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The Effects of Self-Esteem and Motivation on Cognitive Control

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THE EFFECTS OF SELF-ESTEEM AND MOTIVATION ON COGNITIVE CONTROL

by

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ABSTRACT

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Cognitive control describes a set of mechanisms that guide behavior towards a goal (Cohen, 2017). The successful execution of cognitive control is essential for effective learning, information processing, problem solving, and academic achievement (Visu-Petra et al., 2011). The Expected Value of Control framework (EVC; Shenhav et al., 2013) suggests that control carries an inherent cost, which is weighed against the potential benefits of expending it. This cost-benefit analysis determines the direction and intensity that a goal is pursued. Importantly, motivation plays a role in this cost-benefit analysis and may function as the factor that offsets the cost of control expenditure (Yee and Braver, 2018). Motivation itself is a complex concept and may be affected by additional factors, such as self-esteem. Like motivation, self-esteem has also been found to be strongly related to academic achievement and success (Ditzfeld & Showers, 2013). Thus, it is imperative to investigate these affective factors further to better understand the ways in which these factors lead to success and positive outcomes in students. The present study investigates the nature of the relationship of academic achievement motivation, global self-esteem, and state self-esteem with cognitive control using a task of working memory updating. Results indicated that academic achievement motivation and state self-esteem were positively correlated with reaction time. State self-esteem was also positively correlated with accuracy. Global self-esteem, however, demonstrated an alternative reaction time pattern such that there was a negative correlation with reaction time, but a positive relationship with accuracy. These findings may provide insight about the role of affective factors, such as self-esteem, in the orientation of cognitive control.

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Introduction

Cognitive control has long been at the center of cognitive and neuroscience research. Cognitive control refers to the guiding mechanisms that allocate cognitive resources and direct behavior towards a goal (Cohen, 2017; Posner & Snyder, 1975). Specifically, researchers have been interested in the mechanisms behind goal-directed behavior and what factors may contribute to differences found among individuals (Jackson et al., 2017; Kane & Engle, 2002; Smillie et al., 2009). Recent efforts to understand the mechanisms of cognitive control have identified other concepts that contribute to its successful execution, such as motivation (Jones, Siegle, & Mandell, 2015; Kouneiher, Charron, & Koechlin, 2009; Mizuno et al., 2008; Padmala & Pessoa, 2010; Shenhav et al., 2013; Yee and Braver, 2018) . Research relating these two areas has concluded that control is affected by motivation. Motivation determines the direction and intensity of cognitive resources. Specifically, direction and intensity refer to the allocation of resources appropriate for a specific task and the intensity in which the task is pursued. In other words, the engagement of control is driven by an individual's desired reward or outcomes, or avoidance of a negative reward or outcome; these rewards determine how cognitive resources are allocated. (Botvinik and Braver, 2015; Cohen 2017; Padmala and Pessoa, 2010; Yee and Braver, 2018). Both cognitive control and motivation have been found to predict academic and professional outcomes (Botvinik and Braver, 2015; Shanmugan, & Satterthwaite, 2016; Visu-Petra et al., 2011). Additionally, affective factors, such as self-esteem have been found to be related to motivation, in addition to academic and professional success (Baumeister et al., 2003; Ditzfeld & Showers, 2013). Thus, these affective factors may also contribute to the successful execution of cognitive control.

On the following pages, I will provide an overview of the concepts of cognitive control, motivation, and self-esteem. I will (a.) introduce the concepts (b.) describe main characteristics and theories in the fields (c.) describe their overall importance, with an emphasis on learning and academic achievement and (d.) provide a brief overview of research in the field. Lastly, I will shift focus to the present study that attempts to investigate the relationship between self-esteem, academic achievement motivation, and cognitive control.

Cognitive Control

Cognitive control describes a set of theoretical mechanisms that guide an individual's behavior towards a particular goal (Cohen, 2017). This ability is essential for learning, information processing, problem solving, and decision making and differentiates human ability from that of other species (Cohen, 2017; Visu-Petra et al., 2011). The cognitive control system has been identified as the superordinate system that guides executive processes (i.e. inhibition, attention etc.), and behavior towards a goal (Botvinik & Braver, 2015; Shenhav et al., 2013). Specifically, the main purpose of the control system has been identified as monitoring conflict and recruiting control when a process is vulnerable to crosstalk from other processes (Botvinik et al., 2001; Cohen, 2017). This is especially important when encountering novel, nonroutine, and difficult tasks (Engstrom et al., 2017). Cognitive control has been shown to play a role in everyday tasks such as driving, academic performance, and language production and comprehension (Engstrom et al., 2017; Fedorenko, 2014; Luk et al, 2012; Visu-Petra et al., 2011). The ability to flexibly adapt our behavior in response to task demands is necessary for goal attainment and autonomous, healthy functioning throughout the lifespan, thus making it an important area of research (Medaglia, 2019).

As indicated previously, recent research has identified the cognitive control system's main role as a supervisory system that directs subordinate processes in the direction of a goal (Niendam et al., 2012; Shenhav et al., 2013). Understanding what the purpose of the control system is also allows us to understand some of its unique characteristics and how it can be distinguished from automatic processes. Specifically, processes that recruit cognitive control can be distinguished from these automatic processes in that the latter processes are not executed with conscious intention, are more resistant to interference, are executed more quickly, and require less effort (Kiefer et al., 2012; Cohen, 2017; Posner & Snyder, 1975; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). These processes are thought to occur in a bottom-up manner independent from mechanisms involved in control (Kiefer et al., 2012). Cognitive control processes, on the other hand, are distinguished by vulnerability to interference, a slower speed of execution, and require more effort (Cohen, 2017; Kiefer et al., 2012; Posner & Snyder,1975; Schneider & Shiffrin, 1977; Shenhav, Botvinik, & Cohen, 2013; Shiffrin & Schneider, 1977). Furthermore, a controlled process can become automatic with practice and repeated exposure, suggesting that cognitive control lies on a spectrum of automaticity and control (Cohen, 2017; Posner & Snyder, 1975; Engstrom et al., 2017; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

A common task that embodies the spectrum of automaticity and control is the Stroop task (Cohen, 2017; Shenhav et al., 2013). In the Stroop task, individuals are presented with a color word and asked to name the color of the ink in which the word is written. With congruent stimuli, the color of the ink matches the color word (i.e. the word "GREEN" in green ink). However, in incongruent stimuli, the color of the ink does not match the word presented (i.e. the word "GREEN" in red ink). During this task, participants find it easier and quicker to name the color in congruent stimuli than with incongruent stimuli demonstrating an interference effect in the incongruent condition. This effect is not seen when asked to read the word presented (Shenhav et al., 2013). This task illustrates that word reading is an automatic process as compared to reading the color of the ink the word is displayed in. Reading the color of the ink in the incongruent condition requires more control and is vulnerable to interference, particularly in the incongruent condition (Shenhav et al., 2013). This example of the Stroop task allows us to understand automatic processes compared to processes that require control.

The Expected Value of Control (Shenhav et al., 2013)

The Expected Value of Control Framework (EVC; Shenhav et al., 2013) provides an overview of the functions of cognitive control, including a specification function that identifies *what* representations are activated and *when* (Cohen et al., 2017; Shenhav et al., 2013). Specifically, the EVC framework identifies three component functions of cognitive control including regulation, specification, and monitoring. The function of regulation identifies cognitive control as a superordinate system with the capacity to influence and regulate information processing mechanisms at lower or subordinate levels. These lower level mechanisms include functions such as working memory, perceptual attention, and action selection and inhibition (Botvinik & Braver, 2015; Niendam et al., 2012; Shenhav et al., 2013). These lower level mechanisms are necessary to engage in goal-directed behavior. Specification refers to a decision-making process made by the control system in which a decision is made whether or not to engage in a controlled task, and the intensity in which this task should be pursued. Lastly, monitoring refers to the system's ability to detect information about the current circumstances in order to specify the control signal and adjust the intensity accordingly (Shenhav et al., 2013).

