ASSESSING EXECUTIVE FUNCTION AS IT RELATES TO SELF-REGULATION

IN HEALTHY YOUNG ADULTS

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ABSTRACT

Slips of action are cognitive errors that occur during routine tasks in everyday life (Clark, Parakh, Smilek, & Roy, 2012). Minimizing these everyday errors involves executive function, a system of complementary cognitive processes that enable control over thoughts and actions, including attention, inhibition, cognitive switching, and maintaining and manipulating the contents of working memory (Norman & Shallice, 2000). Many aspects of executive function are necessary for self-regulation, or the management of habitual, dominant, prepotent responses (Hamilton, Vohs, Sellier, & Meyvis, 2011). The present study explored the relationship between self-regulation, using self-report questionnaires, and executive function, using task-based assessments. Greater self-regulatory ability was related to fewer attention-related cognitive errors in everyday life, and tasks that require accounting for unexpected, non-habitual information were more difficult than routine tasks with expected information. Speed of responding was significantly related to performance on the task-based assessments and self-regulation potentially interjected when speed was held constant.

Keywords: self-regulation, executive function, attention, inhibition

DEDICATION

For my wonderful parents, who are always unconditionally encouraging and supportive. I cannot express my gratitude enough; I feel so blessed and loved because of you. Thank you, I love you both so much!

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CHAPTER I

INTRODUCTION

Everyday life revolves around tasks that are frequently repeated and can become routine. Cognitive errors that occur during these routine, habitual tasks are referred to as *slips of action* (Clark, Parakh, Smilek, & Roy, 2012). Slips of action can simply be frustrating, like when forgetting the reason for walking into a room (Clark et al., 2012; Reason, 1979), but they can also be very dangerous, like when failing to notice a red light and causing a fatal car wreck (Robertson, 2003). Regulating cognition to minimize slips of action involves cognitive control. Norman and Shallice (1986; 2000) have suggested that cognitive control is made possible through two independent systems, the contention scheduling system (CS), which operates mainly outside of conscious awareness and directs well-learned actions, and the supervisory attention system (SAS), which requires consciously controlled attention to allow for the execution of novel or particularly difficult tasks (Norman & Shallice, 1986; 2000). Therefore, the CS and SAS work together to support both habitual, everyday tasks as well as tasks that are new, or outside of the routine in some way.

Executive Function and Self-Regulation: The Theoretical Link

Cognitive control is considered an executive function. *Executive function* is a system of complementary cognitive processes that enable control over thoughts and actions, the ability to focus attention, inhibit predominant thinking and responding, switch between tasks, monitor and regulate performance, update task demands, enact cognitive flexibility, maintain goals, plan, as well as maintain and manipulate the contents of working memory (Banich, 2009; Garner, 2009; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010; Norman & Shallice, 1986, 2000). Moreover, many of these executive processes support the mechanisms that are necessary for self-regulation (Blair & Ursache, 2011; Hofmann, Schmeichel, & Baddeley, 2012; Hunt, Turner, Polatajko, Bottari, & Dawson, 2013).

As self-regulation involves the management of behavior, thoughts, and emotions, within a specific context, to fulfill goals (Hart & Evans, 2006; Hunt et al., 2013), facets of executive function support self-regulatory processes. These include goal achievement (Hart & Evans, 2006), planning (Levine, Stuss, Milberg, Alexander, Schwartz, & MacDonald, 1998), shifting strategies to successfully complete a goal, and inhibiting prepotent, or habitual, learned responses, to modify behavior based on the current situation (Garner, 2009; Levine, Dawson, Schwartz, Boutet, & Stuss, 2000). Also, much like how executive processes differ depending on whether a task is habitual or novel, self-regulatory processes also differ based on the familiarity of a task. Specifically, self-regulation during routine tasks requires few executive processes, whereas self-regulation during complex or unfamiliar tasks requires more executive processes (Banich, 2009; Hunt et al., 2013). Therefore, while the management of habitual, dominant responses involves self-regulation (Hamilton, Vohs, Sellier, & Meyvis, 2011), it is supplemented by executive processes during novel or complex tasks (Banich, 2009; Garner, 2009; Hunt et al., 2013).

The construct of self-regulation can be broken down into three components: (1) standards of thought, feeling, or behavior that one endorses, mentally represents, and monitors; (2)

sufficient motivation to invest effort into these endorsed standards; and (3) the sufficient capacity to achieve these standards while ignoring temptations or distractions (Hofmann et al., 2012). This is important to consider as working memory can further forge the link between executive function and self-regulation as it serves to mentally represent one's self-regulatory goals (Hofmann et al., 2012). As described by Hofmann, Friese, Schmeichel, and Baddeley (2011), working memory serves as the limited-capacity cognitive workspace in which attention can be controlled, diverse information can be stored and manipulated, and within which other executive processes operate. Therefore, working memory involves storing information for a short period of time and regularly updating and manipulating its contents (Salminen, Strobach, & Schubert, 2012). Working memory is believed to play a critical supporting role for other cognitive functions such as learning, reasoning, and comprehension. Furthermore, it is necessary for the coordination of multiple tasks, the switching of attention between tasks, and the activation of long-term memory when necessary (Baddeley, 1996). Within the workspace of working memory, one's self-regulatory goals are mentally represented and maintained, which is a necessary component in enabling goal achievement (Hofmann et al., 2012).

Self-regulation is a high-level executive skill (Cook, Chapman, & Levin, 2008) and both self-regulation and executive function are actively used on a daily basis when managing goal-related pursuits (Garner, 2009; Hunt et al., 2013; McCabe et al., 2010). Indeed, the manner in which we control our behavior to meet daily task demands can be explained with self-regulation and goal theory (Hart & Evans, 2005). Goal-directed behavior includes two conflicting challenges: shielding goals from interference or distracting information (goal shielding), and monitoring the environment for potentially important, new information (background monitoring). A balance between these two challenges therefore enables people to adjust to changing situations, when necessary, and to improve their chances of successfully achieving and completing their goals (Goschke & Dreisbach, 2008). This type of adaptive adjustment of goal-directed behavior involves both self-regulation and executive function, in that it requires focusing attention on the appropriate task and allowing for flexibility in one's mindset, respectively. More specifically, executive function directs one toward the completion of a goal, whereas self-regulation deals with the ability to adhere to the goal and enact the appropriate behaviors to bring about its success (Cook et al., 2008).

Executive Function, Self-Regulation, and Frontal Lobe Dysfunction

Much of the literature on executive function has focused on patients with frontal lobe brain damage. The general consensus from this body of research is that frontal lobe damage is associated with problems in everyday functioning, specifically in terms of cognitive control and regulation of behavior (Hart & Evans, 2006; Hunt et al., 2012; Miyake, 2000; Stuss & Levine, 2002). Examining executive function within the context of the frontal lobe brings attention to how the executive functions work together, or separately, within the brain. Three key executive processes (updating working memory, shifting, and inhibiting) are seen as unitary in that they highly correlate with one another, but they also have distinguishable functions and ways of being measured (Miyake et al., 2000; Tsuchida & Fellows, 2013).

