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Emotion regulation and executive function measures: exploration of predicted relationships

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EMOTION REGULATION AND EXECUTIVE FUNCTION MEASURES: EXPLORATION OF PREDICTED RELATIONSHIPS

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CHAPTER 1

INTRODUCTION

In psychology, few constructs have undergone such close analysis as Executive Function. It has gone by many names including the central executive, executive control, effortful control, and cognitive control. Despite extensive research, there is no agreed upon definition of executive function (Jurado & Rosselli, 2007). In clinical psychology, for example, deficient executive functioning has been associated with a variety of conditions, including Attention Deficit/Hyperactivity Disorder (Barkley, 1997), traumatic brain disorder (Alvarez & Emory, 2006), Autism spectrum disorders (Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009), and dementia (Sturm, Ascher, Miller, & Levenson, 2008). It has been not been easy to determine whether the construct is unitary, corresponding to one's general capacity to self-regulate, or whether it is a loose collection of specific modules, which each direct a particular aspect of self-regulation (Miyake et al., 2000). Nevertheless, in general, modern research tends to speak of executive function as a global construct made up of several components. However, the exact functions of this construct are notoriously ambiguous (Packwood, Hodgetts, & Tremblay, 2011).

Executive Function and Components

What is clear is that executive functioning is important to self-regulation and higher order cognition (MacDonald, 2008). The more commonly researched components of executive function include inhibitory control, attentional control, working memory, planning, verbal fluency, and emotion regulation (Alvarez & Emory, 2006; Jurado & Rosselli, 2007; Toplak, Sorge, Benoit, West, & Stanovich, 2010; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). The current study investigated the last of this list of components, *emotion regulation*, and its relation to some of the other named constructs. Given the wide variety of components purported to involve executive function, it was important to include more than one measurement of each component.

Emotion Regulation

Like executive function, the construct of emotion regulation has also resisted clear definition (Cole, Martin, & Dennis, 2004). One accepted definition is the recruitment of internal emotional states to regulate other emotions, and another is minimizing felt or expressed emotions through inhibition (Cole et al., 2004). Historically, the latter definition has predominated; that is, emotion and its regulation have been understood as two separate systems: one system that generates an emotion, and another that intervenes to control its expression (J. J. Campos, Frankel, & Camras, 2004). Unlike discussions of executive function, research and theory on emotion regulation rarely include executive function as a factor in emotion regulation; see Rothbart's work as a rare exception to this (Jones, Rothbart, & Posner, 2003; Posner & Rothbart, 2007; Rothbart, Ellis, & Posner, 2004). Indeed, how emotion regulation is operationalized depends on the theoretical perspective of scholar studying it.

Emotion regulation – Psychoanalytic approaches. One difficulty in answering the question of how emotion regulation relates to executive function is that emotion regulation has not been extensively studied and operationalized, certainly less thoroughly than the construct of executive function. Although emotion has been the subject of psychological theory since William James, the challenges involved in empirically studying it meant it was not a major focus until recent decades. Systematic study of emotion has been slow to develop, as reflected in the relatively recent inception of the APA Journal Emotion (2001). Among the first proposed emotion regulation theories were psychodynamic approaches, particularly their concepts of emotional defenses (Westen & Blagov, 2007). These view emotion as unconscious internal conflict between desires and impulses, which clouds rational, logical thinking. Consequently, when these internal conflicts grew too strong, undesired emotion becomes evident. Mature adults were thought to employ strategies to defend against the intrusion of conflicts into clear, reasoned thinking (Gross, 2007). Psychodynamic psychologists identified many psychological defenses used to cope with uncomfortable desires and feelings, such as projection, displacement, and humor, for example (Westen & Blagov, 2007). From this theoretical perspective, emotion regulation is a process of suppression or mitigation of undesired, usually negative emotion, which in the extreme represents individual psychopathology.

Emotion regulation – Cognitive approaches. Cognitive psychologists view emotion regulation somewhat similarly, as cognitive control or top-down inhibition of a lower, primitive, more impulsive system. The model of emotion regulation proposed by Gross generally takes this view (Gross & Thompson, 2007). Gross characterizes emotion as an internal state, brought on through stimuli in the environment or within the body. Emotion regulation is the various strategies a person employs in response to this internal state. The Gross model categorizes four broad sets of emotion regulation strategies by the time period emotion emerges. The first, earliest place for emotion regulation is *situation selection*, in which an individual chooses and modifies their own environment, e.g. removal of arousing stimuli or avoidance of provoking situations. If active adjustment of the environment or situation is unsuccessful, a person can use a strategy in the following time segment of the emotion event, adjusting his *attention* in the midst of an provoking situation to regulate emotion, e.g. distracting himself during a painful medical procedure or concentrating on one aspect of a stimulus to the exclusion of others. Next in time course, (but functionally nearly coinciding with attention), a person can modify their *appraisal* of emotion, e.g. perceiving anxiety before a big athletic event as excitement for success, rather than fear of failure. Finally, an individual can modify their behavioral *response* to an emotional event, e.g. not expressing his anger with a government official after being delayed for an event, suppressing anger at a child who has done something bad accidently, etc. Both psychodynamic and cognitive approaches share much of this view, seeing emotion as predominately negative internal states, which people work to control or suppress. Cognitive scholars who hold this conception of emotion regulation view it as an important skill or skillset. Working from this perspective, researchers have related capacity for emotion regulation variously to impulsivity, a characteristic that makes emotion regulation difficult (Mullin & Hinshaw, 2007); temperament, which makes emotion regulation difficult or easier, depending on genetically determined personality attributes (Rothbart & Sheese, 2007); as well as school outcomes and social competence, which are environments or areas of functioning that pose significant demands on individuals to control emotion (Eisenberg, Hofer, & Vaughan, 2007).

Emotion regulation – Evolutionary psychology approaches. Other researchers emphasize the environmental and informative aspect of emotions (Joseph J. Campos, Walle, Dahl, & Main, 2011) that serve survival. Whereas emotions are experienced internally, they often have external causes. More primitive brain structures, such as the limbic system, are highly active in processing information that might potentially provoke an emotional experience, such as risk and reward. These areas of the brain develop earlier ontologically than higher cortical areas, and are active in processing stimuli from the environment virtually from birth (Fuster, 2008). It is clear that mammalian emotional responses have been shaped by years of evolution, to propel us away from dangerous stimuli, to protect children, and to choose our mates (Westen & Blagov, 2007). Many theorists (Ekman, 1994; Gross, 1998; Nesse & Ellsworth, 2009; Porges, 2001) have highlighted the adaptive and evolutionary function of emotions. Regulation of emotion from this perspective has also been crucial to our evolution. Showing appropriate emotional reactions in social situations requires substantial intelligence and sophistication. The ability to withhold acting reflexively on their emotions allows for greater behavioral flexibility, which is necessary in cooperative societies with many complex social relationships (Izard et al., 2011).

Emotion regulation – Social constructivist approaches. Finally, social constructivists and developmentalists acknowledge the external and environmental causes of emotion regulation, but also emphasize the multitude of forms it takes, particularly in response to social situations. These theorists and researchers see emotion as being social as well as internal, with emotion regulation serving social needs for clear communication and good relationships, among several such functions. Cultures differ in their appraisal of emotions and the modal way emotions are expressed in response to common environmental circumstances (Cole, Bruschi, & Tamang, 2002). Parents and parenting greatly influence the capacity of children to cope with emotionally arousing situations, as well as the form of that coping early as infancy, children look to their parents' emotional expression to inform them how to react to ambiguous or unfamiliar stimuli (Sorce, Emde, Campos, & Klinnert, 1985). This continues throughout life; we look to others to help us regulate our emotions even in adulthood. This regulation serves our needs to be successful in our essential tasks of life. As a specific example, take the finding that people are more inclined to procrastinate and budget less time to complete a task when they are asked to think about how others would help them achieve a specified goal. This suggests that we reduce our own anxiety by including others when we approach difficult tasks (Fitzsimons & Finkel, 2011).

Scholars' contrasting theories of emotion regulation have also produced various methods and approaches to quantifying emotion regulation, e.g. by assessing suppression of internal felt emotion, or of emotion expression; looking at failures to suppress or mitigate felt or expressed emotion; or possibly by assessing a person's emotion control in response to social situations (Gross & Thompson, 2007). There is not likely to be any single method or measurement that captures emotion regulation in a way that adequately encompasses the approaches described here, much less others not discussed. Therefore, research with emotion regulation as a focus would ideally include measures derived from different approaches, cutting across different theoretical perspectives.

Measurement of Executive Function

Assessment of executive functioning reflects the somewhat piecemeal research on the construct. Proposed components are usually tested individually, and there are multiple tests for each component, some more easily measured than others. There are well-operationalized measures for some components, like assessing digit span as a measure of working memory, or using continuous performance tests as measures of inhibitory control. These cognitive tests have been used to identify pathology associated with impulsivity, such as frontal lobe lesions and attention deficit/hyperactivity disorder. For example, tests measuring inhibition control (cf. the Stop-signal, (Logan, 1994);), interference regulation (cf. the Stroop test, (Golden, Freshwater, & Golden, 2003)), and task switching (cf. Trails B, (Reitan, 1958)), have been used as evidence of executive function deficits in individuals with attention deficit/hyperactivity disorder (Willcutt et al., 2005).

Many executive function tests, such as those noted above, lack a strong motivational or arousing component (beyond general testing apprehension) and are thought of as cognitive, "cool" tests (Geurts, van der Oord, & Crone, 2006) with emotional arousal largely eliminated. The introduction of motivational components, such as reward or arousing stimuli can change the task demands, the performance of individuals, and possibly the neural pathways involved in the task.

