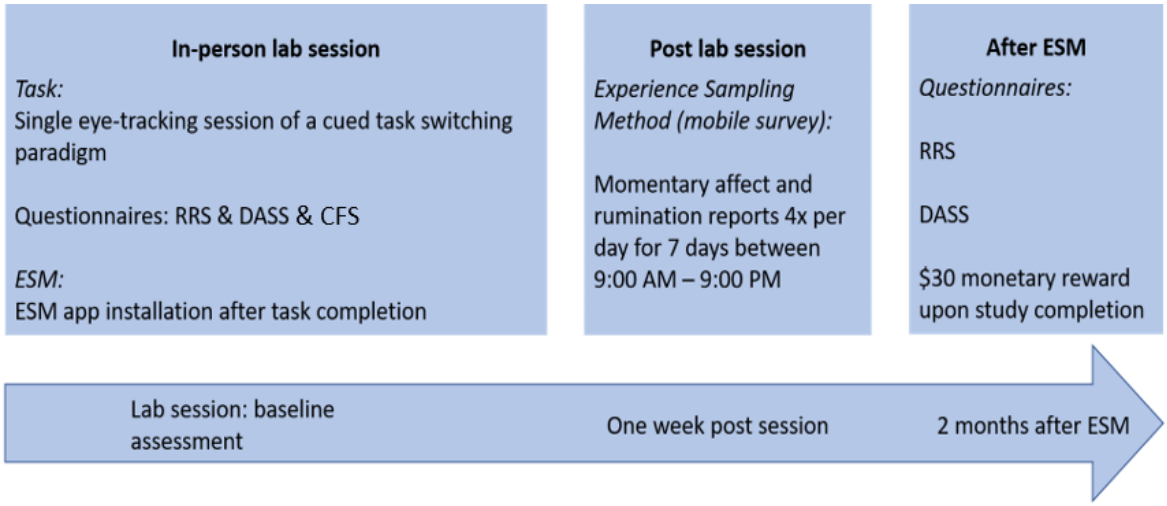


Figure 2. Procedure. RRS = Ruminative Response Scale; DASS = Depression Anxiety Stress Scale; CFS = Cognitive Flexibility Scale.

Data Analysis

All data analyses were performed in SPSS (version 28.0). Given that the sample size was smaller than 30, to avoid the possible influence caused by the violation of normality, a bootstrapping method was used with 2000 bootstrap resamples for all the correlation analyses.

Research question 1: Is there a relationship between self-report as well as task-based cognitive flexibility and trait rumination?

To examine whether or not a relationship exists between self-report cognitive flexibility and trait rumination, the correlation between the scores of the CFS and RRS was calculated. For task-based cognitive flexibility, the eye tracking indexes, such as the duration of fixation, were obtained for switch and repeat (i.e., non-switch) conditions. Next, the switch cost was calculated by subtracting the mean eye tracking indexes of repeat trials from switch trials. After that, the correlation between the switch cost indexes and RRS score were calculated.

CFS was calculated by taking each subjects response on the CFS and first reverse scoring the necessary items. For example, if an "R" appears next to the one of the 12 items on the CFS,

that means the item is reverse scored. On the CFS, items 2, 3, 5, and 10 are reverse scored. For these items, if a response by a subject was 3 (slightly disagree), then it would be reverse scored to the opposite which is 4 (slightly agree) and so on. Once the items were reverse scored, all 12 item responses were added to obtain a sum or total score on the CFS for each subject. Trait rumination total scores were calculated by taking the sum of each subject's responses to the 22-item RRS questionnaire.

Fixation duration switch cost was used to represent the level of cognitive flexibility in the cued task switching paradigm. It was calculated by subtracting fixation duration of correct repeat trails from fixation duration of correct switch trials. Higher fixation duration cost score reflects lower cognitive flexibility to the new rules. Two types of cognitive flexibility were computed based on the valence of the target: Fixation Duration Cost Negative (FDCNeg) when the target presented a negative facial expression and Fixation Duration Cost Neutral (FDCNeu) when the target presented a neutral facial expression.

Research question 2: Is there a relationship between cognitive flexibility and momentary rumination?

To answer the second research question of whether or not a relationship exists between cognitive flexibility and momentary rumination, the correlation between the CFS and mean momentary rumination was examined. Researchers examined the correlation between the switch cost indexes and momentary rumination. Further, to test the influence of different variables on momentary rumination, a linear mixed model was used with trait rumination, cognitive flexibility, and momentary affect as the fixed effect and subject as random effect, and momentary rumination as the dependent variable.

RESULTS

Cognitive flexibility indexes

After calculating the switch cost for the task switching paradigm, Fixation Duration Cost Negative (FDCNeg), M = 60.78, SD = 167.06, Range from -228-432, and Fixation Duration Cost Neutral (FDCNeu), M = 12.78, SD = 163.97, Range from -359-305, were not significantly correlated with each other, $r(27) = -.21$, $p = .295$.

Additionally, the CFS rating was not significantly correlated with FDCNeg, $r(25) = .24$, $p = .228$, or FDCNeu, $r(25) = -.28$, $p = .157$. Interestingly, CFS was significantly correlated with other eye-tracking indexes in valid condition. But this was beyond the scope of the current project.

Trait rumination measurement and its relationship with cognitive flexibility indexes

For the current sample, (N = 27), M = 52.44, SD = 11.13, Range from 29 to 73, trait rumination approached significance with cognitive flexibility rating, $r(25) = -.36$, $p = .066$ (See *Figure 3 & Table 2*). Trait rumination also significantly correlated with FDCNeg, $r(25) = -.50$, $p = .008$, and FDCNeu, $r(25) = .51$, $p = .006$. (See *Figure 4 & Table 2*).