The EVC framework suggests that engagement of cognitive control is aversive and carries an inherent cost. According to this framework, effort is the cost that is expended when cognitive control is recruited (Shenhav et al., 2013). Effort can be defined as the intensity of an activity, in this case, the intensity of cognitive control (Kool et al., 2017). Since cognitive control engagement is costly, or effortful, individuals will naturally seek to minimize its engagement.

The idea that individuals will seek to minimize cognitive demands has a basis in research in the area of physical-effort-based decision making. This idea is based on Hull's widely supported Law of Less Work (Hull, 1943) which says that individuals will prefer to conduct actions with the least demands for physical effort. Hull's Law of Less Work has been extremely influential in research in behavior and economics. More specifically, economists have long assumed that cognitive engagement is similarly as costly as physical effort and that individuals dislike both (Kool et al., 2010). This minimization of effort may be reflected in the use of simpler strategies that result in reduced accuracy (Kool et al., 2010). This idea allows us to better understand why individuals don't always put forth their best effort and how they decide their level of control engagement. Additionally, recent evidence supports the notion that individuals will tend to avoid a more difficult task when the cognitive demand is higher than the expected reward (Kool et al., 2017). For example, in the demand-selection task (DST), individuals are asked to select between two actions, each requiring different levels of cognitive control engagement. Consistent with the law of less work, participants consistently preferred the path that required less mental effort (Kool et al., 2013).

The idea that control is costly leads to the question of *why*. Earlier research focused on the perspective of resource limits suggesting that cognitive control relies on the limited capacity system of working memory. Thus, the engagement of cognitive control may result in exhaustion of cognitive resources (Cohen, 2017). Some theories of resource limits argue that the resource is metabolic, leading to its limitation, though recent theories have turned away from this idea (Cohen, 2017). This allows us to further understand the nature of the cost of control, or effort. Furthermore, the opportunity cost perspective suggests that the cost of effort is dependent on rewards from other tasks that have been forgone to engage in the current one, suggesting that a cost-benefit analysis is conducted to monitor for more lucrative opportunities or actions. (Cohen, 2017; Kool et al., 2017; Kurzban et al., 2013).

The EVC framework integrates the idea that control is costly with the idea that actions are chosen to maximize profit. Specifically, the EVC framework suggests that the control system conducts a cost-benefit analysis in which the cost of expanding cognitive control is weighed against the potential rewards or benefits resulting from successful performance in a controlled task. This cost-benefit analysis results in a value called the "Expected Value of Control". The EVC framework indicates that an individual chooses how much cognitive control to engage at any given moment based on this analysis in an effort to maximize this value (Botvinik & Braver, 2015; Kool et al., 2017; Shenhav et al., 2013). If the costs of exerting cognitive control outweigh the expected benefits, an individual is less likely to engage in an effort-demanding task. In contrast, if the benefits outweigh the costs, an individual will be more willing to engage in the task (Yee & Braver, 2018).

The Neural Basis of Cognitive Control

Several brain regions have been identified as contributing to the execution of cognitive control. The prefrontal cortex (PFC) has been identified as one of the core structures heavily involved in cognitive control and working memory (Cohen, 2017; Shenhav et al., 2013). Theories of cognitive control have indicated that the involvement of cognitive control relies heavily on the control system's ability to adapt to the present task goals. This process involves the activation, maintenance, and updating of context representations in the PFC to fit the current task goals.

Furthermore, this process involves resisting interference from representations that are irrelevant to the goal (Cohen, 2017; Mecklinger et al., 2003).

The maintenance of task relevant context representations is thought to require working memory processes. Some accounts of working memory suggest that there is an organized structure of information (Cowan, 1998; Oberaur 2002, 2013). Specifically, contents in working memory can be stored in either an active part of long-term memory, the region of direct access, or the focus of attention (Oberaur, 2002). The activated part of long-term memory includes information in the background that can only be retrieved by forming associations with representations with the region of direct access, or the focus of attention (Oberaur, 2002). These representations serve to bias the processing of information so that the processing of task-relevant information is facilitated over competing information (Braver and Cohen, 2001). The PFC and the neurotransmitter dopamine (DA) have been found to play critical functions in the maintenance of these representations in working memory (Braver and Cohen, 2001; Yee and Braver, 2018). Primate studies have demonstrated that PFC neurons exhibit sustained activity during response-delay paradigms, providing evidence that the PFC neurons are involved in maintaining representations of a stimulus that will be needed for a delayed response (Bauer & Fuster, 1976; Braver and Cohen, 2001). Furthermore, these representations provide context for the system to respond appropriately during tasks, such as the Stroop task discussed previously, in which you must suppress certain responses (Braver and Cohen, 2001).

Dopamine has also been found to contribute to the mechanisms behind motivational influences on cognitive control. Specifically, PFC DA has been found to contribute to the stabilization of representations when a reward is present, identifying it as a potential substrate involved in the orienting effects of motivation (Yee and Braver, 2018). Striatal DA, on the other hand, has been thought to contribute to the flexible updating of these representations, demonstrating the different roles that DA can have in the successful maintenance of these representations (Cools and D'Esposito, 2011; Yee and Braver, 2018). Thus, DA plays a role in how motivation facilitates the encoding of task rules in the PFC resulting in enhanced control. Though this evidence provides insight about the mechanism in which motivation affects cognitive control, the exact nature of this interaction remains unclear (Yee and Braver, 2018).

Motivation

Intrinsic Motivation

As previously discussed, much of the research connecting the two concepts of motivation and cognitive control involves research in reward-based decision making, specifically, the orienting effects that a reward can have on cognitive and behavioral processes. These rewards can either be extrinsic (i.e. monetary rewards) or intrinsic (i.e. personal enjoyment in engaging in the activity) (Botvinik & Braver, 2015). Motivation has been at the center of cognitive research, however, many of the paradigms investigating behavioral responses to rewards have been conducted using extrinsic rewards. There is less research, however, investigating the direct impact of intrinsic motivation on cognitive control.

Intrinsic motivation refers to the tendency to pursue challenges and novel experiences that "extend and exercise one's capacity, to explore, and to learn" (Ryan and Deci, 2000, pg. 70). A person engages in an intrinsically motivating activity because they find it interesting and satisfying to do so (Domenico, 2017). In other words, the activity or task itself is rewarding. This contrasts with extrinsic motivation in which an individual engages in an activity because it results in a separable outcome such as an external reward, avoidance of punishment, or a valued outcome

(Deci et al., 1991; Domenico, 2017). Intrinsic motivation is essential for development in humans and other species, as it introduces them to novel and uncertain situations, allowing an organism to develop diverse skills that allow them to maneuver through future novel situations. In humans, it allows an individual to develop interests and their identity in a meaningful way (Ryan and Deci, 2012; Domenico, 2017). Intrinsic motivation has been shown to be especially important in education, as it promotes better quality learning, enhanced cognitive skills such as flexibility and engagement and greater persistence, among other advantages (Vansteenkiste et al., 2004, 2006; Walker et al. 2006).

The concept of intrinsic motivation is not new. In fact, the term was originally coined by Harlow in an effort to describe his observation in rhesus monkeys that continued to play with mechanical puzzles when an external reward was not involved (Harlow, 1950). He also found that the monkeys that were not given an external reward demonstrated more curiosity in exploration during playing compared to monkeys that were exposed to a reward (Harlow, 1950; Domenico, 2017). Furthermore, additional research in mammals has led to the discovery of a “seeking” system which has been considered to be equivalent to intrinsic motivation. The idea suggests that mammals are inborn with a system that energizes behavior towards exploratory activity. In humans, and more sophisticated animals, these “seeking” urges afford increased complexity in exploration due to our dexterity and sophisticated cognitive systems (Panksepp, 1998; Alcaro and Panksepp, 2011; Panksepp and Biven, 2012). As a result, it is thought that intrinsic motivation in humans may be an expansion of this “seeking” system and contributed to the development of the Self-Determination Theory (SDT; Ryan and Deci, 2000, 2017; Domenico, 2017).