Another concern with measures of executive function is that observed correlations among tests of executive function components have been low (Jurado & Rosselli, 2007). The tests of the more complex and emotionally stimulating components of executive functioning, like planning, are especially susceptible to low convergent validity. Studies comparing children's performance and neural activation during executive function tasks to adult performance show that children's' activation is broader in the prefrontal cortex and other areas, whereas adults' activation is more localized (Best, Miller, & Jones, 2009; Casey, Tottenham, Liston, & Durston, 2005). Additionally, although strong correlations among performance on tasks of executive functioning tasks have been found in children, they are not evident in adults (Best et al., 2009). This suggests that in adults, executive functioning is not a single entity, but rather a collection of separate integrated processes. Nonetheless, imaging studies of activation during these tasks are localized in the same regions of the brain, largely in the frontal cortex. One possible explanation of these effects is that some executive function components are modular and unitary, whereas others are composites of modules or refer to more general functioning.

The work of Friedman and Miyake suggests that there are lower, fundamental components that act more as modules, and higher components that are more integrative (Friedman & Miyake, 2004; Friedman et al., 2006; Friedman et al., 2008; Miyake et al., 2000). Some fundamental components proposed by Friedman and Miyake include *response inhibition, task switching*, and *working memory*. These components are frequently the focus of executive function research, and have been targeted in particular methods of measurement (Davidson, Amso, Anderson, & Diamond, 2006; McAuley & White, 2011; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010; Packwood et al., 2011).

Response inhibition. Response inhibition is generally defined as the ability to stop a response. It can be further classified by type of response being inhibited. Good tasks of response inhibition require suppression of an automatic behavior. Examples include the **Stroop task**, which requires participants to withhold the impulse to read words and instead have to identify the color of ink that they are printed in, or the **go/no go task**, which requires participants to respond to some stimuli and not respond to others. Errors and reaction time are dependent measures obtained on these tasks. Errors, both omissions and commissions, are considered more diagnostic of difficulty with inhibition, though reaction time can provide evidence of inhibitory ability as well. Inhibition is thought to be the primary deficit in Attention Deficit/Hyperactivity Disorder (Barkley, 1997) and continuous performance tests have been employed in the diagnosis of that disorder.

Task switching. The ability to quickly and accurately shift between tasks and adjust to new demands and rule changes is known as *task switching*. Such ability is thought to be necessary for learning. Simple tasks require participants to categorize ambiguous stimuli based on changing rules. When rule changes occur, the amount of extra time required to accurately implement the change, the switch cost, is assessed. Long and inaccurate switch costs have been linked to pathology. Measures that are thought to assess this ability include, Trails B and the Wisconsin Card Sort Test (WCST), with the Wisconsin Card Sort Test considered by some scholars to be the gold standard of executive functioning tests (Royall et al., 2002).

Working memory. Working memory capacity can be described as the ability to hold and manipulate multiple pieces of information in one's mind. It could be as concrete as being able to remember a list of items for a short period of time (seconds to minutes), to as extensive as performing operations on items in one's mind, such as mentally turning puzzle pieces to determine if they will fit. This capacity is thought to be an important piece of intelligence and many current tests of cognitive ability include a working memory component. Superior ability in working memory can be seen in measures of the relative amount of information able to be recalled (cf. Digit Span, (Wechsler) and the accuracy of manipulations performed on the information (cf. **n-back** measure, (Kirchner, 1958)).

Measurement of Emotion Regulation and Its Components

Although executive function has been separated into specific components that do not overlap much (in adults), emotion regulation has not commonly been deconstructed into distinct modules. One attempt to do this was performed by Gross, who separated emotion regulation by the time course in which the regulation occurs. However, there is likely more overlapping variance between these components compared to the amount of shared variance between executive function components. Like assessment of components of executive function, techniques for assessing emotion regulation are also quite varied; including, physiological measures, behavior ratings, observation of *in vivo* responses to emotion inducing stimuli, and self-reports in response to quite a variety of situations. These assess multiple aspects of the full time course in which an emotion occurs, described by Gross, and reflect the theoretical view of the instrument designer. The method employed to measure emotion regulation can also vary by the age of the participants and the type of emotion being regulated.

Of all these variations and potential circumstances for assessing emotion regulation, there are nevertheless some common approaches to measuring emotion regulation. Typically measures assess responses in terms of internal feelings; appraisal of emotion and emotion expression;

observing emotion expression and behavior following induction or presentation of emotion-provoking stimuli; and asking for self-report of emotional regulation in response to particular situations. These are the widely used due to their ease of use, ability to assess multiple emotions, e.g. sadness, anger, excitement and social responsiveness, and capability to assess the internal experience of emotion, i.e. the responder's perception of an emotion even rather the modal or artificially generated emotion experience. It is particularly relevant to research in adults, who may differ widely in the responses to laboratory emotion eliciting event, but have the capacity to reflect on and report their both internal experiences and external behaviors during emotional events.

Across these various measurement methods, there are some central forms of emotion regulation that can be evaluated. In the temporal focused model of emotion regulation (Gross & Thompson, 2007), these include *situation selection*, *appraisal of emotion*, *control of emotion*, and *instrumental use of emotion*. Currently, however, there is no clear component structure of emotion regulation, nor are there ubiquitously used measures to assess them.

The current study focused on self-report measures of emotion regulation, as they are considered to have adequate external validity and are intended to be applicably in a wide variety of people and situations. In addition, the study will focus on emotion regulation in the present, rather than strategies anticipating future emotional responses or coping with previous emotional events. There are multiple emotion regulation strategies, multiple situations and multiple emotions, so it is difficult to include all of them in a single self-report. Also, many emotion regulation strategies require some self-awareness and accurate assessment of one's emotional reactions. The study's focus on emotion regulation strategies *during* and emotional event, like suppressing expression of negative emotion, may be related to future-focused and past-focused emotion regulation. Consequently, present focused emotion strategies are more frequently utilized and appear earlier in development. The components of emotion regulation studied in this study were:

Appraisal of emotions. Awareness and appraisal of emotion is one proposed component of emotion regulation (Gross, 1998; Gross & Thompson, 2007). Knowledge of one's own internal processes, particularly in unfamiliar situations, can be crucial, since categorization of an emotion experience determines the behavior response. Objectifying and categorizing emotions facilitates discussion of emotion, perspective taking, general understanding of the course of emotions and their regulation. Furthermore, accurate appraisal aids in assessing other's emotional reactions and assists in negotiating social relationships. Those who have difficulty accurately appraising their own emotions and the emotions of others have difficulty in social situations, since their behavioral responses are not likely to be as flexible or appropriate to the social situation.

Control of emotion. Perhaps the most commonly thought of definition of emotion regulation, first proposed by psychoanalytic and cognitive researchers, is control of emotion through inhibition. However, this is a broad definition, referring to either suppression of expression of emotion, that is, a person's behavioral signals of emotion; or changing mood, a person's internal felt emotion. Whereas these two targets of emotion regulation are quite different, both require inhibition, be it of an internal felt state, or the expression of that emotion in overt behavior.

Instrumental use of emotion. Another aspect of emotion regulation that is important to include is the use of emotion instrumentally. It is essential to remember that emotions are not simply internal feelings. Emotions also have communicative and instrumental capacity as well.

They are very important in facilitating social behavior. Often we modify our emotional expression based the people around us, either as a way of anchoring our experience, or to influence the shared emotional tone.

Emotions can also be exercised deliberately, to influence emotion of other persons, thus shaping intra- and inter-personal experience. Often in emotionally charged situations, individuals can feel multiple emotions, some of which may be in conflict with one another (e.g. feeling both happy a friend successfully graduated, but sad that they will be leaving and the relationship will be less close). Whereas using a control component of emotion regulation could focus on suppression of undesired internal emotions, an instrumental strategy that "revved up" or accentuated certain emotions could aid in achieving a goal or resolve ambivalent or conflicting emotions in favor of the more positive emotion. These regulation strategies can target both individuals' own emotions and those of other persons, at the same time. This is most frequently seen in social situations, where positive emotions are emphasized, via such activities as laughing, flirting, or even simply increased motor movement/ These can influence *both* an individual's own internal experience as well as the experience of others in the same social environment. Parents and teachers often do this by expressing excitement through their voice and movements, which are unconsciously mimicked by children. This is very helpful when children are inattentive or upset. This component requires approach or affiliative behavior rather than avoidance and suppression. It is also regulation via overt behavior, not just use of internal states or processes.

Studying active, live regulation of emotion is important. Likewise, taking more physiological approaches to emotion regulation through means such as cortisol measurement or functional imaging, hold promise for revealing emotion regulation without the weaknesses of self-report. However, it was beyond the scope of this investigation to incorporate those types of measures, due to the difficulties and expense involved with *in vivo* and physiological measurement of regulation. In future projects, observing and assessing active regulation of emotion as well as physiological aspects of emotion regulation should be targeted. However, this project was an initial step aimed at exploring the relations among common measures of executive function and common self-reports of emotion regulation.