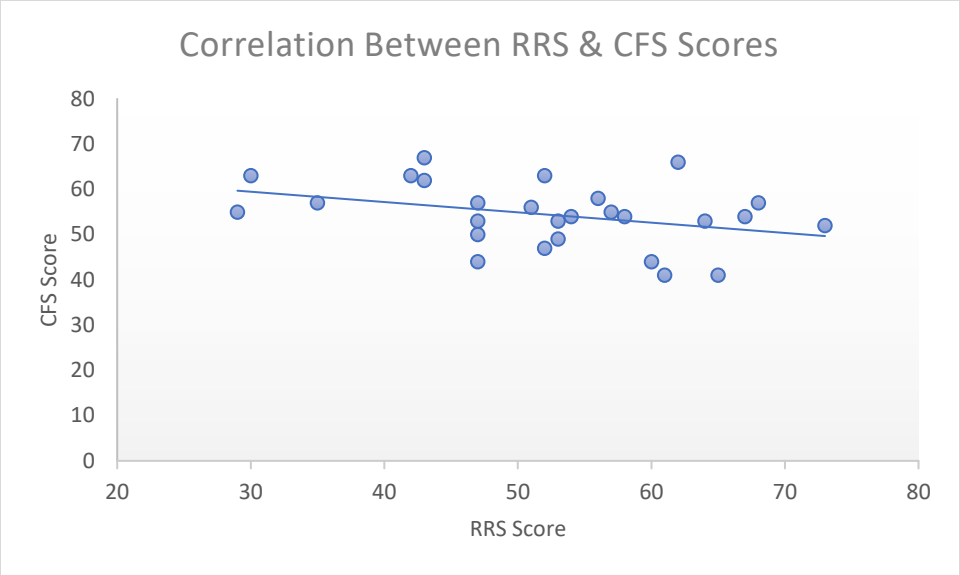
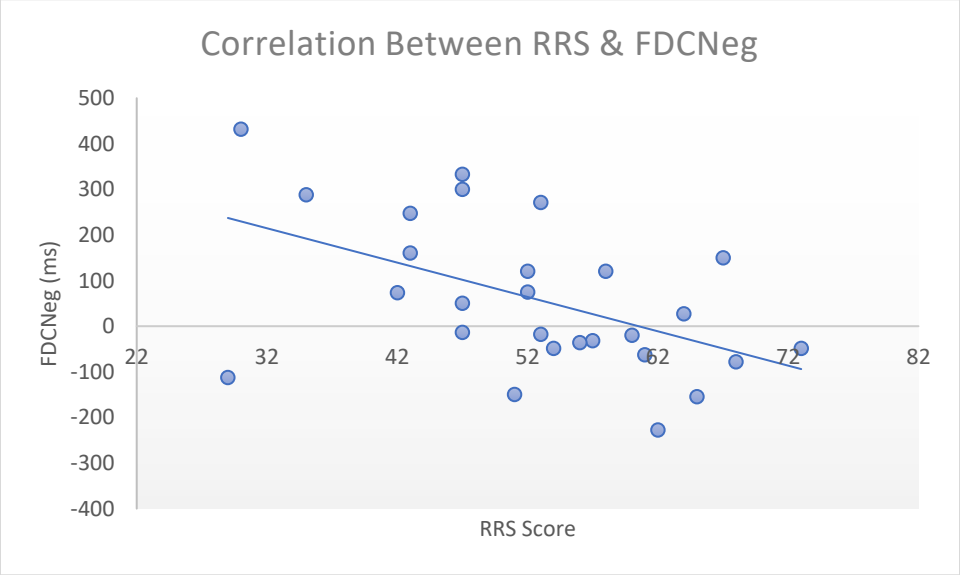


Figure 3. The correlation between RRS scores and cognitive flexibility scores.



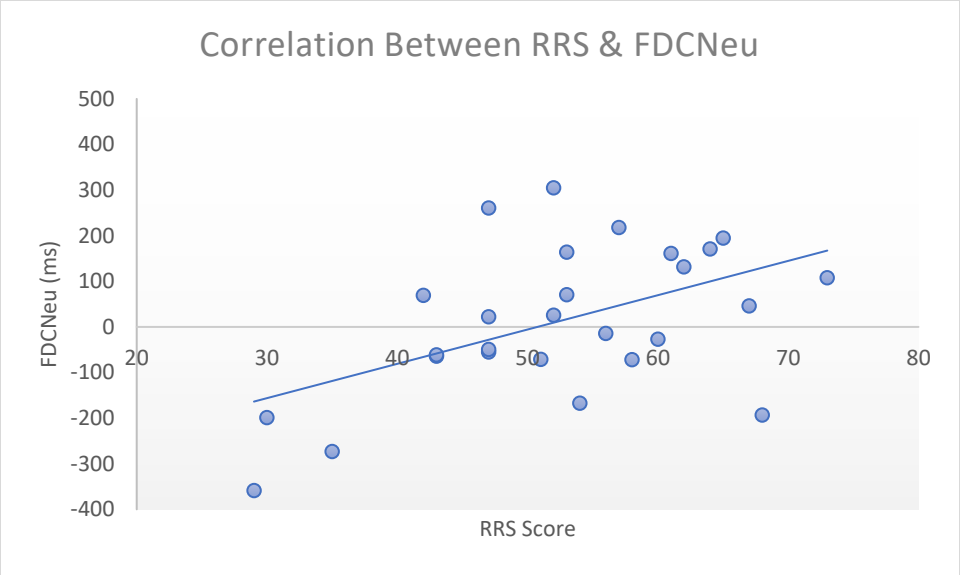


Figure 4. The correlation between trait rumination as measured by (top) the RRS and FDCNeg emotional condition as well as (bottom) the RRS and FDCNeu. FDCNeg, Fixation duration cost in the negative emotional condition; FDCNeu, Fixation duration cost in the neutral emotional condition

Momentary measures and their association with trait rumination as well as cognitive indexes

Momentary rumination was measured by two items: past rumination and future rumination. Ruminating about the past (M = 2.89, SD = 1.21, range from 1.14 to 5.79) was significantly correlated with ruminating about the future (M = 4.02, SD = 1.27, range from 1.32 to 5.86), $r(25) = .48$, $p = .012$. Mean momentary rumination (M = 6.91, SD = 2.14, range 2.46 to 10.50) was created by adding the momentary rumination past and momentary rumination future items together.