Patients with damage to their frontal lobe tend to display goal neglect, in which they ignore goals or struggle to enact goal-directed behavior (Duncan, Emslie, & Williams, 1996; Hart & Evans, 2006; Tsuchida & Fellows, 2013). In addition, these patients are also often impaired in their ability to inhibit their prepotent responses within the context of the task at hand (Banich, 2009; Morris, Miotto, Feigenbaum, Bullock, & Polkey, 1997). For example, when performing the Stroop test, a widely-used measure of inhibition in which one must override the prepotent response of reading a word, and instead focus on the color of the ink that the word in presented in, patients with frontal lobe damage struggle (Demakis, 2004; Miyake et al., 2000). Similarly, these patients also exhibit dysfunction in behavioral control and self-regulation (Kennedy & Coelho, 2005). Indeed, patients with frontal lobe damage show increased behavioral disruption in their everyday lives, especially when confronted with unstructured or novel situations. They are also impaired at inhibiting previously learned responses and shifting strategies (Levine et al., 2000). Even children with traumatic brain injury show specific difficulty in regard to implementing a specific plan for carrying out tasks and following rules, and are prone to using distracter objects in place of appropriate, target objects (Cook et al., 2008). These consistent findings have led researchers such as Hart and Evans (2006) and Hunt and colleagues. (2013) to consider executive dysfunction and impaired self-regulation in patients with frontal lobe damage as being linked, such that the ability to set, maintain, and successfully achieve goals is especially problematic because the impairment is to both self-regulatory and executive functions. This is important to the present study as it reflects an overlap between executive function and self-regulation and validates the exploration of these concepts in healthy young adults.

Assessing Executive Function and Self-Regulation in Healthy Young Adults

Research in patients with frontal lobe damage has revealed that the processes of both executive function and self-regulation significantly overlap. The goal of the present study is to assess the extent to which these constructs overlap within the context of a healthy adult sample. This will be a significant contribution to the literature, as it will further explain how individuals process familiar information as compared to processing difficult, unexpected, or competing information. This study also highlights possible cognitive strategies that may be involved in successfully accounting for difficult or unexpected stimuli, such that one is able to appropriately alter their behaviors to respond correctly with respect to goal achievement. An important facet of this is carefully measuring and capturing individuals' self-regulatory and executive skills. The Behavioral Rating Inventory of Executive Function-Adult Version (BRIEF-A; Roth, Isquith, & Gioia, 2005) is a standardized, self-report, neuropsychological assessment of executive function and self-regulation within the context of everyday life. Though some have suggested that one's capacity for self-regulation is state-based, varying based on a person's internal or external situation and their available self-regulatory resources at any given moment in time (MacKenzie, Mezo, & Francis, 2012), other researchers have that posited self-regulation is a trait-based individual difference.

The Self-Regulation Scale (Schwarzer, Diehl, & Schmitz, 1999) is a measure that is empirically linked to other trait qualities such as general self-efficacy and proactive coping, thus suggesting that self-regulation is potentially a dispositional trait (Schwarzer et al., 1999). Researchers have used this measure to assess self-regulation as it relates to goal-directed behaviors, attention, and inhibition in healthy young adult populations (Hanif et al., 2011), goal pursuit, attention, self-efficacy, proactive coping, and positive affect in healthy young adults, middle-age adults, and older adults (Diehl, Semegon, & Shwarzer, 2006), and self-efficacy, coping, depression and affect across cultures in healthy adults (Luszczynska, Diehl, Gutierrez-Dona, Kuusinen & Schwarzer, 2004). As the Self-Regulation Scale has been consistently related to these constructs, this body of existing research suggests that self-regulation may be studied as a meaningful individual difference variable that is stable in guiding behavior toward a specific, directed goal (Karoly, 1993). It also potentially suggests that some individuals may inherently be more able than others to organize incoming stimuli with the emotional, cognitive, and behavioral control that is necessary to respond appropriately given a particular situation.

Attention, an important aspect of self-regulation (Hanif et al., 2012; Hofmann et al., 2012) and executive function (Hofmann et al., 2011; Hunt et al., 2013; Norman & Shallice, 2000), is typically involved in tasks that require cognitive control and individuals who experience more attention-related errors within the context of everyday life may also be more prone to committing slips of action. Indeed, Clark (2010) found that self-reported attention-related errors in everyday life, as measured by the Attention-Related Cognitive Errors Scale (ARCES; Cheyne, Carriere & Smilek, 2006), were significantly correlated with performance on the Slip Induction Task (SIT; Clark et al., 2012). The SIT is a method for measuring cognitive control as it captures an individual's ability to inhibit a routine response, when necessary, to achieve a specific goal. The SIT involves participants learning a sequence of movements until they become routine. Upon the sequence becoming well-learned, participants complete several more trials that occasionally include random deviations from that previously learned routine sequence. In this way, participants must sometimes inhibit a routine, prepotent response, and instead, respond in a way that is outside of the routine. Consequently, the SIT has been found to induce slips of action in healthy younger adults (Clark et al., 2012), healthy older adults (Clark, Rose, & Roy, in review), and participants with mild brain injury (Clark, Ozen, Fernandes, & Roy, in preparation).

The Stroop test (Stroop, 1935) similarly measures executive attention, inhibition of predominant responses (Cothran & Larsen, 2008; MacLeod, 1991; Strauss, Allen, Jorgensen, & Cramer, 2005), cognitive flexibility (Johnco, Wuthrich, & Rapee, 2013; Strauss et al., 2005), and selective attention (Strauss et al., 2005) by requiring participants to respond to color words (red, yellow, blue, or green) that are presented in colored ink. Participants indicate the color of the ink that a word is presented in and it is either congruent with the actual word that is presented (red is presented in red ink) or it is incongruent (red is presented in blue ink). The Stroop test has been used to study patients with traumatic brain injury (TBI; Novakovic-Agopian et al., 2011) as well as healthy adults (Johnco et al., 2013). Interestingly, results from both the Stroop test and the SIT indicate that inhibiting a prepotent response is difficult and often comes at the cost of slower responses (Clark et al., 2012; Stuss et al, 2005). Accordingly, response time may be an important part of identifying and monitoring attentional and executive processes as they happen, such that time to respond indicates to what extent cognitive processing is underway. A slower response suggests that the individual needed more time to process the difficult, unfamiliar information and make the appropriate response based on the task at hand, whereas simple, expected, automatic processing is able to be processed much faster (Clark et al., 2012).

Hypotheses of the Present Study

The present study was developed with four main goals in mind. The first was to determine whether a neuropsychological assessment of self-regulation and executive function, the BRIEF-A, is related to a more concise measure of self-regulation, the Self-Regulation Scale. Therefore, hypothesis one was that high self-regulatory ability as measured by the BRIEF-A would be significantly correlated with high self-regulatory ability as measured by the Self-Regulation Scale. Specifically, because the BRIEF-A and the Self-Regulation Scale have reverse scales, such that a lower score on the BRIEF-A is indicative of greater self-regulatory ability, and a higher score on the Self-Regulation Scale is indicative of greater self-regulatory ability, the actual measures would correlate negatively.

The second main goal was to assess the degree to which self-regulation is related to everyday attention-related cognitive errors. As such, hypothesis two was that high self-regulatory ability would be correlated with everyday attention-related cognitive errors as measured by the ARCES, such that those with high self-regulatory abilities (indicated by low BRIEF-A scores and high Self-Regulation Scale scores) would report fewer attention-related errors in everyday life.