Previous Research on Executive Function and Emotion

Very little research has focused on links between executive function and emotion, much less emotion regulation. Exploration of mood and executive function is the principal way that emotion has been included in studies of executive function. Some emotions have been shown to influence performance on executive function tasks. For instance, positive mood is positively associated with performance on verbal fluency tasks, whereas negative mood is associated with improved spatial task abilities (Carvalho & Ready, 2010). Positive mood can actually reduce performance on tasks of working memory, planning and task switching, whereas mild amounts of negative emotion can enhance performance (Mitchell & Phillips, 2007). This could be due to an interaction between personality traits and strategy for responding to the test. Those who are more impulsive emphasize answering questions quickly over answering them accurately, which results in different strategic approaches to a task (Suhr & Tsanadis, 2007). Speedier answers results in quicker finishes, and can foster and be fostered by elevation of mood, given that relief often follows completion of a task that is not inherently pleasant. On the other hand, concern for accuracy is associated with negative mood, e.g. worry or fear, though not so negative as to make individuals feel that accuracy is unachievable. Furthermore, in contrast to the immediate relief felt on concluding a task quickly, a concern for accuracy is not met with fast completion of the task, as it usually takes time for accuracy to become known. This makes achievement of accuracy more distal as an evoker of positive emotion, compared to a focus on speed. Those employing strategies emphasizing accuracy out perform those who use strategies emphasizing speed on go/no go inhibition tasks (Leotti & Wager, 2010). Thus emotion, as indexed by contemporaneous mood state, interacts with performance on some measures of executive function.

One of the few researchers to attempt to integrate the two seemingly separate self-regulatory constructs of executive functioning and emotion regulation has been Rothbart, particularly her research with Posner (Jones et al., 2003; Posner & Rothbart, 2007; Rothbart et al., 2004). Infants are largely dependent on their caregivers to anticipate their needs and manage their environment. However, even early in infancy, there is substantial variance between individuals in their motor, attentional and emotional reactivity (Rothbart, 2007). In studying the development of temperament, three factors are identified: surgency, negative affectivity, and effortful control (Rothbart, 2007; Rothbart & Bates, 2006). In adult temperament studies this negative is related to Eysenk's neuroticism factor (Rothbart, Ahadi, & Evans, 2000). Surgency refers to the relative activity level, their shyness (lower in those high in surgency), capacity for high-intensity positive responses (sensation-seeking), their tendency to act impulsively, their positive expectation of events, and their relative amount of affiliation with others (Thompson, Winer, & Goodvin, 2011). In infancy, factor analysis of mother reports showed that positive emotions can be differentiated from negative emotions, and within negative emotions fear/anxiety can be distinguished from anger/irritability (Rothbart & Bates, 2006). Effortful control refers to an individuals level of attentional control, inhibitory control, perceptual sensitivity and low-intensity pleasure (Thompson et al., 2011).

In this conceptualization of self-regulation and temperament, executive function might be thought of as closely mirroring effortful control, while two aspects of emotional functioning, approach driven surgency and negative affectivity, correspond with emotion regulation. Individual differences in each of these components shape our individual experiences to similar stimuli and result in different behavior patterns. Ultimately, these differences shape our concepts of self, separate from the environment and other people in our lives. However, Rothbart's work has been primarily focused on infants and young children, not with adult constructs of executive function and emotion regulation. Her collaboration with Posner has developed the concept of effortful control and its relation to attentional networks. Out of this collaboration, effortful control describes application of a cognitive in a deliberate motivated way, rather than purely skill based that cognitive theorists have emphasized.

Current Study Directions

This study investigated self-report measures of emotion regulation for underlying component structures, and the relationship of these components to executive function components. The components of emotion regulation discussed above are hypothetical, thus the predicted components were compared with the results of an exploratory factor analysis.

After the underlying components of the emotion regulation measures were extracted from the exploratory analysis, the central purpose of this study was to assess the relations among executive function components and emotion regulation components. Overall, it was expected that better executive function performance would be associated with higher self-reported emotion regulation. Furthermore, specific components of executive function would be significantly related to individual emotion regulation components. The emphasis on suppression in both inhibitory control and control of emotion expression suggested that these components would be positively associated. Similarly, working memory skills, which require constant updating of information, were expected to positively relate to appraisal of emotion regulation strategies and instrumental use of emotion, which emphasize constant monitoring of emotion states and additional calculation of behavior. Finally, task switching was predicted to be associated with control of emotional expression, given that expression regulation might require ongoing flexibility in response to sudden changes in the environment.

CHAPTER 2

METHOD

Participants

170 Wayne State University undergraduate students were recruited to participate in the study, primarily from those enrolled in classes within the Department of Psychology. All potential participants were approached via the Department of Psychology's on-line SONA system for recruiting individuals to participate in research projects. All were required to be native English speakers and over 18. The average age of the participants was 22.4 (6.3 SD), with the group ranging from 18 to 55. Student ethnicity, age, and socioeconomic status varied according to the distribution of the students who signed up for the study, and were not characteristics that limited participation in the study (see Table 1).

Instruments

Demographic questionnaire. A brief demographic questionnaire was also completed. Participants were asked to provide their gender, age, ethnicity, school status, language spoken in the home as a baby, and household income.

Executive function. Three components of executive function were measured among the participants, via computerized tasks and research assistant administered tests. The three executive function components assessed were *task switching*, *response inhibition* and *working memory*. Two measures were included for each construct. All executive functioning tasks were selected from the Wechsler Adult Intelligence Scale – 4th edition (Wechsler) or the work of Friedman and Miyake (Friedman & Miyake, 2004; Friedman et al., 2006; Friedman et al., 2008; Miyake et al., 2000).

Response inhibition. The ability to restrain an automatic response is deemed response inhibition. Such skill is often necessary in structured social situations (Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006) and is related to abilities to limit impulsive behavior (Barkley, 1997). Poor performance on tasks requiring this response is associated with pathology (Martel et al., 2007), whereas strong performance is linked to academic success (Best et al., 2009). Two tasks were employed to assess this ability, a Stroop task and a computer administered anti-saccade task.

Anti-saccade task. When a stimulus suddenly appears into view, a person's first impulse is to move his or her eyes to look at it. This movement of the eyes is known as a saccade. In the anti-saccade task, an individual focuses on a fixation point on a computer screen until a box is quickly flashed on either side of the fixation point. A person must inhibit the initial impulse to move his or her eyes and look at the box, instead looking in the opposite side of the screen, where an arrow is briefly shown before being covered up by a grey thatched pattern. Then the person responds with the arrow keys, indicating what direction the arrow is pointing (Roberts, Hager, & Heron, 1994). The score obtained from this task is the proportion of correct responses. Split-half reliability estimates of this measure from Friedman et al. (2006) were .89 for adolescents aged 16-18.

Stroop. The Stroop task is composed of 3 sections: a word test, in which participants see words with color names in black ink; a Color test, with meaningless symbols printed in different colors, and a color-word test, where words consisting of color names first match the color they are printed in, or names that are printed in colors different from their names. (Golden et al., 2003). During the word test, respondents simply read each word. During the color test, they state the color the symbols are printed in. In the color-word test, they must say the color of ink the word was printed in, NOT say the word, which is a color name. The variable analyzed in this investigation is this final score, that is, the number of words correctly read in the time administered (45 sec) during the color-word condition (the interference condition).

Task switching. Task switching is best described as the capacity to shift between tasks; that is, to adjust quickly and efficiently to new task demands and rules. Two computerized tasks were used to assess this ability: a number-letter task and a category switch task.

Number-Letter. During the Number-Letter task, individuals are shown a letter-number pair (e.g. 8R) and indicate whether pairs have either an odd or even number, or consonant or vowel letter (Rogers & Monsell, 1995). A person's regular switch cost is the difference in time between the time to do the task without switching (e.g. an individual item has the same characteristics as the previous item) compared to the time it takes a respondent to do the task when he or she has to switch from letters to numbers or back again. It is calculated by subtracting the average reaction time on trials where no switch occurred from the average reaction time of switch trials. Split-half reliability estimates from Friedman et al. (2006) were .86.

Category switch task. In the Category-Switch task, respondents are asked to classify objects based on seeing their names, as being either larger or smaller than a soccer ball (size), or as living or non-living (alive). Words are presented individually in the middle of the screen while a cue appears above the word, prompting the person to the appropriate classification, a heart indicated living/non-living classification, and four arrows indicated a large/small classification. When an individual item of one type, such as judging size, is followed by the other type (in this case Alive), switching is said to occur. Sometimes a task is followed by exactly the same kind of task, e.g. two items in a row requires judgments about size. That is the absence of a category switch. Each participant's score for regular switch cost (in reaction time) is calculated by subtracting the average reaction time on trials where no switch occurs from the average reaction time of switch trials. Split-half reliability estimates from Friedman et al. (2006) were .85.

Working memory. In this study, working memory is the ability to hold and manipulate more than one thing in one's mind for a short period. The capacity is associated with academic performance and is incorporated into many intelligence tests, which predict such performance (Sattler, 2008). Two experimenter-administered tasks assessed participant's capacity in this area, Digit Span and Letter-Number Span.

Digit span. Respondents to this measure are asked to recall accurately a sequence of numbers read at a rate of 1 digit per second. To answer correctly, all numbers have to be recalled in the correct order. The number of digits in a string increases every two administrations. The task has three sections, repeating forward, backward, and sequencing digits. During forward digits, a person must simply recall the number string in the same order as spoken by the administrator. Backwards digits requires recall of the string in reverse order from what the administrator states, e.g. 5 – 3 should be recalled as 3 – 5. In this project, the total number of strings recalled is the pertinent score, that is the sum of correct forward, backward, and sequencing strings of digits. Test-retest reliability for Digit Span from the WAIS-IV subtest averages .83 for specific age groups, internal consistency averages .9.

Letter-Number span. For this instrument, individuals are read a list of numbers and letters, and are then asked to reorder them into numerical and alphabetical order. To be correct, the person being tested must correctly sequence both numbers and letters. They obtain a standard score based on the number of correct sequences they complete. Like Digit Span, the total number of strings recalled is the score obtained for this project. The WAIS-IV test-retest reliability for this subtest averages .75; the average internal consistency was .82 (Wechsler).