None of the momentary rumination indexes were significantly correlated with trait rumination, $rs < .22$, $ps > .271$. Higher trait rumination did not relate to higher levels of momentary rumination on average.

The mean momentary rumination was significantly correlated with cognitive flexibility measured by the CFS questionnaire (See *Figure 5 & Table 2*), (r (25) = -.43, p = .025). In addition, cognitive flexibility rating was also significantly correlated with ruminating about the future, but not significantly correlated with ruminating about the past, $r(25) = -.31$, $p = .122$.

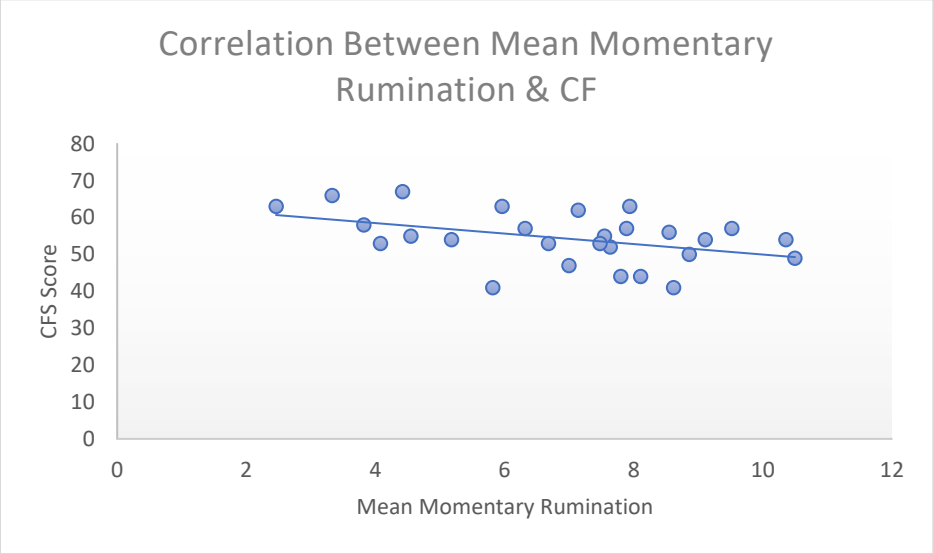


Figure 5. The correlation between mean momentary rumination and cognitive flexibility scores.

Mean momentary rumination was not significantly correlated with FDCNeg $r(25) = .21$, $p = .301$, or FDCNeu, $r(25) = .15$, $p = .456$. Similarly, neither momentary rumination about the past, nor momentary rumination about the future were significantly correlated with FDCNeg or FDCNeu, $rs < .24$, $ps > .236$.

There was a possibility that cognitive flexibility rating and eye-tracking index measure shared and unique components of cognitive flexibility. Therefore, a partial correlation analysis was performed to explore the correlation between momentary rumination and eye-tracking index after controlling for cognitive flexibility rating. The results showed that after taking cognitive flexibility rating into account, the correlation between mean momentary rumination and FDCNeg approached significance (See *Figure 6 & Table 2*), $r(24) = .35$, $p = .076$. After controlling for

CFS, FDCNeg was marginally correlated with ruminating about the past, $r(24) = .34$, $p = .095$, but not ruminating about the future, $r(24) = .26$, $p = .203$. No significant results were found for FDCNeu.

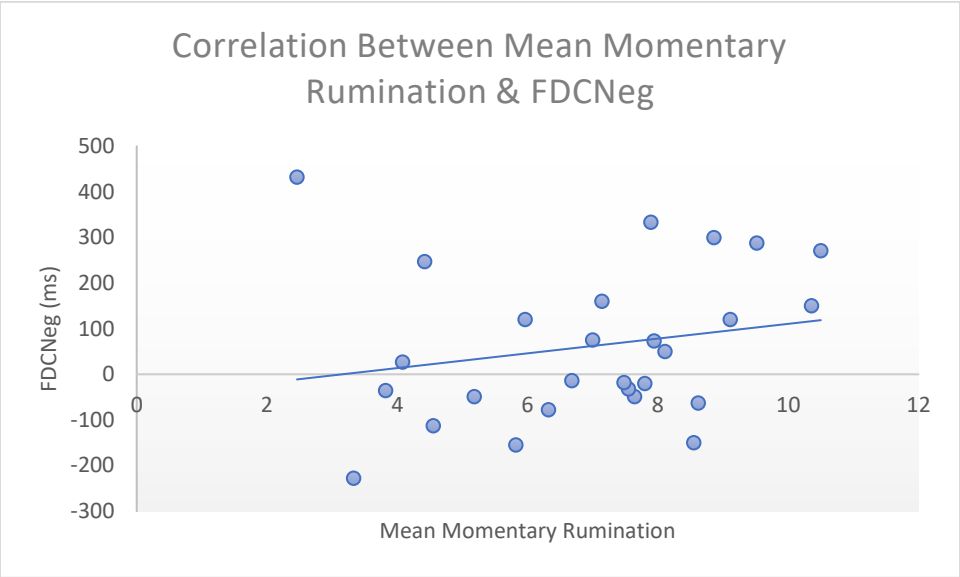


Figure 6. The correlation between mean momentary rumination and FDCNeg condition in milliseconds. FDCNeg, Fixation duration cost in the negative emotional condition.