The third goal was to evaluate the participant's ability to use cognitive control and executive processes to inhibit prepotent responses. Hypothesis three was that participants would make frequent errors on the SIT when confronted with a deviation from the previously learned action sequence (alteration) that required inhibition of a routine, prepotent response. Similarly, participants were expected to make frequent errors on the Stroop test when confronted with incongruent words (red presented in blue ink). Finally, it was also expected that when inhibiting a prepotent response, response times on the SIT and the Stroop test would be longer, as the inclusion of these unexpected or difficult aspects of the tasks would involve cognitive control and executive processes.

The last main goal of this study was to assess the degree to which self-regulation, as measured by the BRIEF-A and the Self-Regulation Scale, was related to performance on the SIT and the Stroop test, the tasks that require executive functioning and cognitive control. Therefore, hypothesis four was that high self-regulatory ability would be positively correlated with accuracy on altered trials of the SIT and with accuracy on incongruent trials on the Stroop test, such that better self-regulation would be associated with better accuracy.

CHAPTER II

METHOD

Participants

All students enrolled in Introduction to Psychology at the University of Tennessee at Chattanooga were invited to participate in this study and 230 students showed their interest by giving their e-mail address to the researcher. Of these students, 186 accessed the online questionnaire and provided informed consent. To avoid confounding results due to age-related decline in processing speed (Ludwig, Borella, Tettamanti & Ribuapierre, 2010) or neurological impairment (Norman & Shallice, 1986; Ozen & Fernandes, 2012) only those participants between the ages of 18 and 25 years, free of self-reported neurological disease or damage, color vision deficiency, and drug or alcohol influence at the time of survey were invited to continue the assessments. In total, 50 students failed to meet these inclusion criteria (see Table 1.1 for the specific reasons each of these students were omitted). This left 136 participants who qualified for the study.

As there were multiple measures included in this study, some self-report measures that were administered online, and some tasks administered in the laboratory, there were 3 phases of assessments (see the *Procedure* section for a description of which assessments were given during which phase). The aforementioned 136 consenting, eligible participants fully completed the initial phase of the assessment, 101 of these participants completed the second phase, and 36 completed the last. Of these 36 final participants (24 female), all were between the ages of 18-22

(*M* = 18.43, *SD* = .76), right-handed, and free of the influence of any illicit drugs or alcohol at the time of assessment.

Table 1.1

Exclusion Criteria and Number of Students Excluded from the Study

Reason for ineligibility	Number of students omitted
Under 18 years of age	2
Concussion	33
Brain Aneurysm	1
Epilepsy	1
Attention-related issues (ADHD)	5
Dyslexia	1
Color Blind/ Deficient	3
Illicit Drugs or Alcohol Use at Time of Study	4
Total	**50**

Procedure

The initial phase of this study involved an online questionnaire that first invited participants to provide informed consent. Then participants completed a demographic questionnaire regarding age, educational background, history of any neurological damage or disorder, history of any color blindness or deficiency, and if they were under the influence of any illicit drugs or alcohol at the time of survey, as these substances may impair their cognitive and self-regulation abilities. Also included in this online questionnaire were the Self-Regulation Scale and the ARCES.

Within 48 hours of completing this online survey, participants were e-mailed a web link to access an online administration of the BRIEF-A. A total of 101 participants fully completed this section of the study. All 101 of these participants were subsequently invited to the final phase of the study. This final phase involved participants coming to the Assessing Cognition Lab on The University of Tennessee at Chattanooga campus within one to four weeks of completing the online administered BRIEF-A. During this final phase of the study, all participants first provided informed consent and then completed a demographic questionnaire. The neuropsychological testing portion of the study followed, where the Delis-Kaplan Executive Function System (D-KEFS) Trail Making, D-KEFS Verbal Fluency, and Advanced Clinical Solution (ACS) Word Choice Test were administered. Participants then completed another administration of the ARCES, Self-Regulation Scale, and BRIEF-A. Finally, participants completed the Stroop test (Stroop, 1935) and the SIT (Clark et al., 2012), the order of which were randomly counterbalanced in order to limit the possibility of carry-over or cognitive fatigue effects. This laboratory-administrated phase of this study took approximately 1.5 hours, and once the experiment had been completed, all participants were debriefed and thanked for their participation. There were no incentives given to participants at any point during the study.

Materials

Self-regulation assessments.

Self-regulation was measured using the BRIEF-A (Roth et al., 2005) as well as the Self-Regulation Scale (Schwarzer et al., 1999). The BRIEF-A is a 75-question, standardized, self-report, neuropsychological assessment that is designed to assess executive function and self-regulation in everyday life in participants who present with a myriad of developmental, neurological, and psychiatric disorders related to issues with attention, learning, dementia, depression, autism spectrum disorders, traumatic brain injury, schizophrenia, and mild cognitive impairment (Roth, Isquith, & Gioia, 2013). The Self-Regulation Scale is a substantially more concise assessment than the BRIEF-A, with 10 questions, that is also designed to measure a participant's perceived self-regulatory ability. The creators of the Self-Regulation Scale suggest that self-regulation is a dispositional trait as it is empirically linked to other trait qualities such as general self-efficacy and proactive coping (Diehl et al., 2006; Schwarzer, et al., 1999).

Neuropsychological assessments.

The D-KEFS (Delis, Kaplan, & Kramer, 2001) was administered to capture the basic executive abilities of the participants. It has been widely used in the neuropsychological assessment of patients with TBI, stroke, and brain tumor (Levine et al., 2000; Novakovic-Agopian et al., 2011). The D-KEFS is a standardized neuropsychological assessment, designed for use in clinical settings to assess executive dysfunction (Swanson, 2005). This assessment tool includes nine stand-alone tests, each used to assess key components of executive function. As the present study involved assessing attention, task switching, cognitive flexibility, response time, and movement tasks, two of the stand-alone tests that specifically measure those skills were used. The two selected tests were the Trail Making Test and the Verbal Fluency Test. The Trail Making Test involves multiple conditions and only condition two and condition four were used in this study. Condition two of the Trail Making Test assesses visual scanning, attention, and processing speed as it involves a visual-motor task in which participants are asked to draw a line connecting a series of numbers together in numerical order. Condition four of the Trail Making

Test assesses cognitive flexibility as it involves drawing a line to connect a number to a letter to a number, etc., in order (see Figure 1.1). The Verbal Fluency Test assesses task initiation, processing speed, and switching. For this test, participants are asked to name as many words as they could think of that start with a particular letter of the alphabet. Participants were given 60 seconds to do this and then subsequently required to switch to a different letter for 60 seconds, all the while remembering a specific set of rules (Swanson, 2005).

The ACS Word Choice Test is a standardized, clinically used subtest of the Wechsler Memory Scale, 4th edition (Pearson Education, 2008) that assesses suboptimal effort by measuring response bias (Miller, Millis, Rapport, Bashem, Hanks, & Axelrod, 2011). Specifically, participants are simultaneously shown and read a series of 50 words, and are instructed to say whether the word represents something that is natural or man-made. For example, the word *tree* would be natural, whereas *building* would be man-made. Immediately after completing the 50 words, the participant is then shown a card with 50 word-pairs, where one of the words in each pair was previously presented. For this part of the test, participants are instructed to identify which word in the pair was previously shown. A score of 48 or lower indicates suboptimal effort (Pearson Education, 2008).