Since then, researchers have attempted to develop a theory of intrinsic motivation to understand *why* individuals may engage in motivated behavior in the absence of an external reward. SDT has emerged as the central framework for studying and understanding intrinsic motivation. SDT theory suggests that an individual exhibits intrinsic motivation when their basic needs for competence and autonomy are met. Competence refers to an individual's feelings of adequacy and sense of growing mastery in challenging activities while autonomy refers to the extent that an individual senses that their behavior is self-organized as opposed to internally conflicted or externally coerced (Ryan and Deci 2000, 2017; Domenico, 2017).

Another theory of intrinsic motivation is called *Flow Theory* (Csikzentmihalyi, 1975). Flow theory particularly focuses on intrinsic motivation relating to task performance. The theory postulates that the experience of intrinsic motivation during task execution results from a balance between task difficulty and the participant's ability to meet task demands. Failure to meet this balance results either in a state of anxiety, if the task difficult exceeds the individual's ability or, on the opposite end of the spectrum, boredom, if the difficulty is much lower than the individual's ability to meet the demands (Nakamura & Csikszentmihalyi, 2005; Huskey et al, 2018)

Motivation is heavily involved in directing cognitive control. Several studies investigating the effects of motivation on cognitive control have used monetary incentives as an attempt to manipulate motivation. However, research investigating the role of intrinsic rewards in laboratory settings is sparse, perhaps due to the challenge of manipulating intrinsic rewards in these settings. Recent literature by Murayama et al. (2015) and Huskey and colleagues (2018) have made advances in this field. Murayama et al. for example, examined the effects of self-determined choice on task performance, in addition to the neural substrates involved in self-determined choice. Participants were asked to stop a stopwatch within a time window. The self-determined condition in this task allowed participants to choose a stopwatch they preferred, while a computer made the choice during the forced condition. They found that performance in a self-determined-choice condition resulted in significantly increased success rate (Murayama et al, 2015). Additionally, Huskey and colleagues successfully created a novel task manipulating intrinsic rewards in the laboratory setting based on *flow theory* and adapted the task for fMRI. During this task, they manipulated the balance of difficulty and the participants ability in a video game task. The researchers found enhanced connectivity between the nucleus accumbens and the Dorso-Lateral PFC (DLPFC)—two structures involved in calculating the EVC and reward anticipation— when there is a balance between task difficulty and (Botvinik, Huffstetler, & McGuire, 2009;Huskey et al., 2018; Kool, McGuire, & Botvinik, 2013). These recent advances in studying intrinsic motivation demonstrates that literature in this field, particularly the mechanisms involved in something that is intrinsically rewarding, is rapidly advancing.

Academic Achievement motivation

Intrinsic academic motivation, also known as academic achievement motivation, is a specific type of motivation and has been defined as the desire to strive for success or successful performance (Singh, 2011). This specific type of motivation has been correlated with better educational outcomes including better performance, quality of learning, and an increase in persistence and effort in academics (Deci et al, 1996; Ryan and Deci, 2000; Mizuno et al, 2008; Domenico, 2017). Additionally, achievement motivation has been shown to predict choices in occupation, subjective well-being, life goals, and learning strategies (Karaman &Watson, 2017; Ahmad & Rana, 2012; Bakhtiarvand, Ahmadian, Delrooz, & Farahani, 2011; Rosa & Bernardo, 2013; Guns, Richardson, & Watt, 2012; Li, Lan, & Ju, 2015).

The extent to which an individual finds learning intrinsically rewarding has been a focus in the area of education as it is related to several outcomes in a student's academic and professional career. Researchers have been particularly interested in investigating whether or not individuals that find academics intrinsically rewarding show similar activation patterns in the outer region of the basal ganglia, the putamen—a region involved in reward-based learning—as those in research conducted using extrinsic rewards. (Mizuno et al, 2008; Schmidt et al., 2012). This would provide further insight about the processes of intrinsic rewards and whether or not those may differ from extrinsic rewards. Research by Mizuno and colleagues (2008) investigated the neural substrates of motivation by comparing both monetary and academic rewards during a working memory updating task of increasing difficulty, the n-back task. Additionally, participants completed a scale of academic achievement motivation. The results showed that activation of the putamen occurred in both reward conditions. Additionally, individuals that reported higher self-reported academic motivation exhibited greater BOLD signals within the putamen. This demonstrates an intrinsic motivation results in similar activation patterns as extrinsic rewards (Mizuno et al., 2008).

Based on the discussion on motivation and cognitive control, one could propose that individuals that are intrinsically motivated to learn or achieve may be more willing to engage in cognitively effortful tasks despite the lack of a reward. In the context of the EVC framework, motivation may act as the factor that offsets the cost of exerting control, making an effortful task more appealing. This, in turn, could explain why individuals with higher academic motivation may experience increased effort and persistence (Deci et al, 1996; Ryan and Deci, 2000; Domenico, 2017).

The Interactions of Effort and Motivation in Cognitive Control

As the EVC framework suggests, effort and motivation are important factors contributing to the allocation of resources that make goal attainment possible. Though closely related processes, it is important to define and distinguish these processes and discuss their individual roles in the allocation of cognitive control. Recall that effort is defined as the *intensity* of an activity and is considered the cost of expending cognitive control in the EVC framework. The EVC framework suggests that effort may increase with the amount of control being allocated. (Inzlicht et. al, 2018; Kool et al, 2017).

Motivation, additionally, plays an important role in directing cognitive control mechanisms and can be defined as the orienting effect that a reward can have on cognitive resources (Botvinik and Braver, 2015). This definition of motivation raises the question of how a reward can guide cognitive mechanisms in the direction of a goal and indeed, much of the research relating motivation and cognitive control lies in two different areas of research: the areas of reward-based decision making and cognitive control, each focusing on its own network of neuroanatomical structures (Botvinik & Braver, 2015). Thus, research attempting to link cognitive control and motivation is centered on how these systems interact (Botvinik and Braver, 2015).

Research in this area has shown that cognitive control and performance are enhanced when a reward is present (Botvinik and Braver, 2015). For example, researchers have observed enhanced response inhibition in stop-signal tasks during a “motivated” condition where participants were rewarded for correct *go* responses (Padmala & Pessoa, 2010). Furthermore, because effort is computed as a cost, it should follow that appropriate incentives will increase willingness to engage in cognitive control. This was exactly what was found in the DST paradigm discussed previously. Recall that this paradigm involves the participants making a choice between two actions, each demanding different levels of cognitive control. In the no-incentive condition discussed previously, it was found that individuals consistently chose the action that required less cognitive control, and thus, less mental effort. However, when monetary incentives were added, the avoidance to engage in the more effortful tasks vanished (Kool et al, 2017).

These findings exemplify how rewards can affect the allocation of control. Additionally, it provides a basis to our understanding of how reward-based decision making may be an essential aspect contributing to the motivated nature of cognitive control (Botvinik and Braver, 2015; Shenhav et. al, 2013). Specifically, motivation may drive or energize behavior towards a certain goal by determining the direction or goal and the intensity in which the goal is pursued (Inzlicht et. al, 2018). In the context of the EVC framework, Motivation may be the factor that offsets the cost of control and increases the subjective value of benefits that result from enhanced control, making the exertion of effort more appealing to an individual. (Yee & Braver, 2018).