Table 2.

Correlations between cognitive flexibility indexes and rumination measurements (N = 27).

	RRS	mRum_past	mRum_future	Mean_mRum	CFS	FDCNeg	FDCNeu
RRS	-						
mRum_past	.22	-					
mRum_future	.06	.48*	-				
Mean_mRum	.16	.85**	.87**	-			
CFS	-.36†	-.31	-.43*	-.43*	-		
FDCNeg	- .50**	.24	.12	.21	.24	-	
FDCNeu	.51**	.08	.18	.15	-.28	-.21	-

Note: RRS, Ruminative Response Scale; mRum_past, Rumination about the past; mRum_future, Rumination about the future; Mean_mRum, Mean momentary rumination; CFS, Cognitive Flexibility Scale; FDCNeg, Fixation duration cost in the negative emotional condition; FDCNeu, Fixation duration cost in the neutral emotional condition.

*† p<.1; *p< .05; ** p < .01; *** p < .001*

Further, to test the predictive effect of different variables on momentary rumination, a linear mixed model was used with trait rumination, cognitive flexibility, and momentary positive and negative affect as the fixed effect and subject as random effect, and momentary rumination as the dependent variable. Results indicated CFS (b = -.13, SE = .05, p = .016), mean momentary negative affect (b = .22, SE = .02, p = .001), and mean momentary positive affect (b = .14, SE = .03, p < .001) can significantly predict mean momentary rumination. Also, FDCNeg marginally predicted mean momentary rumination (b = .004, SE = .002, p = .087). However, trait rumination did not significantly predict momentary rumination (b = -.02, SE = .04, p = .613).

Follow-up anxiety symptom measure

None of the rumination and cognitive flexibility measures were correlated with DASS-Anxiety scores assessed after two months of the ESM (ps > .225). To be noted, this was based on only seven participants' follow-up data.

DISCUSSION

The goal of this study was to provide insight on as well as further investigate the relationship between cognitive flexibility and rumination in both the laboratory setting and in daily life. In the current study, cognitive flexibility was measured by using the self-report questionnaire and cued task switching paradigm, whereas rumination was measured at trait-level via using self-report questionnaire and momentary-level via the PACO smartphone app 4 times a day for 7 days.

It was predicted that there would be a negative correlation between cognitive flexibility and trait rumination. It was also predicted that there would be a negative correlation between cognitive flexibility and momentary rumination. Lastly, researchers predicted that the level of cognitive flexibility together with momentary affect and trait rumination would predict the level of momentary rumination.

The results showed that trait rumination was slightly correlated with cognitive flexibility rating. Therefore, higher trait rumination was associated with lower cognitive flexibility ratings on the CFS. Results showed that trait rumination was negatively correlated with the negative emotional condition (FDCNeg), but positively correlated with the neutral emotional condition (FDCNeu), showing that higher rumination scores were associated with increased flexibility during the negative emotional condition but with decreased flexibility during the neutral emotional condition within the eye-tracking task. Furthermore, momentary rumination was correlated with cognitive flexibility rating. The cognitive flexibility scores significantly correlated with ruminating about the future, but not the past. Mean momentary rumination was also slightly correlated with FDCNeg after controlling for cognitive flexibility score.

Interestingly, it was cognitive flexibility rating, FDCNeg, and mean momentary affect, but not trait rumination that can predict the mean momentary rumination.

Trait Rumination and Cognitive Flexibility Rating

In the current study, the correlation analysis results showed that trait rumination and cognitive flexibility were marginally related. It can be concluded from our results that the higher trait rumination is associated with lower cognitive flexibility ratings. These findings align with previous research on the connection between trait rumination and cognitive flexibility (Alado et al., 2014). Indeed, according to research by Alado et al. (2014), individuals with lower levels of cognitive flexibility would be more likely to stick to the same emotion regulation strategy, especially those that are maladaptive ones. The findings of the current study show that cognitive flexibility is associated with one form of maladaptive emotion regulation strategy, which is rumination. Trait rumination measures how individuals react to depressed mood consistently across time. High levels of trait rumination indicate that people tend to think about the same negative events repeatedly when they are depressed or anxious (Fang et al., 2019). The correlation found may suggest that individuals who use rumination consistently in response to experiencing a depressed or anxious mood may also be less flexible when the requirement of their environment changes. For example, in negative situations, these individuals choose maladaptive emotion regulation strategies like rumination to regulate their mood rather than adaptive emotion regulation strategies. However, when these individuals do not feel relief after using rumination, they should try using another emotion regulation method, preferably an adaptive method like reappraisal or acceptance. However, often times people in these situations are less flexible, therefore less likely to switch emotion regulation methods, which keeps them limited to using rumination. This finding should be explained with caution since the results were

approached significance. However, the results approaching significance could be due to the small sample size and it is likely that the correlation would reach a significant level if the sample size was larger.

Trait Rumination and Cognitive Flexibility Eye-Tracking Indexes

The results of the current study showed that trait rumination score was negatively correlated with FDCNeg, but positively correlated with FDCNeu. These results indicate that higher trait rumination score is associated with lower FDCNeg, but is associated with higher FDCNeu. That is, individuals who use rumination to regulate their mood when they feel depressed frequently across time, tend to be more flexible in the task when a negative target was presented and more inflexible when a neutral target was presented.

Previous research by (Arici-Ozcan et al., 2019) has shown negative correlation between trait rumination and cognitive flexibility as measured by various questionnaires. More specifically, higher level of trait rumination is associated with low cognitive flexibility measured by self-report. In fact, some studies have also used cognitive tasks to measure cognitive flexibility in a non-emotional context and found similar associations between trait rumination and cognitive flexibility (Davis & Nolen-Hoeksema, 2000). However, so far, previous studies that use cognitive tasks have typically used response time to represent cognitive flexibility. Eye-tracking is a more efficient and non-invasive method to measure cognitive flexibility. It is more efficient because it can also be combined with cognitive tasks, allowing for observation of any physiological changes during the task such as saccades, fixation points, and pupil sizes (Eckstein et al., 2017). Besides using eye-tracking methodology, both neutral and emotional stimuli were used in the present study to measure the different components of cognitive flexibility, especially the affective component of cognitive flexibility (i.e., the FDCNeg).