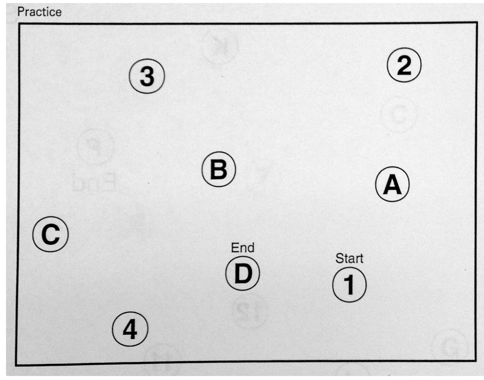

Figure 1.1

D-KEFS Trail Making Test

Stroop Test.

A computerized version of the Stroop test (Stroop, 1935) involved presenting, on a computer screen, words and squares in either red, yellow, blue, or green ink. There were three experimental blocks, in which each of the stimuli were randomized and repeated ten times per color for a total of forty trials per block. Block one was the neutral condition in which squares were presented instead of words (see Figure 2.1). Block two included congruent color-color words (i.e., the word 'red' always displayed in red ink; see Figure 2.2) and block three included incongruent color-color words (i.e., the word 'red' displayed in blue ink; see Figure 2.3). In each block, participants were instructed to focus on the color of the ink displayed on the computer screen in front of them and respond as accurately and as quickly as possible by pressing the key on the keyboard that corresponded to the color presented (Cothran & Larsen, 2008). For this administration, the *c* key was covered with a blue sticker, the *s* key with red, the *m* key with orange, and the *l* key with green. Time from presentation of a stimulus to response was recorded (response time), as was the accuracy of responses (accuracy).

Figure 2.1

Stroop Test, Neutral Condition

Figure 2.2

Stroop Test, Congruent Condition

Figure 2.3

Stroop Test, Incongruent Condition

Slip Induction Task.

The SIT (Clark et al., 2012) involved visually presenting arrow cues on a computer screen and participants responding to that stimulus on a response board that contained five response buttons: a central home button, one above the central button, one below, one to the left, and one to the right (see Figure 3.1). The task required participants to learn and execute a series of movements, with participants instructed to always move to and press the target button on the response board that was associated with the direction of the arrow cue shown on the computer screen. There were two phases of the SIT: a learning phase, in which the same sequence of arrow cues were repeatedly presented such that the sequence became routine (see Figure 3.2 for an example of an unaltered arrow cue), and an alteration phase, which included a manipulation to the direction of some of the error cues such that they were unexpected or novel (see Figure 3.3 for an example of an altered arrow cue).

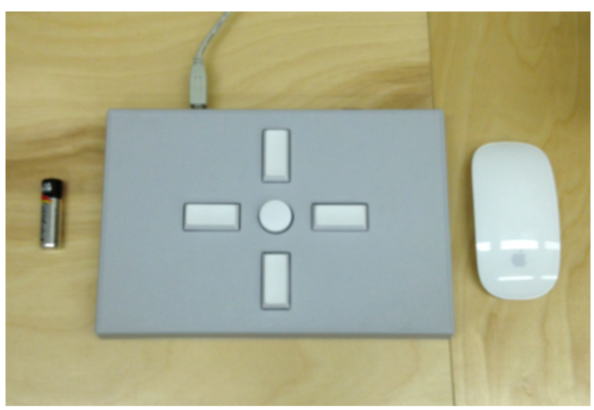

Figure 3.1

Response Board for the SIT

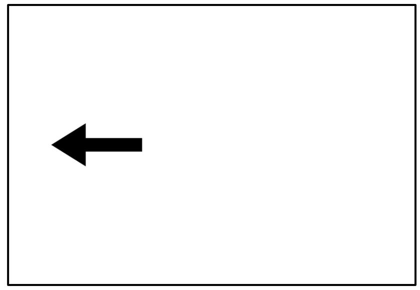

Figure 3.2

Unaltered Arrow Cue

Here, the correct response upon seeing this arrow cue would be to press the left response key.

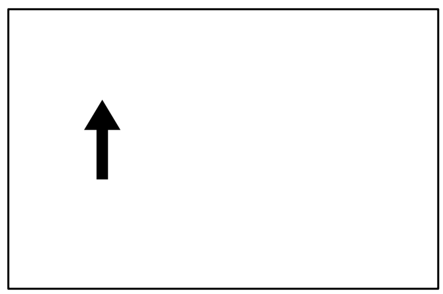

Figure 3.3

Altered Arrow Cue

Here, the prepotent response to press the left key would need to be inhibited, with the correct response being to press the up key, as the arrow is pointing up despite being located on the left side of the screen.

During the learning phase, participants were taught a sequence of seven hand movements to the appropriate target buttons by following arrow cues presented on the computer screen. Each sequence began with a fixation cross in the middle of the screen that remained for a variable period of 500 to 1500 milliseconds, and participants were instructed to press the central home button as soon as they saw the fixation cross disappear. Once the home button was pressed, the first arrow cue appeared and participants moved to and quickly pressed the corresponding target button. The time that elapsed between the appearance of the arrow cue and the depression of the target button was recorded as a measure of movement time (MT). After pressing the target button, participants returned to the central home button in order to trigger the next arrow cue. The learning phase involved participants practicing the exact same movement sequence 120 times. This was determined as Clark et al. (2012) indicate that there is a potential ceiling effect during the learning phase, such that the sequence is just as routine with 120 trials of practice as it is with 720 trials of practice. After completion of the learning phase, participants were offered a short break before proceeding directly to the manipulation phase.

At the beginning of the alteration phase, participants were informed that some of the sequences would contain an arrow cue whose direction was altered from what was expected, and that their task was to always move to, and press, the target button that was consistent with the arrow cue's pointed direction. These unexpected cues required the participant to inhibit their routine response because of a change in the cue's pointed direction. These events are termed *directional alterations* and when encountered, the arrow cue appeared in the expected location, but pointed in an unexpected direction (toward an unexpected target button). The alteration phase contained 150 trials wherein 24% of trials involved a directional alteration to one of the routine movements. Note that this is a truncated administration of the SIT as the alteration phase initially included 600 trials where 24% of trials were altered (Clark, 2012). Throughout the alteration phase, the unexpected cue occurred at either the beginning of the sequence during movement two or three, or at the end of the sequence during movement five or six. During the first few trials of both the learning and alteration phases, the experimenter observed the participant's movements to ensure proper understanding of the instructions. Accuracy was measured based on how successful the participant was at moving to the target that the arrow pointed to, and participants' initiation and movement times were also recorded throughout both phases.

CHAPTER III

RESULTS

As the participants in this study were young adults enrolled in college (*M* = 18.43, *SD* = .76), it was possible that they might not have been as invested in the tasks and questionnaires as would be desired. Therefore, ensuring that participants were giving optimal effort during the task-based assessments was an important consideration. Having participants fail to give optimal effort could potentially confound the results of the study, such that performance on the tasks would not be an accurate representation of participants' cognitive abilities and executive processing. However, results of the ACS Word Choice Test indicated that all participants who completed the laboratory assessments were devoting optimal effort as no participant's score fell below 49 (twenty-six participants scored 50, ten scored 49). With this, it can be trusted that the variations in scores and response times were due to individual differences and not the result of participants failing to adequately try when completing the tasks.