Emotion regulation measures. Three widely used questionnaires designed to assess skills and strategies of regulating emotions were selected for this study. These instruments assess regulation of emotion via self-reports. These were participants' reports of their degree of suppression of felt or expressed emotion; regulation by eliciting other emotions; and active engagement with emotional situations. The three measures used to assess emotion regulation were the Emotion Regulation Questionnaire (Gross & John, 2003), Emotional Approach Coping Scale (Stanton, Danoff-Burg, Cameron, & Ellis, 1994), and The Emotion Amplification and Reduction Scale (Hamilton et al., 2009).

Emotion Regulation Questionnaire (ERQ). This is a 10-item questionnaire measuring individual differences in respondents' habitual use of two strategies for regulating their emotions. These are *cognitive reappraisal*, and *expressive suppression* (Gross & John, 2003), each represented in a sub-scale in the measure. Cognitive reappraisal consists of regulation techniques to help reinterpret emotionally arousing stimuli, to regulate their impact. Expressive suppression techniques inhibit on-going emotion expression. In this study, both sub-scales had internal consistencies (Cronbach's α) near .70, cognitive reappraisal had .76 and expressive suppression had .70, and test-retest reliabilities of .69 in the research cited above.

Emotional Approach Coping Scale (EAC-8). This is an 8-item scale with two scales: *emotional processing*, or the tendency for the respondent to be aware and try to understand his or her own emotions; and *emotional expression*, the amount the respondent feels they can freely expresses their emotions (Stanton et al., 1994). In this study, internal consistency (Cronbach's α) for emotional processing was .69 and .76 for emotional expression.

The Emotion Amplification and Reduction Scales (TEARS). The Emotion Amplification and Reduction Scale is an 18-item rating scale that asks persons to rate their tendency to dampen down or increase the intensity of their emotion (Hamilton et al., 2009). Items are statements about emotion or emotion regulation, which respondents rate on a four-point scale, 1 being "not at all true of me" and 4 being "very true of me". The measure includes two scales, one for tendency to **amplify** emotions and one for a tendency to **reduce** them. Scales had internal consistencies of .85 and .90, respectively, for participants in this project.

Mood Measures. Much research that explored emotion in conjunction with executive function has included mood in operationalizing emotion (Carvalho & Ready, 2010; Smith, Jostmann, Galinsky, & van Dijk, 2008; Suhr & Tsanadis, 2007). Therefore, general positive and negative mood was assessed.

Positive and Negative Affect Scales (PANASX). The PANASX is a self-report measure designed to assess a person's typical mood in the past year (Watson, Clark, & Tellegen, 1988). The measure provides indexes for positive and negative moods; positive mood being the extent to which a person generally feels enthusiastic and active; negative mood consisting of feelings of anger, sadness, or fear. Respondents were asked to rate, on a scale of 1 to 5, how, in general, 20 words describe them. Test-retest reliabilities have been found to be .68 and .71 for 8-week periods. The positive scale had an internal consistency of .88 and .84 for the negative scale among the participants in this project.

Procedure

Information in the syllabus for most undergraduate courses in the Department of Psychology includes information about the SONA system, the on-line program for recruiting participants in research studies. Students read this information, and are directed to the SONA website. Here, the website describe the name and gives a brief description of the activities of various proposed studies, as well as indicates the dates and time commitment required. The description of this project mentioned time required (2 hours) and activities including use of computer, cognitive tasks, and questionnaires about emotion.

If a student decided to participate, they signed up for an appointment time. Potential participants received a reminder email or phone call the day before their appointment. When potential participants arrived at the laboratory, they were met by the project investigator, another graduate student, or a trained, advanced undergraduate experimenter. No experimenter who had prior familiarity with a student met that student to guide his or her participation in the project.

Students were given an information sheet describing the procedures and basic topic of the study. The experimenter read the entire information sheet as students read their copy, giving students the opportunity to ask questions about the study. In addition to responding to student questions, the experimenter clearly informed every student that the study involved research and that the time commitment was 2 hours. All potential participants were informed that they were free to stop the study, at any time, without penalty.

If individuals desired to participate, they indicated their consent by beginning the computer tasks and questionnaires. Participants next completed the six executive function measures. The sequence of tasks was varied at random to avoid any systematic sequence effects. Following the administration of the executive function tasks, the emotion regulation measures were administered. These questionnaires were completed at a table, with paper and pencil. As it was for the executive function tasks, the order of presentation varied at random.

After completing all measures, participants had an opportunity to ask any questions they had about the study. Finally, they were thanked for their participation and given 2 credit units that were applied to the psychology course of their choice.

Data Analysis

Each participant's set of responses was assigned a number to anonymously identify measures belonging to that individual person. Data from questionnaires were scored and hand entered into an SPSS data file. Data from computer tasks were saved as Excel files identified by the number assigned to each individual's set of responses.

Consistent with Friedman and Miyake's procedures, the computer task data were prepared and cleaned. The practice trials and the first 6 responses of the test phase were not include in the analysis, so an accuracy score out of 96 was obtained for each participant. The average difference in switch and non-switch response times was calculated from the fast condition trials only; in these first 10 responses were also omitted. To reduce outlier influence on average reaction times, trials with response times less than 200 ms were omitted as well as trials where there was an error on the preceding answer, since correct responses could have been due to additional time. Finally, median deviation scores for all relevant trials were obtained and response times greater than 3.29 deviations above the median were not included.

All variables were analyzed for univariate outliers. The task switching tests, Number-Letter and Category switch had 1 and 2 positive univariate outliers respectively (greater than 3.29 SD above the mean). The antisaccade task also had one negative outlier. The outliers were not removed since there were so few relative to the size of the data set.

The number and pattern of the outliers were assessed to determine the appropriate steps to take, if any, concerning difficulties such as missing or badly skewed data. After any necessary adjustments to the data from each measure, preliminary analyses assessed the degree of correlation among the measures. Descriptive statistics for each measure were calculated. Estimates of each measure's internal consistency were obtained for questionnaires on emotion regulation and mood.

CHAPTER 3

Questions/hypotheses for the study*:*

1. What are the basic components represented among the responses to the measures of emotion regulation included in this study? We expected the emotion regulation data to coalesce into distinct components. It was expected that one component would represent *appraisal of emotion*; another would correspond to *control of emotion*; and a third would correspond to *instrumental use of emotion*.

Justification. There was no clear set of expected components derived from prior scholarship, as there is no clear body of research or theory that agrees on underlying components of emotion regulation. Thus, this analysis was expected to produce some patterns or clustering among participant responses, but whether they would conform to the particular measures or some other organizing components was not clear, given little or no prior research. Nevertheless, in order to have a preliminary set of expectations against which to compare what the data reveal, we used the theoretical work of Gross (Gross & Thompson, 2007), who describes emotion components in terms of a time course that moves from before an emotion occurs to attention and appraisal to cognitive control, and beyond.

Analysis. A principal component factor analysis was performed on individuals' item responses from the three self-report measures of emotion regulation, to determine if there were coherent underlying sets of factors. The analysis allowed extracted factors to correlate as they naturally occur. Any obtained factors for use in subsequent analyses were to be limited to eigenvalues of at least 1.0.

When a coherent structure emerged, factor-based indices it was intended to construct for each participant, for use in relating emotion regulation components to executive function components. In the absence of a coherent structure emerging, scale and subscale scores from the emotion regulation measures used in this project were to be used to explore relations with the executive function measures. However, if a coherent structure emerged from the factor analysis of the emotion measures' responses, a second question was to be addressed:

2. What is the relation between basic or underlying components of executive function and emotion regulation?

Overall, it was predicted that individuals with higher performance on executive function measures would also be higher in emotion regulation, as indicated in their performance on the derived components of emotion regulation. Although there was no direct prior evidence for this, given the state of measurement of emotion regulation, such overall consistency was predicted from the inclusion of emotion regulation as a part of the theory of executive function (Jurado & Rosselli, 2007).

It was also expected that performance on specific executive function components would predict specific emotion regulation components, as follows:

A. Higher response inhibition performance was expected to be positively associated with control of emotion. This would be observed better control of emotion among those who were faster in responses and higher in accuracy on the Stroop and antisaccade tasks.

B. Relatively higher working memory performance was expected to predict higher scores on the components of control of emotion and instrumental use of emotion. Specifically, individuals with higher scores on digit span and letter number sequencing would demonstrate higher emotion control and greater instrumental use of emotion.

C. High versus low task switching abilities, which included reaction time and accuracy on the Number-Letter and Category Switch tasks, were expected to be positively related to the emotion regulation components of control of emotion and instrumental use of emotion.

Justification. There is no extant research known to link specific components of executive function to basic components of emotion regulation. Thus, the links of executive function components and those expected to be obtained concerning emotion regulation were based on deductive logic.

Analysis of data. Linear regression was conducted, with scores obtained on measures of executive function (task switching, working memory and response inhibition) regressed onto the obtained factor-based scores representing the components of emotion regulation. Current mood and demographic information including age and gender were entered first, followed by the measures of executive function. The ability of the 3 executive function components to predict the individual emotion regulation components was assessed.

Chapter 4

RESULTS

Preliminaries

Table 2 contains descriptive statistics from the participants for the 6 executive function scores and 6 emotion regulation scores. Data were screened for univariate outliers, and 6 individual scores were identified (3.29 SD above the mean). Because these were limited[1], they were included in the analyses. Only 5 participants were missing responses for some of the measures (2 in Number/Letter, 2 in Category Switch, and 1 in Antisaccade). Since there were not many missing scores, they were replaced with their respective variable means. There were 4 variables that were significantly skewed. Antisaccade was skewed negatively; Number/Letter, Category Switch, and PANASX Negative Affect were skewed positively. The positively skewed scores were transformed with a square root function to meet the criteria for normality, and the Antisaccade score was reflected to correct its negative skew.