As being stated above, the findings pertaining to trait rumination and cognitive flexibility scores are in line with previous studies. Moreover, there was a positive relationship between neutral cognitive flexibility (i.e., the FDCNeu) and trait rumination score. That is, a person with a high level of trait rumination was associated high switch cost in the neutral condition, which represents lower flexibility. This finding was in line with previous research by Fang et al. (2019) which shows how this relationship can also be found when eye-movement was used to measure cognitive flexibility. On contrary to the hypothesis, the innovative nature of the present findings about trait rumination and the negative emotional condition show how this relationship may not be extended to cognitive flexibility in the context of emotional processing. Situations that elicit negative emotions (such as failing a class or losing a job) require adequate cognitive flexibility to navigate and find solutions to. Individuals who use maladaptive emotion regulation strategies are assumed to be more likely to fixate on the negative events, or ruminate about them rather than seek solutions or alternative explanations of the events. Individuals with lower level of trait rumination will be more likely to find solutions such as re-take the course that was failed or begin the search for new employment as a way to alleviate the negative emotions. Therefore, the current finding related to affective cognitive flexibility was counter intuitive. Future research should seek to investigate this further, to see if the findings can be replicated.

Momentary Rumination and Cognitive Flexibility Rating

The current study found that mean momentary rumination was correlated with cognitive flexibility measured by questionnaire that needs self-report ratings. Moreover, the results showed that cognitive flexibility self-rating was significantly correlated with ruminating about the future, but not the past. These results suggest that lower levels of cognitive flexibility are related to higher levels of mean momentary rumination in daily life, and that individuals are more likely to

ruminate about the same thing repeatedly in their daily life. This could be due to momentary rumination about the future rather than the past.

Research with regard to the relationship between cognitive flexibility and rumination is still scarce. These findings are one of the first to show the relationship between cognitive flexibility and rumination, specifically momentary rumination. Momentary rumination is described as the brief instances of rumination that occur as a result of day-to-day events. In this context, rumination is not long-term, but fluctuates throughout the day. Ruminating about a future event might look like consistently thinking about an anxiety inducing event such as a pending presentation. In contrast, ruminating about the past would be described as repeatedly thinking about a perceived negative event that has already happened, such as failing a test that had been taken a few days prior.

The present finding of how cognitive flexibility is related to rumination about the future but not the past is interesting. Previous fMRI research by Roberts et al. (2017) revealed that those who are more flexible in cognitive processing related to more diverse constructions of future, especially possible solutions to problems that they might experience in the future (Roberts et al., 2017). Therefore, individuals who have higher levels of cognitive flexibility are willing to as well as able to see solutions to future problems. This is not the case for individuals who have low cognitive flexibility. The results suggest that individuals who have less cognitive flexibility (are cognitively inflexible) may think about the future in maladaptive ways.

However, the items investigated were too simple to allow for detection of which aspects of the past or the future that people might be thinking about while ruminating. To account for this, future research exploring cognitive flexibility and momentary rumination could include questions about specific details pertaining to each person's ruminative thoughts on the past or

future. This would allow researchers the chance to detect which elements of the past and future people think about during moments of rumination.

Momentary Rumination and Cognitive Flexibility Eye-tracking Indexes

Results showed that momentary rumination was not significantly correlated with either FDCNeg or FDCNeu. However, in the exploratory analysis, a partial correlation analysis was performed in order to explore the correlation between momentary rumination and eye-tracking index after controlling for cognitive flexibility rating. The results revealed that after taking the cognitive flexibility rating into account, the correlation between mean momentary rumination and FDCNeg approached significance.

Prior to controlling for cognitive flexibility score, there was no significant correlation. After controlling for cognitive flexibility score, there was a trend that higher mean momentary rumination was associated with higher FDCNeg, meaning that there was a higher switch cost (or lower cognitive flexibility) for fixation duration when the target was negatively valanced.

This was the first study to investigate the relationship between momentary rumination and eye-tracking indexes. Additionally, this was the first study to investigate the relationship between momentary rumination and the affective components of cognitive flexibility. Since FDCNeg was obtained in the condition that needs negative emotion processing, it can be considered as a measure of the affective component of cognitive flexibility. Our findings showed that the affective component of cognitive flexibility was associated with momentary rumination, especially in reference to rumination about past events. This finding may suggest that those who were less flexible in switching to new strategies when negative information was presented in the task, will have the tendency to ruminate about the past more in their daily life.

The findings that were reported only approached significance. It would be necessary for future research to repeat this with a larger sample size. Further, future studies need to see if there is a causal relationship between affective cognitive flexibility and momentary rumination in reference to past events.

Deployment of Rumination in Everyday Life

The current study showed that ruminating about the past was significantly correlated with ruminating about the future in everyday life. The mean momentary rumination indexes were not significantly correlated with trait rumination. That is, on average, higher level of trait rumination did not relate to higher level of momentary rumination in daily life. Furthermore, the current study using the RRS, CFS, FDCNeg (or FDCNeu in another model), momentary positive affect, and momentary negative affect to predict momentary rumination in daily life found that CFS, momentary positive affect, and momentary negative affect, significantly predicted momentary rumination. FDCNeg marginally predicted momentary rumination. However, trait rumination did not significantly predict momentary rumination. There are a few possible explanations for the current findings.