Also important to the overall results was ensuring that the appropriate statistical techniques were employed. Most of the data for this study was normally distributed, but because of concerns over mild skewness, for each of the Pearson *r* correlations the non-parametric equivalent, Spearman's rho, was also used. In like fashion, for each of the paired samples *t*-tests, a Wilcoxon signed paired test was also run. The results of these non-parametric tests were essentially equivalent to the results of the parametric tests. As results from parametric tests have more statistical power as compared to non-parametric tests, only the results from the parametric tests are reported and discussed.

Relationship between Self-Regulatory Measures: Hypothesis One

To explore the relationship between the neuropsychological assessment of executive function and self-regulation, the BRIEF-A, and a more concise measure, the Self-Regulation Scale, a Pearson *r* correlation was used. Due to the design of the study, the BRIEF-A and the Self-Regulation Scale were administered at two separate times, initially to the larger sample of participants wherein 136 participants completed the Self-Regulation Scale and 101 of those participants completed the BRIEF-A, and subsequently to those 36 participants involved in the laboratory-based assessment. As such, separate correlations were used to assess the relationship between the measures at both times of assessment. Consistent with hypothesis one, the correlation analyses exposed a significant relationship between the two measures of self-regulation (see Table 2.1). Specifically, as the BRIEF-A and Self-Regulation Scale have opposing scales, such that a lower score on the BRIEF-A indicates greater self-regulatory ability, while a higher score on the Self-Regulation Scale indicates greater self-regulatory ability, the measures correlated negatively when administered to the larger sample as well as when administered later to the smaller sample.

There was also significant test-retest reliability for BRIEF-A and Self-Regulation Scale. Indeed, when the BRIEF-A scores from time one, with the sample of 101 participants, were compared to time two, with the sample of 36 participants, the scores were highly correlated. Similarly, this test-retest reliability was also seen in comparing scores on the Self-Regulation Scale at both times of assessment (see Table 2.1).

Self-Regulation and Attention Errors in Everyday Life: Hypothesis Two

To assess the degree to which self-regulation, as measured by the BRIEF-A and the Self-Regulation Scale, was related to attention-related cognitive errors in everyday life, as measured by the ARCES, Pearson *r* correlations were used. Again, these measures were administered at two separate times so the relationship between the measures at both times of assessment was assessed. Analyses revealed that there was a significant relationship between self-regulation, as measured by the BRIEF-A, and everyday attention-related cognitive errors as measured by the ARCES, at both times of survey. Specifically, a significant positive relationship between these measures was found when the measures were administered to the larger sample, as well as when administered later on, to the smaller sample (see Table 2.1). This result was consistent with hypothesis two as the BRIEF-A and ARCES have opposing scales, such that a lower score on the BRIEF-A indicates greater self-regulatory ability, while a lower score on the ARCES indicates less everyday attention-related cognitive errors.

The relationship between self-regulation and everyday attention-related cognitive errors was also seen when relating the Self-Regulation Scale to the ARCES, but in this circumstance, because a higher score on the Self-Regulation Scale indicates greater self-regulatory ability, these measures correlated negatively. Interestingly, the analyses also exposed an unexpected trending relationship between everyday attention-related cognitive errors, as measured by the ARCES, and accuracy on altered trials of the SIT. There was also a significant relationship between scores on the ARCES and accuracy on incongruent trials of the Stroop Test. Finally, there was significant test-retest reliability for ARCES scores compared at time one with the sample of 136 participants to time two with the sample of 36 (see Table 2.1).

Cognitive Effects of Unexpected Information: Hypothesis Three

SIT.

To assess participants' ability to use cognitive control and executive processes to inhibit prepotent responses, a paired samples *t*-test was used to compare within-participant accuracy on the SIT when confronted with a deviation from the previously learned action sequence (altered trials) versus accuracy on the SIT when no alteration to the sequence was presented (unaltered trials). Accuracy for both types of trials was computed by dividing the number of errors made by the total number of presented trials, for both conditions. Consistent with the hypothesis, there was a significant difference in accuracy between altered and unaltered trials on the SIT, $t(35) = -17.07$, $p < .001$, $d = -3.93$ (Figure 4.1). This result is consistent with the SIT literature in that participants were significantly less accurate on altered trials than when the trial proceeded as expected (unaltered trials).

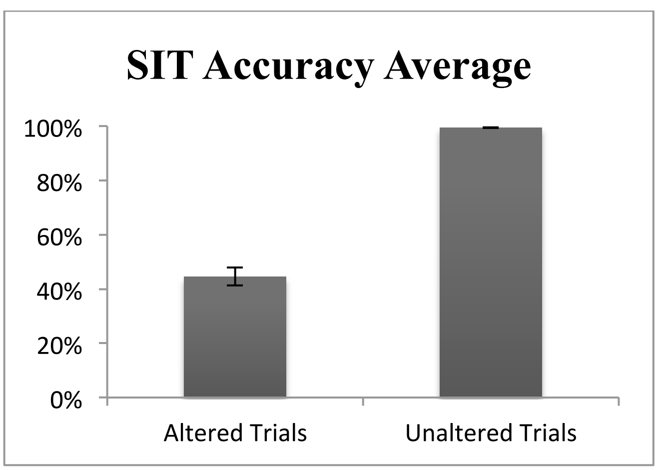

Figure 4.1

Accuracy on Altered Versus Unaltered Trials of the SIT

Also consistent with the literature was the finding that MTs were substantially longer for altered trials as compared to unaltered trials on the SIT, $t(35) = 22.25$, $p < .001$, $d = 3.64$ (Figure 4.2). Furthermore, when comparing MT on altered trials that were answered correctly as compared to altered trials that were answered incorrectly (where an error was made), MTs were substantially slower, $t(35) = 21.45$, $p < .001$, $d = 3.94$ (Figure 4.3). This suggests that accounting for unexpected information and overriding initial, prepotent responses takes considerably more time than does the completion of routine tasks.

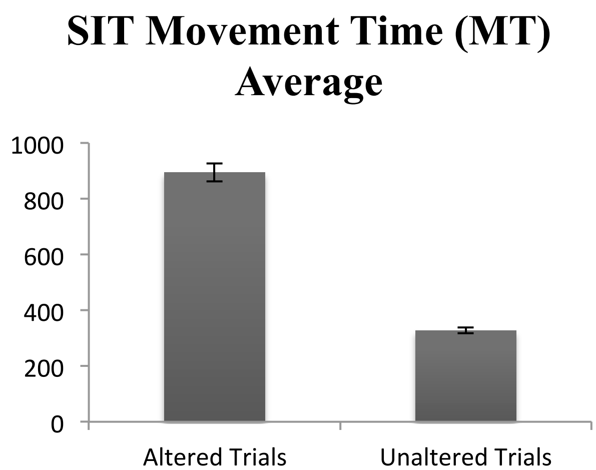

Figure 4.2

MTs on Altered Versus Unaltered Trials of the SIT

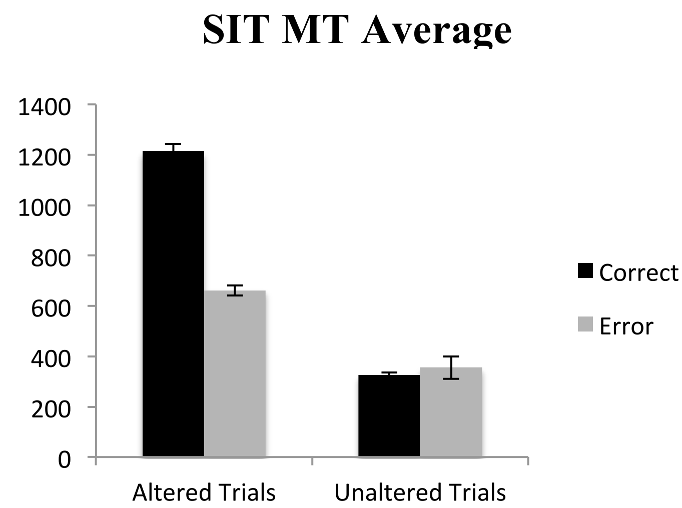

Figure 4.3

MTs on Altered Versus Unaltered Trials of the SIT when Responding Correctly Versus Erroneously

Stroop Test.