Self-Esteem

As discussed in the previous section, both cognitive control and motivation have important implications to academic performance in that cognitive control allows resources to be allocated so behavior can adapt appropriately to the task or goal at hand and motivation may direct the intensity in which the task is pursued by increasing the EVC (Cohen, 2017; Inzlicht et. al, 2018; Yee and Braver, 2018). Other factors such as individual differences, emotional states, and clinical disorders, have been shown to influence both motivation and cognitive control. For example, individuals with depression have been shown to have deficits in both cognitive control and motivation in addition to exhibiting low self-esteem (Phillips & Hine, 2016; Harvey et al, 2005; Jones, Siegle, & Mandell, 2015)

Self-esteem is one of the oldest and most widely studied concepts in research. The first description of self-esteem dates back to 1890, when William James defined it as a sense of positive regard towards oneself that develops as one meets self-relevant goals (Ditzfeld & Showers, 2013). This definition has been maintained and agreed upon throughout the years, with researchers creating additions. For example, Morris Rosenberg added that self-esteem also includes feelings of self-respect and self-acceptance (Rosenberg, 1965).

Self-esteem varies among individuals, with some individuals exhibiting a favorable view of the self (high self-esteem), while other individuals may exhibit negative or uncertain views of the self (low self-esteem). These views of oneself begin in early childhood and are consistently developed and regulated across the lifespan, following specific patterns with age. Specifically, self-esteem tends to be higher in childhood and drops beginning adolescence. From then on, self-esteem has a tendency to increase throughout adulthood with a peak around age 60. It then tends to decline in older adulthood (Erol and Orth, 2011; Orth et al., 2012; Ditzfeld & Showers, 2013). These age-related changes have been attributed to life achievements.

More specifically, individuals begin to gain an understanding of themselves in adolescence while concurrently facing changes in their physical, mental, and social identities; for example, body changes in puberty and more challenging academic work, contributing to this decrease in adolescence (Baldwin and Hoffmann, 2002). With an increase in age, individuals are more likely to have increased relationship and job satisfaction as well as increased and stable salaries and higher positions, contributing to the rise in self-esteem throughout adulthood (Orth, Robins and Widaman, 2012). As higher self-esteem is positively correlated with these important life outcomes, the decrease observed in older adults can be attributed to these as well, as they retire, tend to have less social support, and a decline in both physical and mental health (Orth, Robins, And Widaman, 2012; Tavares et al, 2016). Though age-related trends have been found to occur, it is typically the case that overall self-esteem, or global self-esteem remains reasonably consistent throughout life (Ditzfeld & Showers, 2013; Rosenberg, 1965). However, immediate and context-specific self-esteem, or state self-esteem tends to fluctuate.

Recent research has suggested that it is not only important to look at global self-esteem, but to consider specific areas that an individual values, as these areas may differ across individuals and reflect how their self-esteem is maintained and affected (Ditzfeld & Showers, 2013). These domains are called contingencies of self-worth (CSWs) and refer to the areas in which an individual is invested and motivated to prove to themselves and others that they possess specific qualities (Park and Crocker, 2013; James 1890). This model also suggests that individuals are motivated to pursue self-esteem in these specific domains where they place their sense of self-worth. This can in turn, be reflected in the goals and activities that an individual chooses to engage in. For example, research has shown that women placing their self-worth on physical attractiveness were found to be more likely to join sororities (Crocker et al.,2003). Other CSWs can include academic competence, romantic relationships, and obtaining the approval of others (Ditzfeld & Showers, 2013; Park and Crocker, 2013). Consideration of the domains in which individuals base their self-worth also allow us to predict fluctuations in state self-esteem (Park and Crocker, 2013). For example, an individual that bases their self-worth on physical appearance may experience an immediate increase in self-esteem following compliments on their appearance. Similarly, this same individual may experience significant drops following criticisms on appearance. This research shows us the importance of looking at CSWs in addition to global self-esteem.

While individuals vary in both global self-esteem and CSWs, there exist patterns in self-esteem among groups. For example, it is well-known that there are significant differences in reported self-esteem among women compared to men (Ditzfeld & Showers, 2013; Robins et al, 2002). This may, in fact be the largest difference and follows specific trajectory. In childhood, for example, boys and girls report relatively comparable scores. However, the large gender difference in self-esteem seems to begin in adolescence when boys begin reporting significantly higher selfesteems. This difference continues throughout adulthood, until older adulthood, when men's self-esteem tends to drop off and again become level with that of women's self-esteem (Robins et al., 2002). These differences have been thought to occur due to differential treatment of girls and boys in classroom settings, such as teachers paying increased attention towards boys. This sexism does not stop in grade school, but even follows a woman into professional settings (Sadker & Sadker, 1994). Furthermore, women in leadership roles tend to experience more challenges than their male counterparts. Rudamen and Glick (2001) found that agentic women were rated as less socially skilled and likeable than a man that presented himself the same way, demonstrating how societal gender constructs contribute to this lower self-esteem observed in women that we see throughout the lifespan (Ditzfeld & Showers, 2013; Robins et al, 2002; Sadker & Sadker, 1994;).

In addition to gender differences in self-esteem, specific groups have been found to have lower self-esteem as well. Specifically, overweight individuals, individuals with physical abnormalities, and individuals with learning disabilities and language impairments have been shown to have lower self-esteem (Cosden, Brown, and Elliot, 2002; Heyman, 1990; Marton, Abramoff & Rosenzweig, 2005; Wadman, Durkin, & Conti-Ramsden, 2008). Furthermore, individuals with psychiatric disorders such as anxiety and depression typically report lower self-esteem scores compared to their peers (Sowislo & Orth, 2013). Furthermore, self-esteem has been found to be a potential risk factor for depression, anxiety, eating disorders, among other mental health disorders (Neumark-Sztainer et al., 2007; Bosacki et al, 2007). Additionally, it has been found to be related to violent behavior, substance use, and long-term outcomes such as financial difficulties and poor physical health (Mann et al, 2004; McClure et al, 2010; Phillips & Hine, 2016; Waddell, 2006; Trzesniewski, 2006). Thus, it is important to identify these individuals with low self-esteem in order to improve interventions and promote better life outcomes.

Self-esteem plays an important role in developing the self and disseminating information about the self to the environment. Additionally, self-esteem may play a protective function against threats including rejection and failure. Specifically, high self-esteem offers resilience following negative and stressful experiences, whereas low self-esteem may increase susceptibility to the effects of stress (Brown, 2010; Ditzfeld & Showers, 2013). Given its protective function, it is no surprise that self-esteem has been shown to be related with various life-outcomes such as self-reported happiness, life satisfaction, psychopathology, physical health, interpersonal relationships, and academic outcomes (Diener & Diener, 1995; Ditzfeld & Showers, 2013; Furnham & Cheng, 2000; O'Brien, Bartoletti, & Leitzel).

Self-esteem has also been found to relate to academic outcomes. The protective function of self-esteem may particularly help us understand why we see this relationship, and how self-esteem is important in the areas of learning and education. Individuals with higher self-esteem may apply more effort and persevere despite occasional failure in comparison with individuals with lower self-esteem (Ditzfeld & Showers, 2013). However, though the relation between self-esteem and academic achievement is well known, research is mixed as to whether self-esteem contributes to academic achievement or whether it is simply a consequence of past experiences with academic achievement (Baumeister et. al, 2003; Ditzfeld & Showers, 2013). Research has supported the notion that self-esteem does, in fact, contribute to academic achievement. Programs with the goal to increase academic self-worth have been shown to lead to improvements in overall performance and grades. This demonstrates that improving beliefs about one's abilities in addition to promoting skills and strategies supports better outcomes (Ditzfeld & Showers, 2013; O-Mara et al, 2006).