Principle Component Analysis

To assess the underlying structure of the emotion regulation measures (Emotion Approach Coping Scale, Emotion Regulation Questionnaire and The Emotion and Amplification and Reduction Questionnaire), principle components analysis with varimax rotation was used[2]. In evaluating the factorability of the data, most items within a scale correlated at levels above .3, and a few correlated highly with items from other questionnaires. Most notable were items on the EAC expression and ERQ suppression scales. Communalities indicating adequate variance

[1] Ranging from 3.67 to 3.3 SD above

[2] The varimax rotation was employed instead of the proposed oblimin oblique rotation for two reasons: first, the factors were very similar regardless of the rotation, second, the resulting factors were essentially uncorrelated. Varimax was used to maximize the distinctiveness of the obtained factors.

(above .3) were extracted for most items; only two items had relatively small amounts of variance (less than 30%) extracted. This indicates the factor analysis was largely successful in consolidating the data.

The initial factor analysis of the measures produced 9 factors with eigenvalues greater than 1, a common criterion used to determine the number of viable patterns of variance, e.g. factors, found in a set of data. However, on inspection of the loadings, these factors were largely unable to be interpreted. At least 5 or 6 of the 9 putative factors had no discernable meaning, some consisting of a single variable with a weak loading. Therefore, the Scree plot of eigenvalues was inspected to see whether fewer factors could be a better choice, with potentially more meaningful factors. Analysis of the angle of the Scree plot suggested adequate solutions of between 4, 5 or 6 factors (see Figure 1).

Analyses were run for 4, 5, and 6 factor solutions. Each was reviewed carefully for the meaningfulness and clarity of the emergent factors. The 4 factor solution was deemed most parsimonious. The first 4 factors in each of these three analyses were highly similar. These 4 factors did not change with the addition of the 5^{th} and 6^{th} factors, and only 2 items loaded heavily on each additional factor beyond the fourth one. The 4-factor solution accounted for 48% of the variance, suggesting that this solution was moderately successful in representing and replicating the data. In the rotated 4 factor solution, the first factor accounted for 15%, the second 12%, the third 11% and the fourth 8%, respectively, of the variance in the overall set of emotion regulation scores.

The emotion regulation items were expected to show three component factors, *appraisal of emotion*; *control of emotion*; and *instrumental use of emotion*. However, the pattern of loadings indicate that the first, second and fourth factor strongly resemble particular measures taken from the TEARS and the ERQ. The first factor of the rotated solution loaded heavily on the 9 items of the TEARS Reduction scale, with the addition of a single item from the ERQ. The second factor was composed predominately of the items on the TEARS Amplification scale plus one item from the EAC. The third factor was composed of a combination of items from the EAC expression and ERQ suppression scales. The final factor was loaded most heavily by items of the ERQ reappraisal scale.

Overall Relationship Between Emotion Regulation and Executive Function

To analyze the overall relationship between executive functioning and the emotion regulation factors, the executive function measures were standardized, and summed to create a single variable, with a constant added to transform every individual's score to a positive integer. The median of this overall index of executive function was used to divide the participants into low and high executive function performance groups. The performance of low and high executive function groups on each of the 4 emotion regulation factor scores was tested with between group analysis of variance (ANOVA) tests (see Figure 2). Higher performance on executive function was associated with significantly higher scores on the expression (Factor 3) emotion regulation component [$F(1,168) = 4.32$, $p < .05$]. No other emotion regulation components showed significant differences between persons who were high vs. low in their performance on overall executive function.

Prediction of Individual Emotion Regulation Factors from Executive Function Components

A series of hierarchical linear regressions were performed to assess the relative importance of specific executive function components in relation to their possible prediction of emotion regulation factors, above and beyond characteristics of age, gender, and the situational occurrence of mood. Four multiple regressions were performed, one for each emotion regulation factor. In the first step, variance due to gender, age, positive affect, and negative affect served as the baseline model of comparison. In the second block, the three standardized positive executive function component scores (working memory, inhibition and task switching) were entered into the model. The change in predictive power and the individual contribution of variables were compared and evaluated.

Executive function as a predictor of confidence in internal control of emotion. In the first analysis, the combined age, gender and mood variables significantly predicted scores on the TEARS Reduction factor (Factor 1) [$R^2 = .182$, $F(4, 165) = 9.204$, $p < .05$]. Positive [$\beta = .273$, $p < .05$] and Negative Affect [$\beta = -.243$, $p < .05$] significantly predicted *confidence* in regulating one's own emotion. When the executive function variables were added to the analysis, the prediction of the TEARS Reduction factor improved [$R^2 = .199$, $F(7, 162) = 5.738$, $p < .05$], but not significantly [$\Delta R^2 = .016$, $F(3, 162) = 1.095$, $p = .353$]. No executive function variable significantly predicted TEARS Reduction, but the Task Switching component approached significance [$\beta = .127$, $p = .078$].

These approaching significant findings may reflect real underlying differences that are not detectable due to current data set limitations. For instance, while close to the minimum 5 cases per variable recommended for a principle component analysis, additional data might produce cleaner factors, which in turn might clarify factor relationships with predictor variables.

Executive function as a predictor of internal utilization of emotion. Age, gender and mood variables significantly predicted scores on the TEARS Amplification (Factor 2) scores as well [$R^2 = .105$, $F(4, 165) = 4.830$, $p < .05$]. Positive [$\beta = .226$, $p < .05$] and Negative Affect [$\beta = .283$, $p < .05$] significantly predicted instrumental use of one's own emotion. When the executive function variables were added to the model, the prediction of the TEARS Amplification factor improved [R^2 = .117, $F(7, 162) = 3.702$, $p < .05$], but as for the other factors, not significantly [$\Delta R^2 = .012$, $F(3, 162) = .757$, $p = .520$]. No executive function variable significantly predicted TEARS Amplification.

Executive function as a predictor of behavioral expression of emotion. In the third regression, age, gender and mood variables significantly predicted scores on the Expression factor (Factor 3) [R^2 = .140, $F(4, 165) = 6.708$, $p < .05$]. Positive Affect [$\beta = .277$, $p < .05$] and gender [$\beta = -.265$, $p < .05$] significantly predicted behavioral *expression* of emotions. When the executive function variables were added to the model, the prediction of the Expression factor improved [R^2 = .174, $F(7, 162) = 4.887$, $p < .05$], and this was a significant improvement in the model [$\Delta R^2 = .034$, $F(3, 162) = 2.255$, $p < .05$]. This improvement was driven by the Inhibition executive function component, which was a significant predictor of emotion expression [β = .186, $p < .05$]. Neither Task Switching nor Working Memory was significant.

Executive function as a predictor of appraisal of emotion. The age, gender and mood scores did not significantly predict the ERQ reappraisal factor scores (Factor 4) [R^2 = .033, $F(4, 165) = 1.414$, $p = .232$]. No individual variables significantly predicted reappraisal either. When the executive function variables were added to the model, the prediction of the ERQ Reappraisal factor improved slightly, but not enough to adequately predict the factor [R^2 = .048, $F(7, 162) = .468$, $p = .323$], nor was this a relatively significant improvement in prediction [$\Delta R^2 = .015$, $F(3, 162) = .851$, $p = .468$]. Similar to the initial variables, no single executive function variable significantly predicted ERQ Reappraisal.

Chapter 5

DISCUSSION

The factor analysis of the emotion regulation items did not produce the 3 hypothesized components. Appraisal was expected to include items from EAC Emotion Processing and ERQ Reappraisal, Control of Emotion was assumed to be loaded by items from the EAC Expression, TEARS Reduction and ERQ Suppression; and Instrumental Use of Emotion was predicted to be made up of items from TEARS Amplification and EAC Expression. Instead, 4 factors were observed, the first and second of these loaded almost entirely with items from either the TEARS Amplification Scale (the first factor) or the TEARS Reduction scale (the second factor), with little association of items from other scales.

Initially, the first and second factors appear to reflect their scale titles, Reduction and Amplification of emotion respectively. However, close examination suggests that the underlying constructs all do not reflect instances of down-regulation and up-regulation of emotion. For instance, amplification and reduction could be opposite sides of a single regulation component, however the data show they load on separate factors (as found in Hamilton et al. 2009). The reduction items do not load with the predicted suppression/expression factor, though if reduction corresponded to general suppression of emotion behavior these two should be associated. Instead the Reduction scale items appear to reflect *confidence* in the ability to reduce *internally* felt emotion rather than suppress expression of emotion. Similarly, Amplification items do not load with EAC expression items. Like the Reduction scale, its items seem to reflect intensifying of *internal* emotion rather than overt behavioral expression. Of the observed factor scales, this one most reflects the spirit of the proposed utilization of emotion.

The third factor consists of items related to expression of emotion, drawn from the EAC and ERQ scale and corresponding somewhat to the hypothesized Control of Emotion, with the addition of a few weakly loading items related to emotion processing and reappraisal.

This factor is composed of items from EAC expression and ERQ suppression, the pattern predicted in the Control of Emotion factor. However, the obtained factor did not reflect complete inhibitory control of emotion described in the hypotheses. Instead, it corresponded specifically to behavioral emotion expression, not internal emotion regulation. The two scales each assess the two poles of this expression dimension, either negative, in the case of ERQ Suppression, or positive, in the case of EAC Expression.

Similarly, the fourth factor bears some resemblance to the expected Appraisal component structure, as it consists predominately of reappraisal items, drawn from the ERQ Reappraisal scale. These appear to reflect a person's overt cognitive attempts to reframe his or her mood, principally by reappraising the external situation (e.g. "change what I'm thinking about"). In general, it seems to reflect the hypothesized Appraisal of emotion construct, and the reflective approach to emotion described in that expected finding. It is notable that these items do not load heavily on the first or second factors. This indicates that cognitive reframing is a separate component from all types of internal approaches to emotion, suppression of the internal feeling of emotion in particular.