When considering the Stroop test, a paired samples *t*-test was used to compare accuracy on trials with incongruent color-color words to accuracy on trials with congruent color-color words. Again, accuracy was computed by dividing the number of errors made by the total number of presented trials, for each block. One participant in the sample was extremely inaccurate on the incongruent trials of the Stroop test, with an accuracy rate of only 8%. As such, this participant's Stroop test data were omitted from the data set. Consistent with hypothesis three, there was a significant difference in accuracy between incongruent and congruent trials on the Stroop test, $t(35) = -7.82$, $p < .001$, $d = 1.79$ (Figure 4.4). Specifically, accuracy was significantly lower for incongruent trials, where the word stimulus was presented in an ink color that was inconsistent with the actual color word (the word red is presented in blue ink) as compared to congruent trials, where the word stimulus was presented in ink color that was consistent with the actual color word (the word red is presented in red ink)**.**

A paired samples *t*-test also indicated that, as expected, response times were significantly slower for incongruent trials as compared to congruent trials on the Stroop test, $t(35) = 6.03$, $p < .001$, $d = -1.33$ (Figure 4.5). These results identify that it takes more cognitive processing, depicted by slower response times, to adhere to atypical rules or information than it does to follow the predominant response.

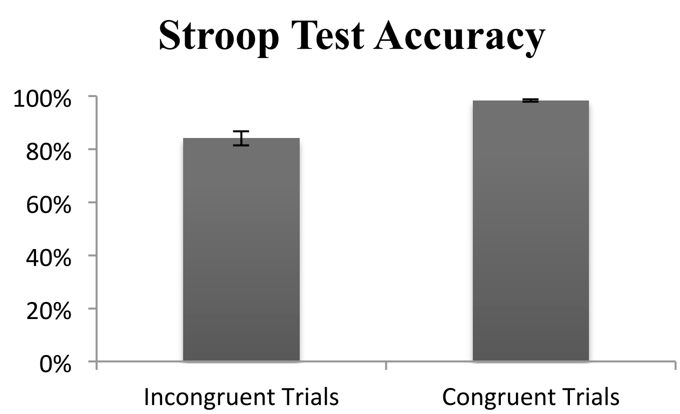

Figure 4.4

Accuracy on Incongruent Versus Congruent Trials of the Stroop Test

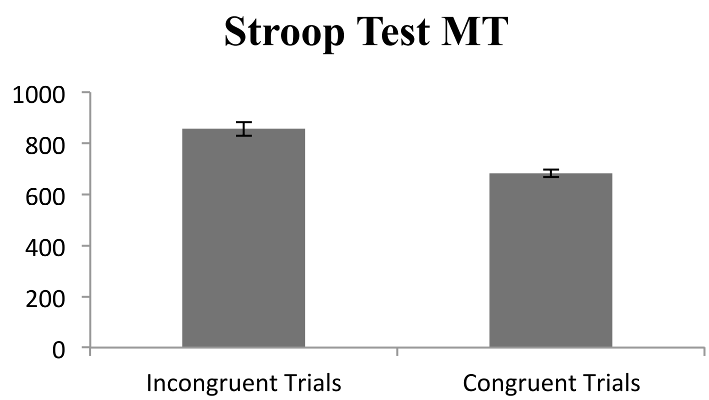

Figure 4.5

MTs on Incongruent Versus Congruent Trials of the Stroop Test

The Overlap of Executive Function and Self-Regulation: Hypothesis Four

Neuropsychological assessments of executive function.

Turning now to the relationship between the measures of self-regulation and the neuropsychological assessments of executive function, a Pearson *r* correlation was used to assess the relationship between the BRIEF-A and switching, a facet of cognitive control, as measured by D-KEFS Verbal Fluency. This correlation analysis indicated a significant correlation between these measures, $r(34) = -.51$, $p = .001$, such that greater self-regulatory ability as indicated by a low BRIEF-A score is related to the spontaneous production of more words across the three trials. This indicates that those with higher self-regulatory ability had better cognitive control within the task. This relationship is also seen when correlating the Self-Regulation Scale and D-KEFS Verbal Fluency, $r(34) = .35$, $p = .02$, such that greater self-regulatory ability, as indicated by a high score on the Self-Regulation Scale, is related to the spontaneous production of more words. A Pearson *r* correlation was also used to assess the relationship between everyday attention-related cognitive errors, as measured by the ARCES, and switching, as measured by D-KEFS Verbal Fluency, which also resulted in a significant negative correlation, $r(34) = -.37$, $p = .01$, such that those who generated more words in D-KEFS Verbal Fluency reported fewer attention-related cognitive errors in their daily lives.

With respect to D-KEFS Trail Making, there was no significant relationship between scores on the BRIEF-A and time to complete condition two of D-KEFS Trail Making, $r(34) = -.010$, $p = .48$, nor condition 4, $r(34) = .09$, $p = .31$. There was also no significant relationship between scores on the Self-Regulation Scale and time to complete either condition of D-KEFS, condition two: $r(34) = .01$, $p = .48$; condition four: $r(34) = -.25$, $p = .074$. This lack of relationship was also seen between scores on the ARCES and time complete condition two of D-KEFS Trail Making, $r(34) = -.14$, $p = .20$, and condition four, $r(34) = .19$, $p = .13$. Interestingly, there was a significant Pearson *r* correlation between timing on condition two of D-KEFS Trail Making and accuracy on altered portions of the SIT, $r(34) = .282$, $p = .048$. While often condition four is indicative of executive processing as it requires task switching, this finding with condition two highlights the importance of timing when accounting for unexpected information, such that drawing a line connecting sequential numbers in a slow pace was related to responding accurately when confronted with altered trials on the SIT.

Experimental assessments of executive function.

To assess the relationship between self-regulatory ability and accuracy on altered trials of the SIT on incongruent trials of the Stroop test, Pearson *r* correlations were used. There was no relationship between self-regulation, as measured by the BRIEF-A, and accuracy on altered trials of the SIT, nor scores on the BRIEF-A and accuracy on incongruent trials of the Stroop test. There was also no relationship between self-regulation as measured by the Self-Regulation Scale and accuracy on altered trials of the SIT, nor scores on the Self-Regulation Scale and accuracy on incongruent trials of the SIT. Consistent with the literature, there was a substantial relationship between MT and accuracy on altered trials on the SIT, and also between response time and accuracy on incongruent trials on the Stroop test (see Table 2.1). Because of these strong relationships between response time and accuracy, a partial correlation was used to compare the relationship between BRIEF-A scores and accuracy on altered trials on the SIT, and accuracy on incongruent trials of the Stroop test, holding MTs constant. Note that two participants had extremely variable response times on the SIT (z of the residual less than -2) so their data was omitted from this portion of the analysis. Though the partial correlation did not support any relationship between BRIEF-A and accuracy on the Stroop test, $r = -.078$, $p = .328$, it did expose a significant partial correlation between BRIEF-A scores and accuracy on the SIT when controlling for movement time, $r = -.360$, $p = .018$ (see Figure 5.1). Therefore, when MT was held constant, self-regulatory ability appeared to play a role in monitoring for unexpected information and being able to appropriately manipulate responses so they matched the task at hand.