Previous research has mixed findings about the relationship between trait rumination and momentary rumination. In line with previous studies (Fang et al., 2019), the findings of the current study did not show any significant correlation between trait and momentary rumination. However, in some other studies, higher levels of trait rumination were found to be correlated with higher levels of momentary rumination (Moberly & Watkins, 2008). The mixed findings in the literature could be because the RRS is measured by asking individuals to think about what they will do when they feel depressed, whereas momentary rumination items used here did not ask those questions. Second, the RRS measures how people react across different situations for a

relatively long period of time compared to momentary rumination, which changes from moment to moment. Therefore, momentary rumination is a measure that relates more to rumination fluctuation in individuals. Moreover, trait rumination refers to a more consistent fixation on events or experiences. It is a baseline of rumination that remains more regular, not changing from moment to moment (Kocsel et al., 2017). Momentary rumination differs from trait rumination as it changes from moment to moment each day, not fixed to any baseline.

In the current study, the results showed that higher mean positive momentary affect and negative momentary affect both were significantly associated with mean momentary rumination. Prior research has shown an association between mean negative momentary affect and mean momentary rumination (Moberly & Watkins, 2008). In the present study, similar results were found for negative affect. It was also found that higher positive momentary affect can be associated with higher momentary rumination. This might be because in the momentary rumination items, participants were not specifically asked if they were ruminating only when they felt sad. Prior studies reported that a positive mood can also induce momentary rumination in high trait ruminators (Whitmer & Gotlib, 2013).

The most important finding in the current study is that it was cognitive flexibility and FDCNeg, but not trait rumination, that can predict momentary rumination in daily life. This may suggest that both cognitive and affective components of flexibility can predict more frequent rumination in daily life. Future research should try to manipulate cognitive and affective flexibility to see the causal impact on momentary rumination. For example, in order to manipulate cognitive flexibility, researchers might ask participants to reflect on or imagine a stressful situation. After manipulating cognitive flexibility, researchers could then assess the impact on momentary rumination by using ESM, or other self-report methods.

Limitations and Future Directions

Sample size

The main limitation for this study is the small sample size. In any study, power and sample size estimations are necessary so that researchers know how many participants are needed for the study in order to answer the research question(s) and then be able to make inferences about the population based on the results (Jones et al., 2003). Increasing the sample size or collecting data for a longer period of time would be necessary to allow for more statistical power (Sassenberg & Ditrich, 2016). Based on power analyses performed for the present study, the desired number of participants for this study was 62. A total of 44 participants were recruited via mass email and flyers with QR codes on campus. Of the 44 participants recruited, 32 participants went on to complete the initial lab session. If participants presented to the lab wearing contacts, or they failed the calibration and validation portion of the eye-tracker set up after three attempts, they were disqualified and asked to reschedule. Once the lab session was complete, participants were required to respond to the ESM sessions for 7 consecutive days. Some participants did not respond to the ESM questions on their devices for the required 7-day mark, leading to 8 or more missed responses on their devices, which disqualified them from finishing the entire study. A few participants failed to join the ESM portion of the study altogether, leading to loss of participation. Only 7 participants finished the entire 2-month study. The final sample size for the current study was 27.

The smaller sample size was due to a few factors such as attrition, technical difficulties during eye-tracking and ESM, as well as consequences of the Covid-19 pandemic. When this occurred, participants were contacted via email and compensated $10 for their time. Additionally, if the participants eye could not be tracked for some reason, or the machine could

not be successfully calibrated and validated during the apparatus set up after three attempts, the participant was disqualified and compensated $10 for their time in the lab.

Aside from attrition relating to technical difficulties as noted above, Covid-19 greatly impacted the ability of obtaining an increased sample size. Due to the fluctuation of campus and community wide Covid-19 cases, recruitment was greatly disturbed. The nature of the study required close proximity between researcher and participant, preventing the social distance measures that were in place by the university to reduce Covid-19 transmission. Once cases and transmission rates declined, the recruitment process began. In some instances, participants who were on the schedule had to miss their sessions due to possible exposure, pushing their initial lab session back two more weeks. When in the eye-tracking lab, participants and researchers wore KN95 masks, and researchers also wore face shields. During the eye-tracking set up, face masks occasionally came into the cameras field of vision, impacting the machines ability to accurately collect psychophysiological data.

In 2018, a meta-analysis was conducted to examine the replicability of psychological research and found that in general, research in the field is afflicted with low statistical power (Stanley et al., 2018). There has been difficulty in recent years to replicate studies, revealing challenges for progress in psychological research. It can be assumed that this has only worsened since the onset of the global pandemic in terms of recruitment, attrition, and ability to develop effective experiments that allow for social distancing.

Generalization to Clinical Samples and Possible Intervention Methods

What should also be noted is how our sample is a sample of convenience. This method used for sampling is considered a non-probability sampling method, which means that the participants were gained based on availability and proximity to the campus, lab, and university

area. Due to this, our current sample cannot be generalized into a clinical sample as it is not representative of a population. Consequently, the results obtained may only apply to the current participants (Elfil and Negida, 2017). It is important to investigate the same research questions in clinical samples because the results would be subject to less bias, and have the ability to be generalized outside of the participant group to individuals with a shared diagnosis or condition (Stratton, 2021). Subsequently, results obtained from clinical samples may lead to more effective treatments and interventions for anxiety.

The finding that it was CFS and FDCNeg, but not trait rumination, that can predict momentary rumination in daily life shed new light on possible interventions to reduce daily rumination, and therefore prevent individuals from developing further depression and anxiety symptoms. For example, if increasing a person's cognitive flexibility levels can decrease their level of momentary rumination, then daily exercises or activities to increase flexibility can reduce instances of negative mood. Trait rumination was not found to predict momentary rumination. Since trait rumination is a more consistent level of rumination, whereas momentary rumination fluctuates multiple times per day based on events, there is an indication of hope for the efficacy of interventions that would prevent or alleviate symptoms of anxiety and depression.