Although some predicted components, like control of emotion and appraisal of emotion, seem to be supported to some extent, in general there are problems with these hypothesized factors. There are a number of possible reasons the predicted factors were not observed. Perhaps the items of the scales do reflect distinct genuine aspects of emotion regulation. The Reduction and Amplification scales of the TEARS in particular do not correspond with what was expected.

These scales as labeled could reflect real emotion regulation constructs. If so, their items could capture true self-perception of emotion regulation. On the other hand, the meaning of the construct may not fit the scales' names. If the TEARS Reduction scale truly reflects ability to suppress emotions, why should it load on a factor distinct from items explicitly discussing suppression of emotional expression? Perhaps the TEARS reduction scale is misnamed. Its items could reflect another construct related to emotion regulation, but not found within the existing emotion regulation literature: self-confidence in managing one's own emotion, or in other words, self-perceived competence in regulating emotion. Many of the item statements reflect confidence in successfully coping with negative emotions or emotions aroused under stress.

It is difficult to definitively confirm the meaning of the emotion regulation components identified from these self-report measures. One explanation is components of the latent emotion regulation construct mirror the diversity and organization of components proposed for executive function. The multitude of executive function measures, which individually do not correlate very highly, can be thought of as somewhat distinct modules. Likewise, these emotion regulation scale components appear distinct and could fail to relate to *all* that would be considered as emotion regulation. Instead, they may be modular elements of a larger emotion regulation latent construct. Just as executive function includes planning, working memory, and inhibitory control, this emotion regulation construct could include self-confidence, possibly assessed by the TEARS Reduction scale, as well as other important situational factors seen in live behavioral and physiological responses. Clearly, observing live, "real world" emotion regulation should both broaden the possible components of emotion regulation and help rule out indirect correlates of the construct. However, obtaining behavioral indices of emotion regulation was beyond the scope of this investigation.

Relationship between Observed Emotion Regulation and Executive Function

Only one emotion regulation factor, regulation of expression (Factor 3), is significantly higher for individuals with higher overall executive function performance. Further analysis shows that the inhibitory control executive function component significantly predicts the expression factor emotion regulation component. This significant association is the only predicted relationship between executive function and emotion regulation components supported in this study. The higher regulation of expression scores of the group with overall executive function scores above the median is likely driven by this specific relationship with inhibitory control. Previous research has found that the inability to withhold behavioral responses is associated with pathology like ADHD (Barkley, 1997) and traumatic brain injury (Alvarez & Emory, 2006). Our results further support this important cross-construct relationship.

Other predicted relations were that working memory would be associated with appraisal of emotion and instrumental use of emotion; and that task switching would be associated with control of emotion. None of these is supported by the results. Working memory was not significantly related to any emotion regulation component. Task switching was not significantly related to control of emotion, but it approach being related significantly to the first emotion factor, which is largely defined by the TEARS Reduction items. This was unexpected, but may further reflect the conceptual nature of this factor. Items on the TEARS Reduction scale appear to pertain to *confidence* respondents have in their ability to control internal emotions. It is unclear what the relation with task switching scores mean, however simple reduction of emotion does not seem to fit with the observed demand situation of task switching. Confidence, however, could be a regulation component among persons more adept at task switching.

Other unexpected relationships are observed between the emotion regulation components and mood and gender variables. Though not predicted, it is clear that general mood ratings significantly predict emotion regulation scores. Higher positive affect and lower negative affect predict higher scores on the first factor. Higher positive and negative affect predict elevated scores on the second factor, and being female and reporting greater positive affect is associated with elevated scores on the third factor. Only the fourth factor, cognitive reappraisal, has no relation with gender, age, or mood. This is surprising. However, given that this factor mostly taps reflective, distant cognition about emotion, its dissociation from both “cold”, executive function measures in this study and the responses to self-reports about emotion regulation may not be surprising. It is possible that a behavioral, “hot” emotion regulation challenge could reflect individual differences that are influenced by gender or mood.

Limitations

The nature of the emotion regulation factors obtained in this study is still unclear. Particularly ambiguous are the TEARS Reduction and Amplification scales. Comparison of these factors in conjunction with other psychological constructs related to emotional reactivity could better elucidate these components. For instance, if the TEARS Reduction scale truly reflects capacity to suppress negative internal feelings, it should be distinct from responses designed to be more socially desirable, placing the respondent in a more favorable light. The Reduction scale could also be related to personality constructs like neuroticism and conscientiousness. The emotional overtones of a neurotic personality trait might emerge in an individual’s capacity to cope with negative emotion.

It must be noted again that this study is not designed to tap all aspects of executive function and emotion regulation. This limitation likely affects at least some relations between these two sets of constructs. Behavioral observations of live regulation of emotion, beyond the low-level of challenge presented in study activities, were not included in this project, due to its preliminary nature. Some aspects of emotion regulation could be measurable only in live situations, and actual situations requiring emotion regulation could correspond very poorly, if at all, to pencil and paper methods. Our findings must be qualified that *these specific* emotion regulation and executive function components are largely distinct from one another, given the circumstances in which they were studied. Additional research is needed to determine whether the underlying latent constructs are truly separate in conditions more salient to the participants.

The participants in this project were mostly young adults. Their ability to regulate their emotions as well as their executive functioning could be better developed later in adulthood than it was in this project. A full range of skills related to both constructs could be better studied in somewhat older participants. Thus, relations between the two sets of constructs studied in this project could be influenced by the age of our participants, with additional links more easily observed among fully mature adults.

Recommendations for Future Research

More research with a broader focus is needed to understand the structure and function of emotion regulation components. One primary question is whether the components identified in this study are valid emotion regulation components. To answer this question, constructs known to relate to emotion, e.g. personality traits, self-esteem, psychopathology, social desirability and mood, should be investigated in conjunction with emotion regulation. Another question is whether emotion regulation is modular the way executive function components appear to be. Alternatively, are attempts to regulate emotion more dynamic and contextually dependent? If emotion regulation components are distinguishable from other constructs or only weakly related to them, it likely is structured similarly to executive function.

Any component should be validated with a multi-trait-multi-method analysis. Therefore, non-self-report measures of emotion regulation should also be included in these analyses. Behavioral measures should be used to test control of specific emotions, e.g. laboratory activities designed to elicit specific emotions in the participant manage them, or video and music segments designed to provoke sadness or humor while performing another activity. Ratings from friends or acquaintances, if possible, might also provide additional validity to self-report measures while assessing a breadth of emotions behavioral tests would be unable to capture.

Table 1

Participant Information

Variable		N	%
Gender	Female	129	75.9
	Male	41	24.1
Ethnicity	Caucasian	54	31.8
	African American	48	28.2
	Hispanic/Latino	9	5.3
	Arabic	26	15.3
	Native American	1	0.6
	Asian/Pacific Islander	19	11.2
	other	12	7.1
	No Response	1	0.6
Student Status	Full-time	133	78.2
	Part-time	20	11.8
	No Response	17	10.0
Year	Freshman	39	22.9
	Sophomore	48	28.2
	Junior	42	24.7
	Senior	38	22.4
	No Response	3	1.8
Income	less than 20,000	34	20.0
	20,000-39,999	27	15.9
	40,000-59,999	30	17.6
	60,000-89,999	35	20.6
	90,000-109,999	21	12.4
	more than 110,000	13	7.6
	No Response	10	5.9

Note. N = number of cases out of 170. % = relative frequency in the total sample.

Table 2

Measures of Executive Function, Emotion Regulation, and Mood

Construct	Measure	Mean	Standard Deviation
Executive Function			
Response inhibition	Antisaccade	7.53	0.95
	Stroop	47.33	9.05
Task switching	Number Letter	26.46	5.24
	Category Switch	20.33	5.30
Working memory	Digit Span	28.54	4.79
	Letter Number Sequencing	1.30	0.06
Emotion Regulation			
	EAC Emotion Processing	3.13	0.56
	EAC Emotion Expression	2.71	0.68
	ERQ Cognitive Reappraisal	5.25	0.99
	ERQ Expressive Suppression	3.54	1.21
	TEARS Amplification	3.58	0.79
	TEARS Reduction	0.30	0.14
Mood			
	PANASX Positive	3.60	0.77
	PANASX Negative	2.09	0.71

Note. EAC = Emotion Approach Coping Scale; ERQ = Emotion Regulation Questionnaire; TEARS = The Emotion Amplification and Reduction Scale; PANASX = Positive and Negative Affect Scale.