Table 2.1

Correlation Matrix

	1	2	3	4	5	6	7	8	9	10
1. SRScale 1	1									
2. ARCES 1	-0.58**	1								
3. BRIEF-A 1	-.59**	.62**	1							
4. SRScale 2	.39**	-0.25	-.31*	1						
5. ARCES 2	-.64**	.85**	.62**	-.39**	1					
6. BRIEF-A 2	-.56**	.60**	.84**	-.55**	.63**	1				
7. SIT ALT Acc %	0.07	-0.1	-0.16	0.07	-0.25	0.01	1			
8. SIT ALT MT	0.06	0.01	0.03	0.07	-0.11	0.2	.79**	1		
9. Stroop Incon Acc %	0.07	-.35*	-0.04	0.09	-.33*	-0.16	-0.2	-0.13	1	
10. Stroop Incon RT	0.05	0.27	0.05	0.09	0.2	0.13	0.13	0.16	-.69**	1

Note. ** p < .01 *p < .05

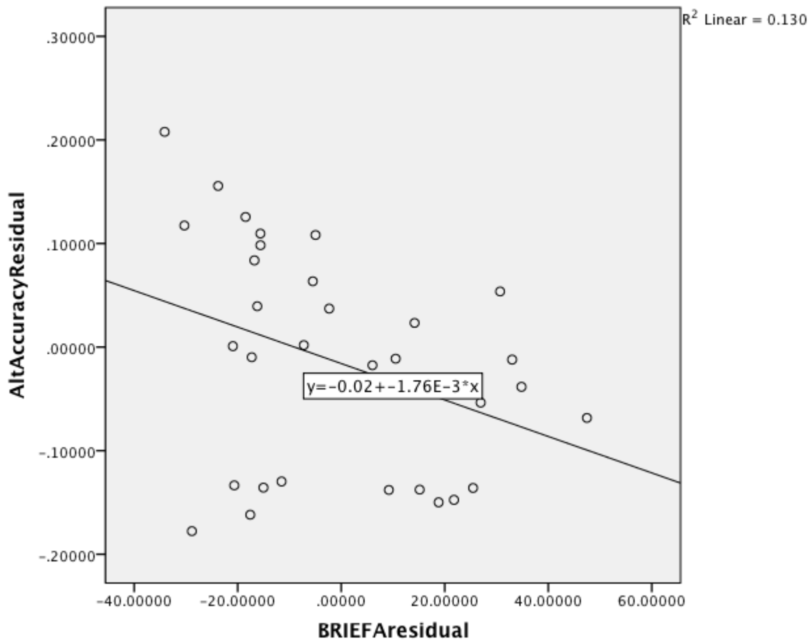

Figure 5.1

Scatterplot depicting the partial correlation between BRIEF-A Scores and ALT Accuracy on the SIT, while controlling for SIT MT

CHAPTER IV

DISCUSSION

Self-Regulatory Measures

The present study was developed with four main goals in mind. The first was to determine the relationship between a neuropsychological assessment of self-regulation and executive function, the BRIEF-A (Roth et al., 2005), and a more accessible, concise measure of self-regulation, the Self-Regulation Scale (Schwarzer et al., 1999). This study is believed to be the first to provide substantial evidence for the construct validity of the Self-Regulation Scale, a concise, readily available measure of self-regulation. This evidence was demonstrated in terms of significant correlations between participants' scores on the Self-Regulation Scale and a more established measure of self-regulatory ability, the BRIEF-A, which is primarily used by clinicians within clinical populations. The BRIEF-A assesses self-regulation as well as a variety of others executive processes. Therefore, the strong psychometric relationship between with the BRIEF-A and the Self-Regulation Scale bolsters the theory that self-regulation is either supported by other executive processes (Blair & Ursache, 2011; Hofmann et al., 2012; Hunt et al., 2013) or at the very least, is associated with them. Moreover, this relationship generally validates the Self-Regulation Scale as a measure. The Self-Regulation Scale is publically available and is substantially shorter, with only 10 questions, than the more time-consuming, laborious BRIEF-A, which contains 75 questions and is generally reserved for clinical use. In this way, it is possible that the Self-Regulation Scale could be used in place of the BRIEF-A when assessing self-regulatory ability in healthy adults.

Cognitive Effects of Unexpected Information

SIT.

This study provides support for a truncated version of the SIT as a technique for inducing slips of action; the truncated version that was used in the present study demonstrated effects that were comparable to those associated with the full-length version of the SIT (Clark et al., 2012). Specifically, experiencing alterations to the routine sequence not only hindered participants' ability to respond correctly, but also came at the cost of longer response times. Furthermore, response times were significantly longer when the participant was confronted with unexpected information and responded correctly. This offers a theoretical window into the cognitive control and executive processes that are involved when having to account for unexpected stimuli.

Stroop Test.

With regard to the Stroop test, participants' responded less accurately when having to account for incongruent trials that required inhibition of their prepotent response of reading the color word. On this test, the congruent trials are often easier because the participant will get the answer correct if they either read the word or if they focus on the color of the ink; with the incongruent trials, performing the habitual response of reading the word instead of focusing on the color of the ink results in an incorrect response.

Overall Implications

When taken with the SIT results, the overall findings indicate that inhibiting prepotent responses is often difficult and the executive processes involved in addressing unexpected or unfamiliar stimuli are different from those involved in processing automatic or familiar information (Norman & Shallice, 2000). Specifically, it indicates that while executing a routine, habitual action (like reading a word, or completing a routine movement sequence) can be completed quite automatically, inhibiting a prepotent response requires the involvement of additional, possibly executive, processes. Furthermore, doing so takes considerable time. Indeed, the results suggest that slowing response speed is associated with an increased probability of inhibiting the prepotent response and making a correct response.

Importantly, participants were instructed to simply move as quickly and accurately as possible, which allowed them to complete the task at their own pace. In addition, participants could not predict when an altered trial was going to occur. As such, they needed to balance their speed of responding with the knowledge that at some point, an unexpected event might occur. This is important because when holding response speed constant, self-regulation does begin to play a role in the inhibition and cognitive control process. Initially, the speed at which the task is performed precludes blatant self-regulatory processes from being involved, or, at least, noticed by the assessments that this study used to measure self-regulation. However, when statistically holding MT constant such that it is no longer taken into account when assessing the processes present when a having to account for unexpected information, self-regulatory ability begins to intersect with those executive processes.

As self-regulation is a highly goal-oriented process, it is also possible that by instructing participants to complete the task as quickly *and* as accurately as possible the goals at hand were in conflict with one another. Specifically, some participants may have focused on being accurate, and thus responded more slowly, whereas other participants may have focused on moving and responding quickly, allowing their accuracy to fall. With this, the self-regulatory process of altering behavior to encourage goal attainment would be present within the interaction between time and accuracy. If the primary goal was to move fast, accuracy suffered; if the primary goal was to be accurate, response times suffered.