Summary of the Literature

In the previous discussion, I reviewed three concepts that have been shown to significantly contribute to academic performance and achievement, as well as other life outcomes: cognitive control, motivation, and self-esteem. As the literature shows, these concepts are interrelated. Specifically, cognitive control is the supervisory system that coordinates and drives subordinate processes, such as working memory, attention, inhibition towards a goal (Niendam et al, 2012; Shenhav et al, 2013). In this review, I focused on the EVC framework (Shenhav et al., 2013). This framework suggests that the direction and intensity of control engagement is dependent on a cost-benefit analysis that weighs the cost of effort against the benefits of expanding effort (Shenhav et al., 2013).

Since motivational factors play a large role in determining the direction and intensity (effort) that goals are pursued, they are considered immensely important in the area of education. Specifically, the extent to which an individual finds academics intrinsically motivating positively impacts the amount of effort they are willing to exert and improves performance (Inzlicht et. Al, 2018; Deci et al, 1996; Ryan and Deci, 2000; Mizuno et al, 2008; Domenico, 2017).

Given the importance of cognitive and motivational factors and the tendency for them to vary among individuals, it is imperative to look at other variables that may contribute to their variability. Self-esteem has been a widely researched topic in several areas and has also been shown to be related and to contribute to both motivation and academic achievement (Baumeister et al., 2003; Ditzfeld & Showers, 2013) . More specifically, the importance of looking at the domains in which individuals base their self-esteem, in addition to global self-esteem may better help us understand variability across populations (Park and Crocker, 2013; James 1890). Though many studies in the area of self-esteem and motivation have found that they contribute to academic success, no studies known to date have looked at if they are directly related to cognitive control performance and willingness to perform well on a task of increasing difficulty.

The Current Study

Study Goals:

The goals for the present study were three-fold. The first goal was to examine if there is a correlation between self-esteem and performance on an increasingly difficult task of working memory updating, the n-back task. The n-back task was chosen as it requires an individual to update content in their working memory while subsequently processing incoming information. Cognitive control relies on this function and WM updating reflects the adaptability of the control system (Cohen, 2017; Wadhera, Campanelli, Marton, 2018; Waksom et al., 2014). The second goal was to examine if there was a correlation between self-reported scores of academic motivation and performance on the n-back task. Lastly, the third goal was to examine if there was a correlation between self-esteem and reports of academic motivation.

Hypothesis:

It was hypothesized that (a) a correlation between self-esteem and performance on the n-back task such that higher global self-esteem, as well as state self-esteem will be related to shorter reaction times and increased accuracy (b) Due to the importance of motivation in the allocation of cognitive resources and recruitment of cognitive control, it was hypothesized that academic achievement motivation predicts performance on the n-back task in such a way that increased self-reported academic achievement motivation would correlate with shorter reaction times and increased accuracy in all conditions. (c) Lastly, an impact of set-size and probe type on reaction time and accuracy was anticipated in all participants, such that an increase in set size would result in longer reaction times and in a decrease in accuracy. Furthermore, individuals would also have more difficulty on proactive interference items, as the continuous updating of representations required in this task will prevent strong binding of task items to their contexts, making them more susceptible to interference (Oberauer, 2009; Szmalec et al., 2011).

Methods

Participants

Participants included 13 adults (7 Females, 6 Males) between the ages of 21-31, with one participant aged 50. This age range was selected to consider all potential age ranges in The Graduate Center student community. Age was used as a control variable to control for age related differences. The sample included 10 monolingual and 3 bilingual participants. Among the bilingual participants, additional languages spoken included Korean, Chinese, Hindi, and Kashmiri. English was the first language for 11 out of the 13 participants and all participants were proficient in English.

Participants had no known language disorders. Expressive and receptive language skills were measured using the Clinical Evaluation of Language Fundamentals Screening Test, 3rd edition (CELF-3; Semel et al., 1996). One of the inclusion criteria was a minimum score of 29 on this test. One participant scored below the criterion score due to English as a second language. Despite this, the participant was still included in the sample as they are enrolled in a PhD program, indicating that the individual is proficient in the English. Additionally, participants' IQs were measured by the *Test of Nonverbal Intelligence,4th edition* (TONI-4; Brown et al, 2010) and were within the "Average" (25 - 75 percentiles) or "Above Average" (76 - 91 percentiles) ranges. All participants additionally completed a hearing screening and were within normal limits. Specifically, they responded to frequencies at 500-4000 Hz at 20 db. Participants were primarily recruited within The Graduate Center-CUNY community and other universities throughout the New York City Metropolitan Area. Ten participants were currently enrolled in an undergraduate (n=1) or graduate program (n=9). Three participants were not currently enrolled in any higher education program, but had obtained bachelor's degrees (16 years of education).

Screening Tools:

Clinical Evaluation of Language Fundamentals-Third Edition (CELF-3; Semel et al, 1996)

The Clinical Evaluation of Language Fundamentals-Third Edition Screening Test (CELF-3 *Screening Test;* Semel et al, 1996) is a clinical tool designed to screen to identify individuals that may need referral for further language assessment. The CELF-3 Screening test consists of 45 items and not all items are administered to all participants, depending on age. Adults are only administered items 10-45, consisting of a total of 36 items. The criterion score for up to age 21:11 is 29, meaning that if an individual meets this score, they pass and do not need to be referred for further language testing. Participants completed this screening tool to screen for language disorders, as these disorders have been shown to impact working memory processes (Archibald & Gathercole, 2006; Im-Bolter, Johnson, & Pascual-Leone, 2006)) All participants but one in the present study met the criterion score for age 21:11 (See Table 1 for participant demographics).

Test of Nonverbal Intelligence-Fourth Edition (TONI-4; Brown et al, 2010)

The Test of Nonverbal Intelligence-Fourth Edition (TONI-4; Brown et al, 2010) is an individual assessment which assesses both fluid and general intelligence without the confounding effects of motor or linguistic skills. More specifically, the test measures abstract reasoning and problem solving and is designed for ages 6:00 to 89:11. The IQ test attempts to decrease cultural and language factors that commonly influence intelligence tests. All participants scored within normal range for their age (See Table 1).

Table 1: Participant Demographics

	Age (in years)	CELF-3 Criterion	TONI-4 IQ
Mean	27.744	33.666	105
SD	7.237	1.614	8.689
Min	22	23	91
Max	50.25	35	119

Self Esteem Measures:

The Rosenberg Self-Esteem Scale (Rosenberg, 1965)

The Rosenberg Self-Esteem Scale (RSES, Rosenberg, 1965) is a 10-item self-report measure of global self-esteem in an individual and remains one of the most widely used measures of self-esteem (Schmitt & Allik, 2005). Individuals are instructed to respond to an item according to their "general" feelings about themselves. Some examples of items included in this measure are "I feel that I am a person of worth, at least on an equal plane with others" and "I am able to do things as well as most people" (see Appendix A for full measure). The scale is considered to be unidimensional and participants respond according to a 4-point Likert scale format ranging from *strongly agree* to *strongly disagree.*

The State Self-Esteem Scale (Heatherton and Polivy, 1991)

Though self-esteem has been thought to be relatively stable, research in the area has demonstrated that are momentary fluctuations in self-esteem. The State Self Esteem Scale (SSES; Heatherton and Polivy, 1991) is a continuous measure of an individual's self-esteem at the moment in which it is taken as there may be minor fluctuations in self-esteem as discussed in the literature review. The scale consists of 20 items and three categories embodying 3 different components of self-esteem: performance, social and appearance self-esteem. Only the questions pertaining to performance and social self-esteem were administered in the present study. Examples of items in this scale include "I feel confident about my abilities" (performance item) and "I am worried about whether I am regarded as a success or failure" (social item). Participants respond on a 5-point scale (1=not at all, 2 = a little bit 3=somewhat, 4=very much, 5=extremely; See Appendix B for full measure).