Table 3

Bivariate Correlations of Executive Function and Emotion Regulation Variables

	DST	LNS	Stroop	ASA	NL	CS	EAC Proc	EAC Expr	ERQ Reapp	ERQ Suppres	TEARS Amp	TEARS Reduc
DST	1.00											
LNS	0.60**	1.00										
Stroop	0.35**	0.35**	1.00									
ASA	-0.33**	-0.21**	-0.30**	1.00								
NL	0.00	0.02	-0.03	0.05	1.00							
CS	0.06	0.15	-0.06	0.04	0.28**	1.00						
EAC Proc	-0.08	0.05	-0.04	0.21**	0.00	-0.06	1.00					
EAC Expr	-0.01	0.01	0.09	0.12	-0.05	-0.02	0.37**	1.00				
ERQ Reapp	0.13	0.12	0.08	-0.05	0.02	-0.07	0.26**	0.17*	1.00			
ERQ Suppres	-0.07	-0.13	-0.03	-0.11	-0.05	-0.06	-0.15	-0.56**	0.01	1.00		
TEARS Amp	0.10	0.05	0.09	0.06	0.02	-0.11	0.33**	0.22**	0.28**	-0.20*	1.00	
TEARS Reduc	-0.03	-0.02	-0.05	0.11	0.01	-0.04	0.01	-0.04	-0.20*	-0.04	-0.23**	1.00

Note. DST = Digit Span Total; LNS = Letter Number Sequencing; ASA = Antisaccade; NL = Number/Letter; CS = Category Switch; EAC = Emotion Approach Coping Scale; ERQ = Emotion Regulation Questionnaire; TEARS = The Emotion Amplification and Reduction Scale;
*** correlation is significant at .01 level (2-tailed)*
** correlation is significant at .05 level (2-tailed)*

Table 4

Factors 1 & 2 Loadings from a Principle Components Analysis with Varimax Rotation for Emotion Regulation Items

	Component			
Item	Factor 1	Factor 2	Factor 3	Factor 4
TEARS16	0.80	-0.05	0.08	0.05
TEARS14	0.78	0.02	-0.02	0.20
TEARS10	0.76	-0.08	-0.03	0.07
TEARS18	0.76	0.07	-0.01	0.10
TEARS13	0.75	-0.04	-0.14	0.19
TEARS17	0.73	0.14	-0.01	0.05
TEARS12	0.68	0.15	-0.04	0.10
TEARS15	0.62	0.13	0.00	0.11
TEARS11	0.60	0.16	-0.04	0.19
ERQ5	0.42	0.05	-0.20	0.32
TEARS6	0.15	0.77	0.09	0.01
TEARS7	0.08	0.75	0.14	0.01
TEARS9	-0.10	0.70	0.02	-0.02
TEARS4	0.16	0.69	-0.03	0.24
TEARS1	0.03	0.69	-0.04	0.14
TEARS2	0.10	0.66	-0.17	0.29
TEARS8	-0.20	0.58	0.04	-0.13
TEARS3	0.27	0.53	-0.13	0.40
TEARS5	0.17	0.48	0.17	0.21
EAC7	0.20	0.37	0.36	0.06

Note. TEARS = The Emotion Amplification and Reduction Scale; EAC = Emotion Approach Coping Scale; ERQ = Emotion Regulation Questionnaire. Rotation converged in 6 iterations.

Table 5

Factors 3 & 4 Loadings from a Principle Components Analysis with Varimax Rotation for Emotion Regulation Items

	Component			
Item	Factor 1	Factor 2	Factor 3	Factor 4
EAC3	-0.04	-0.03	0.78	0.13
ERQ2	0.12	-0.01	-0.72	0.05
EAC1	-0.19	0.07	0.70	0.15
EAC4	0.07	-0.14	0.65	0.31
ERQ6	0.23	0.08	-0.61	-0.11
EAC2	0.20	0.12	0.57	-0.11
ERQ9	0.22	0.00	-0.52	0.18
EAC8	0.16	0.24	0.51	0.08
ERQ4	0.08	0.05	-0.40	-0.21
EAC6	0.29	0.31	0.39	-0.10
EAC5	0.31	0.23	0.31	-0.07
ERQ8	0.22	0.18	-0.05	0.72
ERQ10	0.24	0.06	0.14	0.71
ERQ7	0.22	0.16	0.03	0.68
ERQ3	0.09	-0.02	0.26	0.62
ERQ1	0.05	0.15	0.12	0.58

Note. TEARS = The Emotion Amplification and Reduction Scale; EAC = Emotion Approach Coping Scale; ERQ = Emotion Regulation Questionnaire. Rotation converged in 6 iterations.

Table 6

Between Groups Analysis of Variance for Emotion Regulation Factors by Level of Executive Function (High/Low)

Emotion Regulation Factor		Sum of Squares	df	Mean Square	F	Sig.
Factor 1	Between Groups	0.02	1.00	0.02	0.02	0.88
	Within Groups	168.98	168.00	1.01		
	Total	169.00	169.00			
Factor 2	Between Groups	0.27	1.00	0.27	0.27	0.60
	Within Groups	168.73	168.00	1.00		
	Total	169.00	169.00			
Factor 3	Between Groups	4.24	1.00	4.24	4.32	0.04
	Within Groups	164.76	168.00	0.98		
	Total	169.00	169.00			
Factor 4	Between Groups	0.34	1.00	0.34	0.33	0.56
	Within Groups	168.67	168.00	1.00		
	Total	169.00	169.00			

Note. The factors 1-4 were obtained through the Principle Component Analysis in Tables 3 & 4. The Executive Function variable was composed of the sum of standardized positive scores from the six measures. This variable was then median split to create high/low groups.

Table 7

Hierarchical Regression of Executive Function Components Predicting Emotion Regulation Factor 1

	Predictor	B	S.E. B	β	*p*	$_{s}r$	F	R^2	*p*	Δ R^2	*p*
		Factor 1									
Step 1							9.20	0.18	0.00		
	(constant)	-0.25	0.68		0.72						
	Gender	0.24	0.17	0.10	0.16	0.10					
	Age	0.01	0.01	0.04	0.60	0.04					
	Positive Affect	0.36	0.10	0.27	0.00	0.26					
	Negative Affect	-1.02	0.31	-0.24	0.00	-0.23					
Step 2							5.74	0.20	0.00	0.02	0.35
	Working Memory	0.00	0.04	0.00	0.97	0.00					
	Inhibition	0.02	0.05	0.02	0.74	0.02					
	Task Switching	0.08	0.05	0.13	0.08	0.13					

Note. B = unstandardized regression coefficient. S.E. B = standard error of unstandardized regression coefficient, β = standardized regression coefficient, *p* = probability value, $_{s}r$ = partial correlation; Δ R^2 = change in R^2. Working Memory = sum of standardized positive scores from the Digit Span and Letter Number Sequencing; Inhibition = sum of standardized positive scores from the Antisaccade and Stroop; Task Switching = sum of standardized positive scores from the Number Letter and Category Switch.

Table 8

Hierarchical Regression of Executive Function Components Predicting Emotion Regulation Factor 2

Predictor		B	S.E. B	β	*p*	$_{s}r$	F	R^2	*p*	Δ R^2	*p*
		Factor 2									
Step 1							4.83	0.11	0.00		
	(constant)	-2.93	0.72		0.00						
	Gender	0.18	0.17	0.08	0.30	0.08					
	Age	0.00	0.01	-0.01	0.86	-0.01					
	Positive Affect	0.29	0.10	0.23	0.00	0.22					
	Negative Affect	1.19	0.32	0.28	0.00	0.27					
Step 2							3.07	0.12	0.00	0.01	0.52
	Working Memory	0.01	0.04	0.01	0.85	0.01					
	Inhibition	-0.08	0.05	-0.11	0.15	-0.11					
	Task Switching	0.02	0.05	0.03	0.71	0.03					

Note. B = unstandardized regression coefficient. S.E. B = standard error of unstandardized regression coefficient, β = standardized regression coefficient, *p* = probability value, $_{s}r$ = partial correlation; Δ R^2 = change in R^2. Working Memory = sum of standardized positive scores from the Digit Span and Letter Number Sequencing; Inhibition = sum of standardized positive scores from the Antisaccade and Stroop; Task Switching = sum of standardized positive scores from the Number Letter and Category Switch.

Table 9

Hierarchical Regression of Executive Function Components Predicting Emotion Regulation Factor 3

	Predictor	B	S.E. B	β	*p*	${}_sr$	F	R^2	*p*	Δ R^2	*p*
		Factor 3									
Step 1							6.71	0.14	0.00		
	(constant)	-1.10	0.70		0.12						
	Gender	-0.62	0.17	-0.27	0.00	-0.26					
	Age	0.02	0.01	0.10	0.18	0.10					
	Positive Affect	0.36	0.10	0.28	0.00	0.27					
	Negative Affect	0.16	0.31	0.04	0.62	0.04					
Step 2							4.89	0.17	0.00	0.03	0.08
	Working Memory	0.01	0.04	0.02	0.74	0.02					
	Inhibition	0.13	0.05	0.19	0.01	0.18					
	Task Switching	-0.01	0.05	-0.02	0.79	-0.02					

Note. B = unstandardized regression coefficient. S.E. B = standard error of unstandardized regression coefficient, β = standardized regression coefficient, *p* = probability value, ${}_sr$ = partial correlation; Δ R^2 = change in R^2. Working Memory = sum of standardized positive scores from the Digit Span and Letter Number Sequencing; Inhibition = sum of standardized positive scores from the Antisaccade and Stroop; Task Switching = sum of standardized positive scores from the Number Letter and Category Switch.

Table 10

Hierarchical Regression of Executive Function Components Predicting Emotion Regulation Factor 4

Predictor		B	S.E. B	β	*p*	$_{s}r$	F	R^2	*p*	Δ R^2	*p*
		Factor 4									
Step 1							1.41	0.03	0.23		
	(constant)	0.47	0.74		0.53						
	Gender	0.10	0.18	0.04	0.58	0.04					
	Age	-0.01	0.01	-0.07	0.36	-0.07					
	Positive Affect	0.10	0.10	0.08	0.32	0.08					
	Negative Affect	-0.50	0.33	-0.12	0.14	-0.11					
Step 2							1.17	0.05	0.32	0.02	0.47
	Working Memory	0.05	0.04	0.09	0.24	0.09					
	Inhibition	-0.04	0.05	-0.05	0.50	-0.05					
	Task Switching	-0.05	0.05	-0.07	0.36	-0.07					

Note. B = unstandardized regression coefficient. S.E. B = standard error of unstandardized regression coefficient, β = standardized regression coefficient, *p* = probability value, $_{s}r$ = partial correlation; Δ R^2 = change in R^2. Working Memory = sum of standardized positive scores from the Digit Span and Letter Number Sequencing; Inhibition = sum of standardized positive scores from the Antisaccade and Stroop; Task Switching = sum of standardized positive scores from the Number Letter and Category Switch.