Furthermore, as response time was identified to participants as an important aspect of the SIT, it is possible that response time was qualitatively different from what would typically be found in tasks of every life. This may be important idea to consider with respect to everyday tasks where speed of responding would not be allowed to vary as freely as it is in the SIT. For example, it is possible that when reaction time must be very fast, for example, when a driver realizes on oncoming car wreck and needs to immediately slam on the brakes, self-regulatory ability plays a role in the attentional processes that need to be focused on the situation at hand. In doing so, executive processes are recruited to make the appropriate behavioral changes (maybe swerving into another lane or on the curb, which would involve planning, switching, etc.). Here, the goal shifts from accelerating the vehicle forward to abruptly slowing the vehicle and possibly altering its direction in just a matter of moments. Having strong self-regulatory abilities in a situation like this would likely increase one's probability of making the appropriate behavioral adjustments to avoid the car wreck. Failing to notice that the goal has changed, to inhibit prepotent responses, to manipulate incoming stimuli to fit the new goal, to harness attentional resources, etc., would presumably hinder the ability to recruit those executive processes such as task switching, assessing task demands, exacting cognitive flexibility, planning, that are necessary to avoid the wreck,. This highlights the fact that the executive functions are complementary processes (Banish, 2009; Garner, 2009; McCabe et al., 2010; Norman & Shallice, 1986, 2000) and many of them support self-regulation (Hart & Evans, 2006; Levine et al., 1998).

Limitations

While this study does provide useful information about the overlap between self-regulatory processes and executive functioning, there are several limitations. The first would be that of sample size. Due to time restraints and participant interest, only 36 participants were involved in the laboratory-based portion of this study. As a result, the power behind several of the statistical results of this project (.42) is not as high as would be ideal. A larger sample size of 90 participants would yield a more desirable power of .8, in which the results would be more generalizable. A larger sample size may also enable the use of more complex, indicative statistics, such as an analysis of covariance (ANCOVA), where cause-and-effect relationships could be addressed. Alternatively, structural equation modeling (SEM) could also be useful, where exploratory modeling could be used to assess any latent variables present within self-regulation and executive function. This would offer a more discrete model by which these two constructs fit together. Furthermore, it is possible that some of the "trending" correlations found (those with p-values at .07 or lower) would be even stronger if assessed within a larger, more representative sample. Despite the small sample size, many of correlations were very strong and this suggests that many of the findings from the present study are significant and meaningful.

Another possible limitation of this study is that of potential common method-variance, as all of the measures of self-regulation were self-report questionnaires, and all of the measures of executive function were task-based. Also, because the measures of self-regulation were self-report, it is possible that some participants may have over- or under-estimated their self-regulatory abilities. However, the strong correlation between these measures and the neuropsychological measure of D-KEFS Verbal Fluency does suggest that the scores on these assessments were accurate, at least with respect to task initiation, processing speed, and switching.

Future Directions

Possibly one of the most difficult things about this study was honing in on the very specific processes involved in executive function and self-regulation. Many researchers agree that these constructs are difficult to assess. This is primarily because there are so many sub-processes found within or associated with these executive and self-regulatory processes (Garner, 2009; Blair & Ursache, 2011; Hunt et al., 2013). While the current work explores the more attention- and inhibition-related correlates of self-regulation, there is a great deal of literature that highlights the importance of the physiological, personality, and emotional aspects of self-regulation (Brown & McConnell, 2011; Gendolla & Brinkmann, 2005; Kubzansky, Park, Peterson, Vokonas, & Sparrow, 2011; Pu, Schmeichel, & Demaree, 2010).

Future work may involve addressing those facets of self-regulation as they relate to cognitive control and executive functioning. Specifically, it may be interesting to assess how physiological functions such as heart rate (Kubzansky et al, 2011), cardiac vagal control (the role of the vagus nerve in controlling beat-to-beat changes in heart rate; Rottenberg, Chambers, Allen & Manber, 2007; Pu et al., 2010), and respiration relate to self-regulatory processes. With respect to emotional aspects of self-regulation, it may be beneficial to explore how it correlates with self-efficacy, proactive coping, positive affect (Diehl et al., 2006), depression (Luszczynska et al., 2004), and stress, and to assess self-regulation within the context of mood (Gendolla & Brinkmann, 2005) and personality characteristics. Examining self-regulation in a more integrative, complete manner would be beneficial as it is possible that the self-report measures from this study did not significantly relate to executive processing simply because they failed to adequately measure the specific facets that overlap.

Future studies may also benefit from including quantitative or task-based measures when assessing self-regulation in addition to self-report measures. Again, it is possible that solely utilizing self-report measures hindered this study's ability to assess self-regulation as a complete web of processes as it relates to everyday tasks. Examining a wider scope of self-regulation and incorporating more task-based measures would give a more well-rounded assessment of the construct, and may offer more points of connection with executive function.

Similarly, it may be worthwhile to assess executive function with a wider scope of measures to better capture the many processes involved. Both the SIT and Stroop test focus on inhibition, attentional control, and processing speed, but these are only a few of the processes embedded within the central executive. Broadening the assessment battery to include measures that specifically assess working memory, planning, goal setting, self-monitoring, task switching, performance monitoring, cognitive flexibility, and planning would give a more complete depiction of executive processes. This, again, may offer up more points of connection between self-regulation and executive function.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL

THE UNIVERSITY of TENNESSEE UT CHATTANOOGA

Institutional Review Board
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MEMORANDUM

TO: Ms. Sarah Finley **IRB # 13-121**

FROM: Lindsay Pardue, Director of Research Integrity
Dr. Bart Weathington, IRB Committee Chair

DATE: September 26, 2013

SUBJECT: IRB #: 13-121: Executive Function in Young Adults High vs. Low in Self-Regulation

The IRB Committee Chair has reviewed and approved your application and assigned you the IRB number listed above. You must include the following approval statement on research materials seen by participants and used in research reports:

***The Institutional Review Board of the University of Tennessee at Chattanooga (FWA00004149) has approved this research project #* 13-121 .**

Please remember that you must complete a Certification for Changes, Annual Review, or Project Termination/Completion Form when the project is completed or provide an annual report if the project takes over one year to complete. The IRB Committee will make every effort to remind you prior to your anniversary date; however, it is your responsibility to ensure that this additional step is satisfied.

Please remember to contact the IRB Committee immediately and submit a new project proposal for review if significant changes occur in your research design or in any instruments used in conducting the study. You should also contact the IRB Committee immediately if you encounter any adverse effects during your project that pose a risk to your subjects.

For any additional information, please consult our web page http://www.utc.edu/irb or email instrb@utc.edu

Best wishes for a successful research project.

VITA

Sarah Kate Finley was born in Memphis, TN, to the parents of Dr. William H. Finley and Judy C. Finley. She attended the University of Tennessee at Chattanooga for her undergraduate degree and graduated in May 2012 with a Bachelor of Science in Psychology. She then continued her education at the University of Tennessee at Chattanooga by joining the Research Psychology Program, specifically working in the Assessing Cognition Lab. After graduating with her Master of Science in Research Psychology in May 2014, she is pursuing a Ph.D. in Behavioral Science at the University of North Texas.