Motivation Measure:

Waugh's Scale of Academic Motivation (Waugh, 2002)

Waugh's Scale of Academic Motivation is a unidimensional scale of motivation containing attitude items which are linked to behavior items. The questions are designed to reveal a student's academic motivation. The motivation items are conceptualized based on 3 first order orientations which are operationally defined by second order orientation that are found to contribute to them. The three first order orientations were found to contribute to the variable of motivation and consist of: striving for excellence, desire to learn, and personal incentives. The orientations found to contribute to Striving for Excellence include standards, goals, tasks, effort, and values. The orientations found to contribute to desire to learn include interest, learning from others, and responsibility for learning. Lastly, the orientations found to contribute to personal incentives were intrinsic and social rewards (Waugh, 2002).

The scale consists of 24 items in each response set (Motivation and behavior items). As previously stated, each motivation item is linked to a corresponding learning behavior. The response sets included *What I aim for* (motivation items) and *What I actually do* (behavior items). Participants were given an item such as “I make strong demands on myself to achieve in academic work” and asked to provide a response category for each response set. Response categories include *None or only one of my subjects, In some, though not most of my subjects, In most, though not all of my subjects* and *In all or nearly all of my subjects.* Participant scores range from 0-72 for each response set, with lower numbers pertaining to lower motivation scores (Waugh, 2002; Mizuno, 2008; See Appendix C for full measure).

Letter N-Back Task

As indicated in the literature review, cognitive control relies on working memory system to maintain and update context representations (Cohen, 2017; Mecklinger et al., 2003). The N-back task is a valid task of working memory updating (Jaeggi et al, 2010). In the letter N-back task, participants are presented with a stream of letters, one at a time on the computer screen (See **Figures 1 and 2** for a demonstration of the task). Participants are asked to make a decision regarding whether or not the current letter on the screen matches the letter that came “n” items before. The task requires the individual to continuously update contents in working memory as they process incoming information.

Each session of the n-back included a minimum of one practice block in which participants were required to score > .6 accuracy to move on to the task. Participants completed a 0-back for baseline. Participants then performed the task with manipulations in set size (1-back and 2-back), and lures (No interference vs. proactive interference). Each block included 24+n trials and each condition had 3 blocks, resulting in 72 trials for the 0-back, 75 trials for 1-back, and 78 trials for 2-back.

Procedure

Participants arrived at the Cognition and Language Lab located inside *The Graduate Center, City University of New York (CUNY)* and were tested individually. Participants were consented and brought into a quiet testing room where they completed a hearing screening, *The Test of Non-verbal Intelligence-4* (TONI-4; Brown et al, 2010) and the *Clinical Evaluation of Language Fundamentals Screening Test-Third Edition* (CELF-3 screening; Semel et. al, 1996). Participants were then taken to another lab room where they completed the *Rosenberg Self-Esteem Scale* (Rosenberg, 1965), *The State Self-Esteem* Scale (Performance and social scales; Heatherton and Polivy, 1991) and *Waugh's Scale of Academic Motivation* (Waugh, 2002). Participants were then taken into a computer room and completed the *Letter N-back task*. Each session of the n-back lasted around 10-15 minutes with the included practice block.

For the Letter N-back task, participants came into the lab and were asked to sit comfortably in a chair in front of a computer screen with their feet on a footrest. The set up was consistent with the use of the Tobii TX300 (Tobii Technology AB, Sweden. Participants sat at a distance of 60-65 cm from the screen and asked to sit comfortably in front of the screen. Participants were then asked to judge whether the present letter on the screen matched the letter presented "n" items before it. In this case, participants judged whether the letter on the screen matched the item presented 1 or 2 items prior. Responses were indicated via button press whether to accept or reject an item. Participants pressed the "GREEN" button to accept the item, or "RED" button to reject the item.

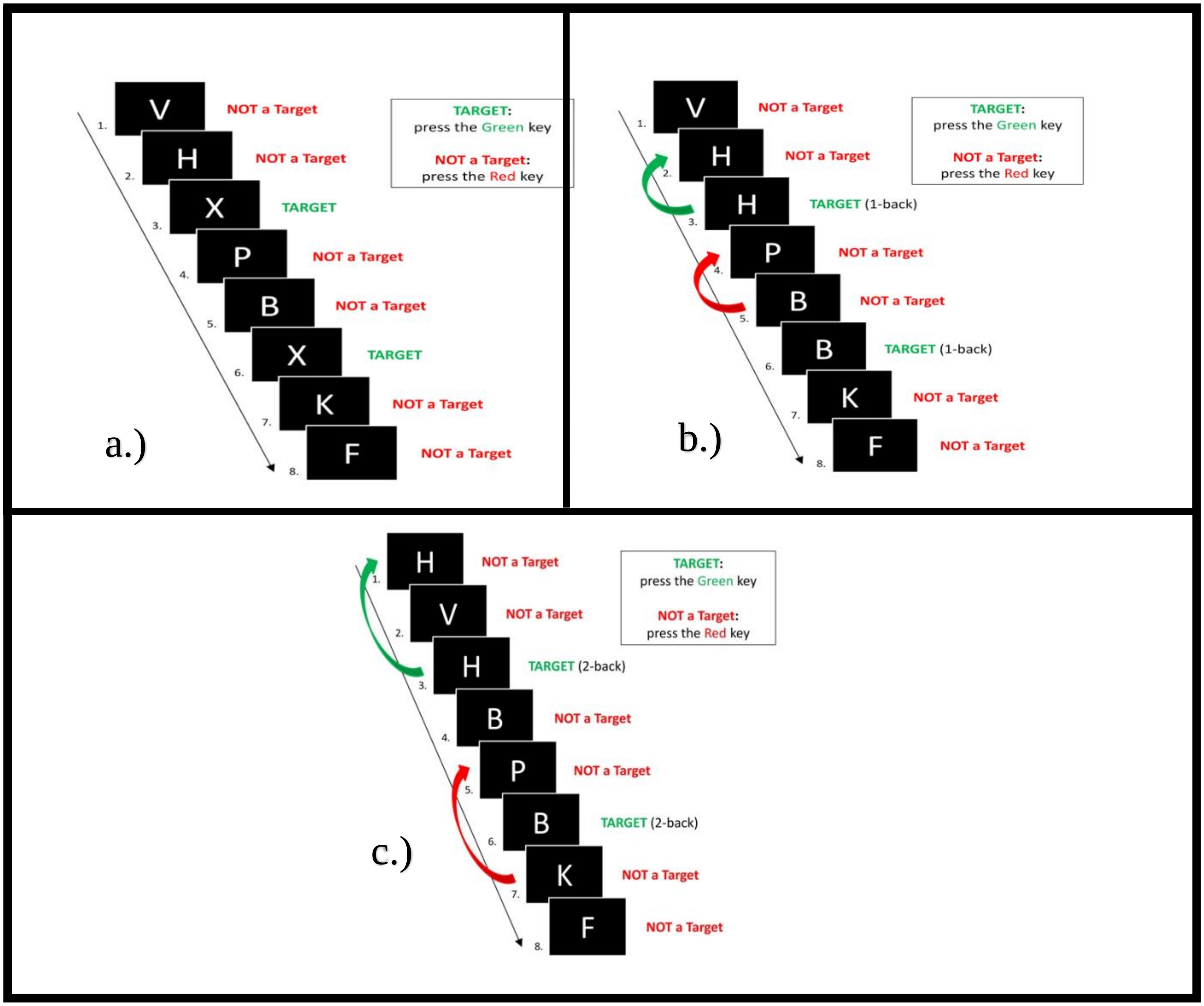


Figure 1. **N-Back, No Interference (0-2 Back)** N-back task stimuli (No Interference). Participants were instructed to press the green key when the letter presented on the screen matched the letter presented "N" items ago; 0-back was performed as a baseline; a.) 0-back, b) 1-back No Interference c). 2-back No Interference