Cognitive flexibility can be improved or corrected in many ways such as physical fitness, mindfulness, and meditation exercises, etc. Physical activity has been shown in the literature to increase cognitive flexibility and decrease levels of anxiety and depression (Themanson et al., 2008). For individuals in which physical fitness activities and exercises may not be suitable, other methods like meditation might prove more useful. Further, concentrative meditation was shown to increase cognitive flexibility levels (Muller et al., 2016). Clinical interventions seeking to reduce symptoms of anxiety and depression in more natural ways by increasing cognitive

flexibility could use one of the methods previously listed or a conjunction of them both, to name a few.

The present study explored cognitive flexibility and rumination as risk factors for anxiety in adults using a task switching paradigm and questionnaires, followed by seven days of ESM responses. Future research might focus on the development and maintenance of anxiety in other age groups besides adulthood, which is more widely researched. Another worthwhile direction for future study would be to examine comorbidity of anxiety disorders with other mood-related disorders, addiction, or chronic physical health conditions. This study may help influence others to use experience sampling methods for longer periods of time, in order to continue collecting data on momentary affect and rumination in regards to anxiety, which may yield more accurate longitudinal data.

CONCLUSION

Psychiatric disorders are one of the most common contributing factors to the global health burden, with anxiety shown to be most prevalent of those psychiatric disorders (Lepine, 2002). Although anxiety remains widely researched and talked about in the literature, it has gone largely undetected and untreated in the population at large (Kroenke et al., 2007). Due to factors such as the prevalence, comorbidity with other psychiatric disorders, and lack of access to adequate mental health services, further exploration of anxiety and effective treatment remains paramount.

This thesis project sought to answer important research questions pertaining to the relationship shared between cognitive flexibility, trait rumination, and momentary rumination. It also investigated these variables in the context of anxiety, which is still scarce in the literature. These relationships were investigated and measured via use of the task switching paradigm, eye-tracking measurements, questionnaires assessing cognitive flexibility, rumination, and anxiety (CFS, RRS, DASS), and experience sampling methodology. To the best of our knowledge, this is one of the first studies investigating the relationship between cognitive flexibility and rumination in the context of anxiety that provides answers to those questions.

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APPENDIX A

IRB Approval

NORTHERN MICHIGAN UNIVERSITY

Graduate Studies and Research
Marquette, MI 49855-5301
906-227-2300
www.nmu.edu/graduatestudies/

MEMORANDUM

To: Lin Fang
Department of Psychological Sciences

Date: March 25, 2022

From: Lisa Schade Eckert
Dean of Graduate Studies and Research

Project Title: The relationship between cognitive flexibility and emotion regulation from laboratory to daily life
Approved Send Date: 3/25/2022

Your mass email request related to IRB protocol HS20-1152, "The relationship between cognitive flexibility and emotion regulation from laboratory to daily life" has been approved by the Dean of Graduate Studies and Research to be sent to 20% of NMU students.

If you have an email list, you may send your mass email to those on the list.

If you need to send to a specified group of potential participants that you do not have email address for, you will need to use the NMU ePostal system. Only faculty and staff members are able to use the ePostal system. The intended recipients and email message can be specified in the EPostal submission.

Please note that all consent forms approved by the IRB must be available with the email send.

Information about and instructions for using the EPostal system and the contact information for the survey distributor in the Business Intelligence Office can be viewed here:
https://www.nmu.edu/informationtechnology/e-postal-email-services

APPENDIX B

MASS Email Script

Subject: Paid Emotion Regulation Eye-Tracking Study: Participants Needed!

Hello,

This is the Cognitive x Affective Behavioral & Integrated Neuroscience (CABIN) Lab in the Department of Psychological Science contacting you about the possibility of participating in our paid ($30) emotion regulation eye-tracking study. This study includes: 1h cognitive experiment in the eye-tracking lab + 1-week daily mood measurement via a customized app (you will receive notifications to complete a short survey about your mood 4 times a day for 7 days, each short survey will only take 1-2 minutes), and 5 min follow-up online survey. To participate, you must be between the ages of 18 and 42, have normal vision or corrected-to-normal vision.

If you are interested, please sign up for the study using this link:

https://calendar.google.com/calendar/u/0/selfsched?sstoken=UUVzWVJQdFhoVWNGfGRlZmF1bHR8Nzg5NDQwMDhkYjk1ZjNlYzdlZjEzNjdhZGRiNTMzMDc

APPENDIX C

Informed Consent Statement

NORTHERN MICHIGAN UNIVERSITY
INFORMED CONSENT STATEMENT

Title of Project: The relationship between cognitive flexibility and emotion regulation: from laboratory to daily life

Investigators: Dr. Lin Fang (Assistant Professor, Department of Psychological Science, NMU)
Dr. Joshua M. Carlson (Professor, Department of Psychological Science, NMU)

You are invited to participate in our research study. The purpose of this study is to investigate the relationship between cognitive control and emotion regulation in real life. A research assistant at Northern Michigan University will be conducting the study under the advisory of Dr. Lin Fang.

INFORMATION

100 people will participate in this study, which will consist of one laboratory session, one experience sampling method (ESM) session at home using cell phone app, and one online follow-up session. In the lab session, participants will be asked to perform the following tasks: (1) task-switching paradigm (8-10 min) (2) dot-probe task (10-15 min) (3) personality questionnaires (10– 15 min). In the ESM session (2 min per assessment x 4 times/day x 7 days), participants will receive notification from app four times a day in seven consecutive days. In the online follow-up session (3-5 min), participants will be contacted 2 months after the last ESM session and will be asking to fill up several short questionnaires online.

Participants will be males or females between the ages of 18 and 42 with normal or corrected to normal vision (i.e., by wearing contacts or glasses). After reading this document and agreeing to participate in this study, we will begin the experiment.