Figure 1

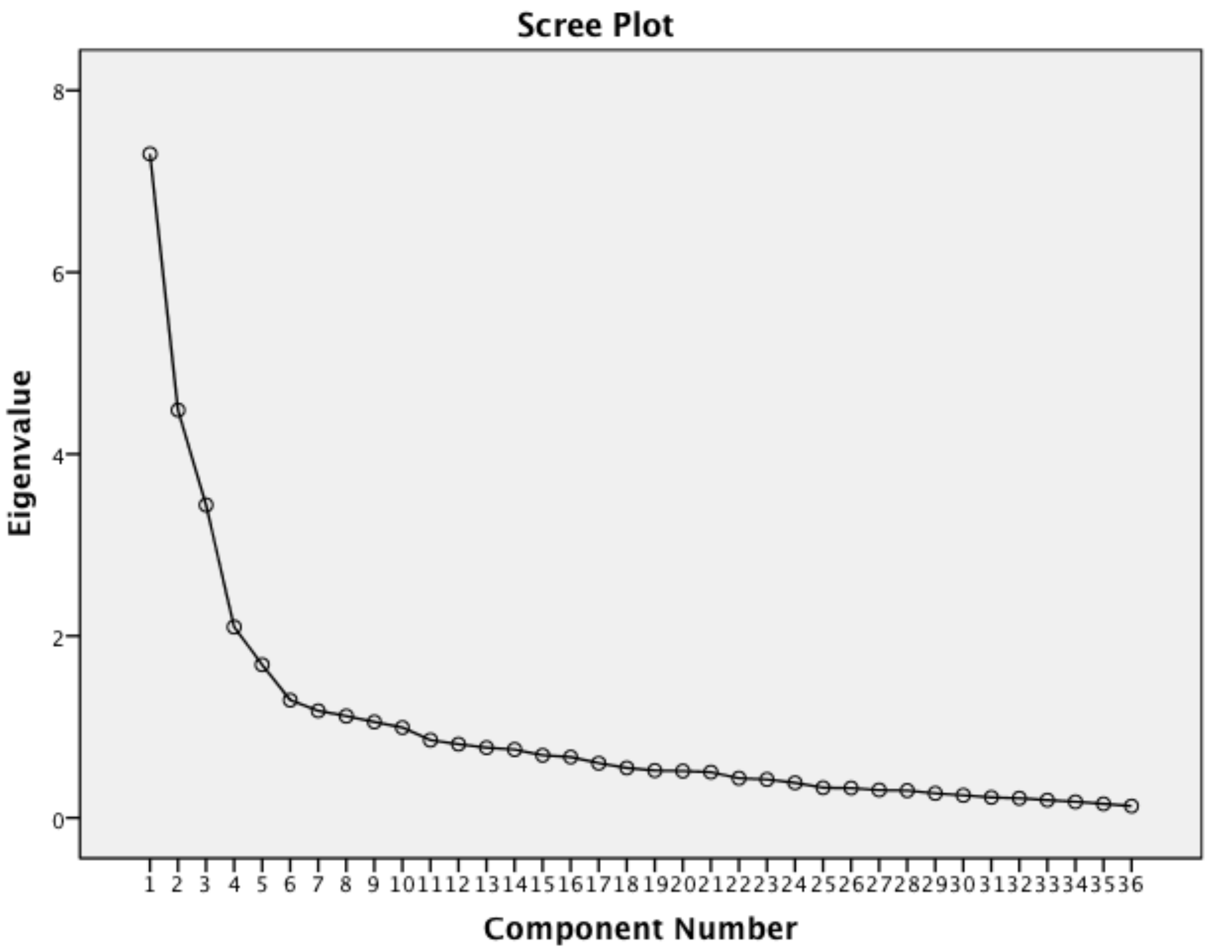
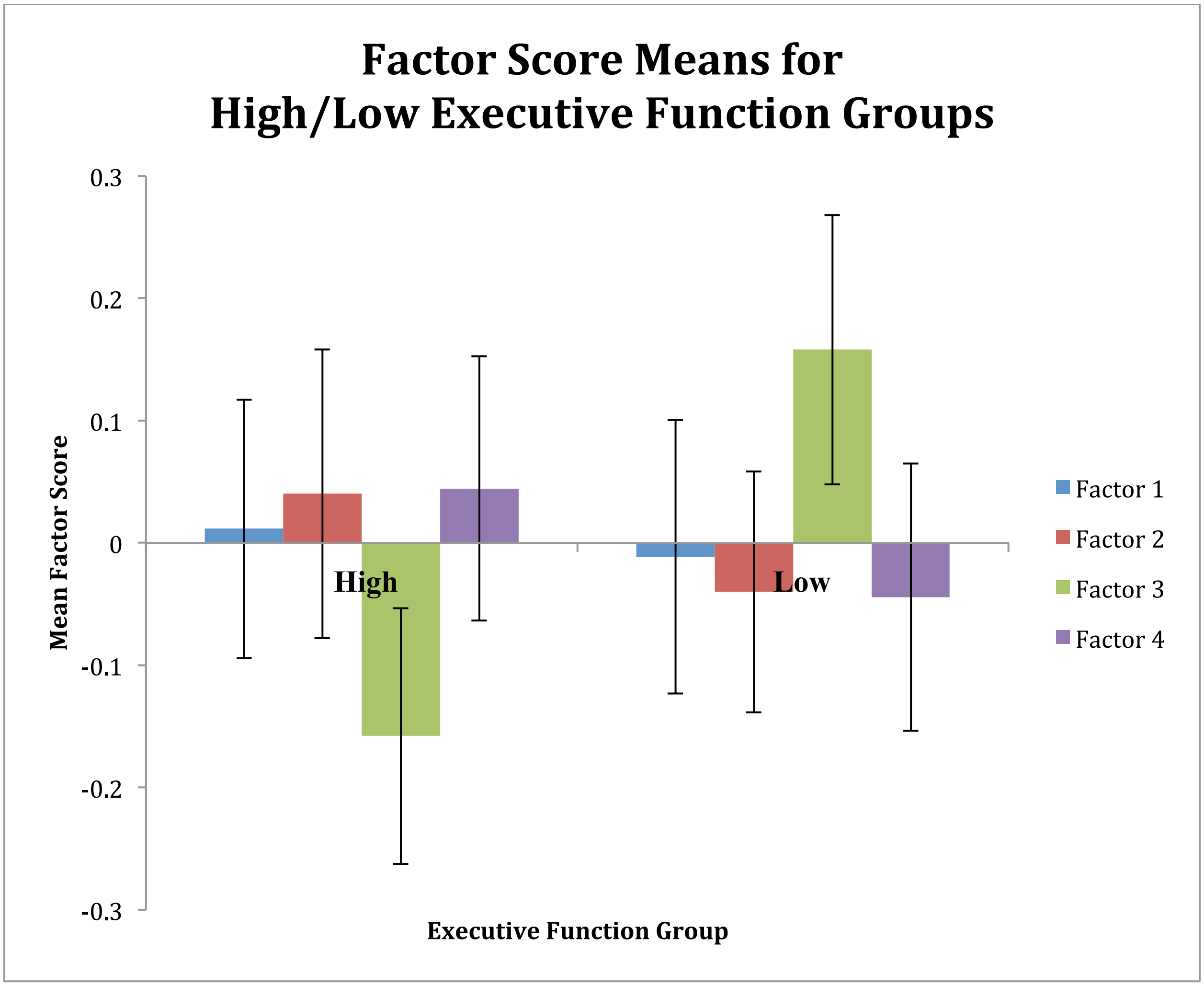

Scree Plot
Eigenvalue
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Component Number

Figure 2


Factor Score Means for
High/Low Executive Function Groups
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
Mean Factor Score
High
Low
Executive Function Group
Factor 1
Factor 2
Factor 3
Factor 4

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ABSTRACT

EMOTION REGULATION AND EXECUTIVE FUNCTION MEASURES: EXPLORATION OF PREDICTED RELATIONSHIPS

by

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August 2012

Advisor: Dr. Rita Casey

Major: Psychology (Clinical)

Degree: Master of Arts

Undergraduate college students (N – 170) were assessed with measures of executive function and emotion regulation, to determine whether the two constructs were related. Students completed 6 executive function tasks and 3 emotion regulation questionnaires. The executive function tasks were grouped into 3 components: inhibition, working memory, and task switching. A principle components factor analysis of emotion regulation questionnaire items was expected to produce 3 factors: appraisal of emotion, control of emotion, and instrumental use of emotion. Contrary to expectation 4 clear emotion regulation factors were produced, but only one, *control of emotion*, corresponded to a hypothesized component, and this was limited to control of emotional behavior. Relations among the 4 observed emotion regulation factors and overall executive function and individual components of executive function were also evaluated. Only the obtained *control of emotional behavior* factor was significantly related to overall executive function, and the inhibition component specifically. Possible implications are discussed.

AUTOBIOGRAPHICAL STATEMENT

In 2006, I graduated with a B.S. in Brain, Behavior, and Cognition from the University of Michigan. There, under the mentorship of Dr. Priti Shah, I became interested in the executive functions. When I began my graduate studies at Wayne State in 2008, I hoped to continue studying this construct in conjunction with emotion. Dr. Rita Casey's provided direction in further exploration of executive functions and guided me in a careful survey of the emotion regulation literature. As I continue my doctoral education, I hope to examine these the development of these constructs and their relationship with psychopathology.