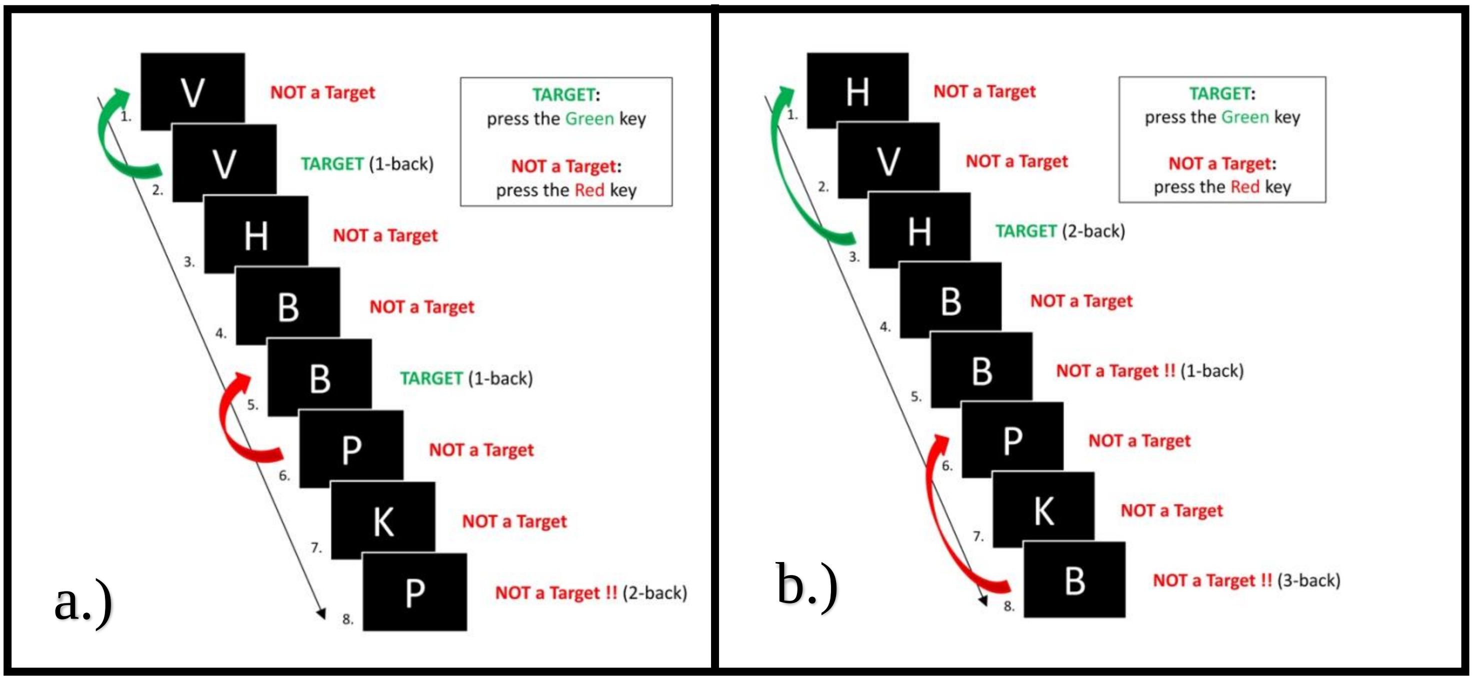


Figure 2. Figure 1. **N-Back Proactive Interference (1-2 Back)** N-back task stimuli (Proactive Interference). Participants were instructed to press the green key when the letter presented on the screen matched the letter presented "N" items ago; a.) 1-back Proactive Interference b) 2-back Proactive Interference

Data Analysis

In order to examine the relationship of self-esteem and motivation on n-back performance, a fixed effects model was used. All data were completed using RStudio (RStudio Team, 2015). Data was first cleaned and filtered according to my variables of interest. Data was inspected for validity, accuracy, outliers, normal distribution and homeodasticity. Reaction time was not normally distributed, as expected with this variable, and was log transformed. There were two dependent variables used to analyze data from the n-back task: percent accuracy and reaction time. Each self-report was included as an independent variable. These variables were examined using fixed effects regression, which assumes constancy in the independent variables and allows us to examine its average relationship on the dependent variables. I chose this simpler model, as my main interest was looking at the overall effects of set size and probe type on n-back performance and how these differ based on self-reported scores of self-esteem and motivation. As stated above, though most of the participants in this study were between the ages of 21-31, there was one participant that was enrolled in a graduate program but was above that age range. To account for this participant, age was included as a control variable.

Results

Reaction Time

As expected, there was a significant effect of set size and probe types on response times across all conditions ($p < .001$; **Table 2**). Participants were slower in the 2-back conditions and showed the longest response times on proactive interference conditions. Responses to target items were significantly slower compared to new items ($p<.001$; **Table 2**), and the longest reaction times resulted from proactive interference items.

There was a significant negative relationship between self-reported global self-esteem and reaction time across all task conditions ($p<.001$) such that higher self-esteem predicted quicker reaction times. This occurred in all task conditions (**Figure 3**). Interestingly, there was also a significant relationship ($p<.001$) between state self-esteem and reaction time. However, unlike the negative relationship observed with global self-esteem, state self-esteem seemed to have a positive relationship with reaction time, such that individuals with higher state self-esteem—that is, their reported self-esteem in the moment of the self-report—showed longer response times compared to those with lower reported state self-esteem (**Figure 4)**.

Lastly, I examined the relationship of motivation scores on reaction times. Similar to state self-esteem, academic motivation had a significant positive correlation ($p<.001$) with response times, such that higher academic motivation scores predicted longer response times across all tasks and probe types (**Figure 5**).

Accuracy

Unlike the reaction time analysis, there was not a mean difference between new, proactive interference, and target item types on any of the task conditions, as indicated by the heavy overlaps in **Figures 6-8.** Accuracy on all tasks except for the 2-back proactive remained above 90% for all individuals. However, accuracy was impacted on the 2-back proactive task. This demonstrates a significant effect of set-size ($p<.001$), though not probe type across tasks.

Overall, there was a significant positive relationship between global self-esteem and accuracy in that the higher reported self-esteem predicted increased accuracy **(Figure 8)**.

Additionally, there was also a significant positive relationship between state self-esteem and accuracy such that individuals reporting a higher state self-esteem showed higher accuracies compared to those with lower self-esteem (**Figure 7**). Lastly, and of interest, there was no significant relationship found between motivation and accuracy (**Figure 8**).