Lab session
The lab session will take place in the Cognitive x Affective Behavior & Integrative Neuroscience (CABIN) Lab in the Psychology Department at Weston Hall Room 1205. All the computer tasks and personality questionnaires will be presented with desktops in CABIN Lab and a response box will be using to collect reaction data. Participants will be asked to complete the following tasks: Task-switching paradigm and Dot-

probe task. During those tasks, you will be asked to follow the instruction and make corresponding response with the response box. After that, you will fill out several brief questionnaires assessing your personality type.

Task-switching paradigm: In this paradigm, participants will be asked to respond to the facial stimuli according to different rules (i.e., cue words), such as "emotion", "gender", or "color", which will be presented in the center of the screen for 500 ms on every trial. Immediately after the cue word, four faces will be displayed on the screen in a squared grid (2 x 2) matrix with a black background. Each face would be different on three distinct stimulus dimensions: emotion (negative vs. positive), gender (female vs. male), and color. Participants will be asked to detect and locate the face that differs from the others based on the relevant dimension indicated by the preceding cue word as fast and accurately as possible, by pressing the corresponding button on a response box. After the response, a blank screen will be presented for 100 ms before the cue for the next trial appeared.

Dot-probe task: In this task, each trial will start with a white fixation cue (+) centered on a black background. Then two cues will be simultaneously presented to the left and right of fixation. Afterward, a target stimulus (e.g., a small dot) will be immediately presented in the location of either the left or the right stimulus cue and remain until the participant responds. Participants will be instructed to identify the location of the target as quickly as possible by pressing the first button with their right index finger for left sided targets and pressing the second button with their right middle finger for right sided targets. Participants will be instructed to always fixate on the fixation cue, which will remain in the center of the screen throughout each trial. A response terminates the current trial and initiates the next trial.

Experience sampling method (ESM) Session

After the lab session, you will be asked to complete an ESM procedure with your mobile phones outside the lab, where daily dynamics of stress, affect, and emotion regulation will be measured with four assessments per day during seven consecutive days. Feelings at the moment and emotion regulation strategies used since last beep (last ESM survey) will be measured. Using questions like "How energetic do you feel at the moment?" the momentary energetic, happy, satisfied, stressed, angry, sad, anxious, depressed, and lonely status will be measured. To measure the momentary emotion regulation strategies, questions will be asked about the usage of major emotion regulation strategies, such as "Since the last beep, have you ruminated about something in the past?". Participants will be asked to rate all their momentary emotion and emotion regulation status on separate 100-point scales with 0 = not at all, 100 = very much. Within the 30 minutes of receiving notification, you will need to answer a short survey assessing your momentary stress, affect, and emotion regulation on your cell phone app. Each assessment should only take approximately 2 minutes. So, in total, you will spend 56 min across 7 days (2 min per assessment x 4 times/day x 7 days). If there are more than 8 missing time points (i.e., no reply for 8 of 28 measurements), then the whole ESM will be invalid and you will be compensated for the lab session only. The whole time frame is 12 hours and notifications will be sent at a random time point within each 3 hours (e.g., between 8-11 am, 11-2 pm, 2-5pm, and 5-8 pm). The assessment time frame will be customized based on your schedule (e.g., whether it is between 8 am – 8 pm, or 9am – 9 pm, or 10 am – 10 pm).

Follow-up

Two months after the last ESM assessment, you will receive online survey assessing your personality and emotion regulation.

RISKS

Risks associated with participation in this study are considered minimal. If you experience any discomfort during the experiment sessions, please notify the experimenter so that adjustments can be made to improve your comfort. Although it is unlikely, some of the survey questions could elicit unexpected thoughts or feelings. If you ever feel uncomfortably anxious/depressed/stressed, or if you feel that you have the need for counseling, please contact the NMU Counseling Center (906-227-2980), it has free services for NMU students.

BENEFITS

There are no direct benefits to the participants other than research experience and payment. This research will be the first to demonstrate the relationship between cognitive flexibility and emotion regulation in daily life. The findings of this research will provide new venues to study the interaction between cognition and emotion as they occur in real-life. Furthermore, since cognitive flexibility is one of the most important risk factors for the vulnerability in depression and anxiety, a better understanding its role in daily emotion regulation would have potential clinical implications for a new direction in the cognitive training treatments.

CONFIDENTIALITY

In the current research, all the participants will be assigned a unique participant number, which will be used in all their performance, so that no identifying information will be associated with participants' data. To ensure the confidentiality of the data, the electronic consent forms with participants' names will be stored on a computer in the lab, without a subject number. All the data which will only be associated with the participant number will be stored on a computer in the lab. Only Dr. Fang and CABIN lab research assistants will have access to the lab computers.

COMPENSATION

Since the whole study will take approximately 2 hours in total (40 min lab + 56 min ESM + 5 min follow-up online survey) you will receive $30 for fully completing this research. For incomplete procedure (e.g., only lab session, only ESM, or only lab + follow-up, only ESM + follow-up), then you could only receive $10.

PARTICIPATION and CONTACT

Your participation in this study is completely voluntary. You have the right to withdraw from the study at any time without consequence or penalty. You have the right to omit any questions or decline any procedures.

If you have any further questions regarding your rights as a participant in a research project you may contact Dr. Lisa Schade Eckert of the Human Subjects Research Review Committee of Northern Michigan University (906-227-2300) leckert@nmu.edu. Any questions you have regarding the nature of this research project will be answered by the principal researcher who can be contacted as follows: Dr. Lin Fang (906-227-1169) lfang@nmu.edu.

CONSENT

I have read and understand the above information. I have received a copy of this form. I agree to participate in this study.

Participant's signature_____ email _____ Date _____

Age_____ Gender _____

Investigator's signature_____ Date _____