Response Time Results

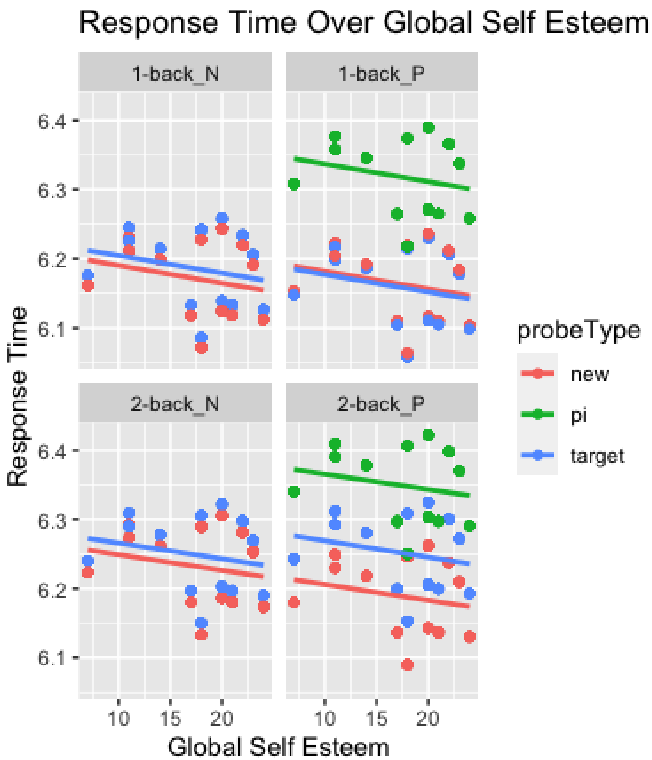
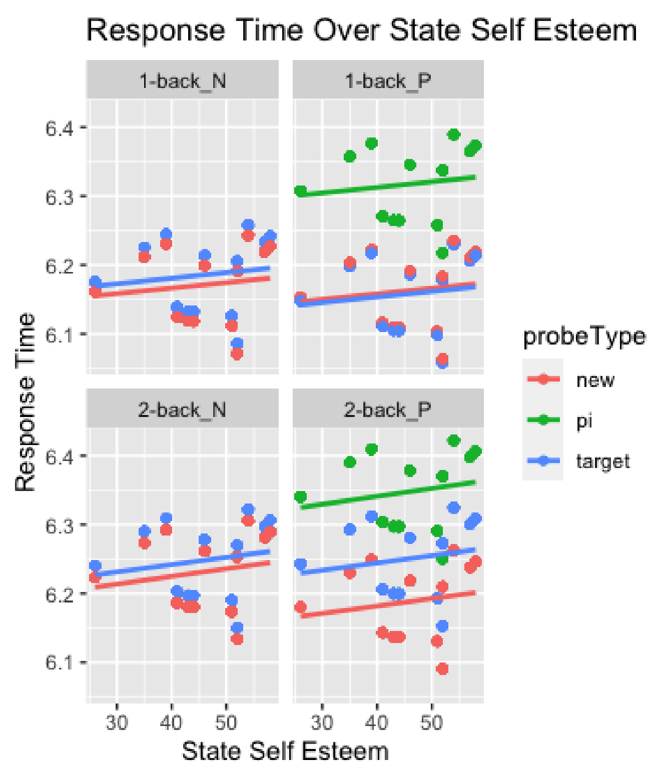


Figure 3: Response Time vs. Global Self-Esteem: This graph indicates the overall relationship of Global Self-Esteem and response time in each task condition (1-back Neutral and Proactive and 2-back Neutral and Proactive).

*Note that Response Time is reported as the log of Response Time

Figure 4: Response Time vs. State Self-Esteem: This graph indicates the overall relationship of State Self-Esteem and response time in each task condition (1-back Neutral and Proactive and 2-back Neutral and Proactive).

*Note that Response Time is reported as the log of Response Time



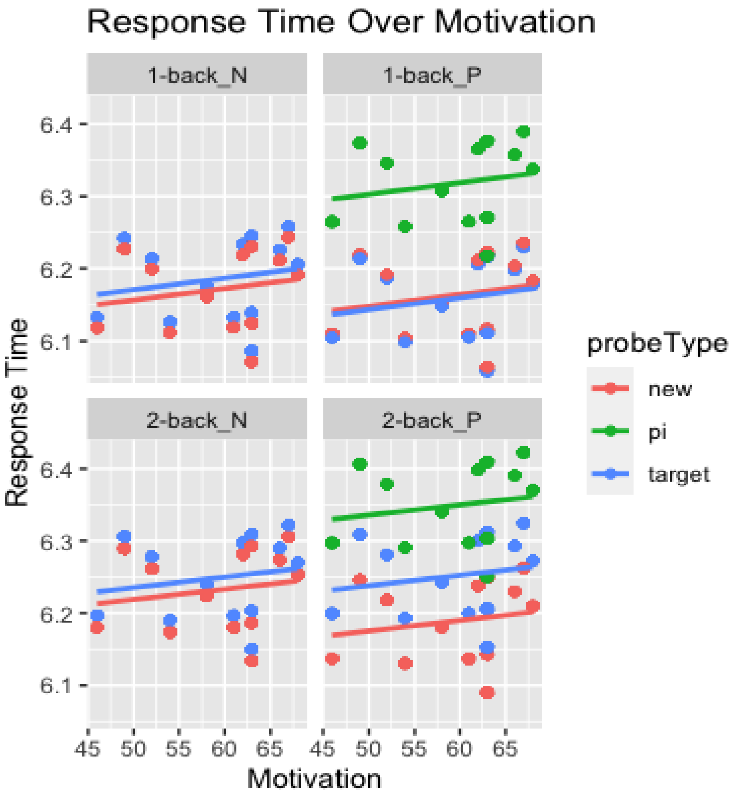


Figure 5: Response Time vs. Motivation: This graph indicates the overall relationship of Academic motivation and response time in each condition (1-back Neutral and Proactive and 2-back Neutral and Proactive).

*Note that Response Time is reported as the log of Response Time

Table 2: Results of Reaction Time (RT) Model

Fixed Effects	Estimate	SE	t	p
Intercept	5.990	0.058	102.824	<.001*
New probe	-0.160	0.025	-6.523	<.001*
1-back Neutral	-0.067	0.024	-2.748	0.006
Target Probe	-0.098	0.025	-3.966	<.001*
1-back Proactive	-0.033	0.024	-1.333	0.182
2-back Neutral	-0.003	0.025	-0.114	0.909
Waugh's Motivation	0.004	0.001	5.367	<.001*
Rosenberg Self-Esteem	-0.014	0.002	-8.231	<.001*
State Self-Esteem	0.008	0.001	8.414	<.001*
Age	-0.167	0.011	-8.483	<.001*
New probe*1-back N	0.048	0.032	1.501	0.133
New probe*1-back P	0.005	0.034	0.162	0.871
Target probe*1-back P	-0.062	0.034	1.793	0.073
New probe*2-back N	0.046	0.032	1.424	0.155

Accuracy Results

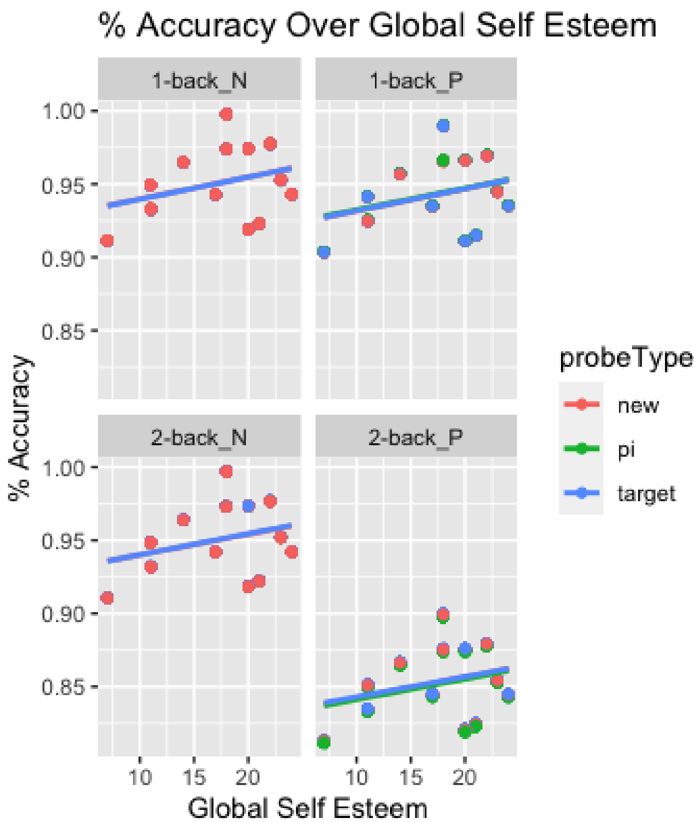


Figure 6: Percent Accuracy vs. Global Self-Esteem: This graph indicates the overall relationship of global self-esteem and percent accuracy on all conditions (1-back Neutral and Proactive and 2-back Neutral and Proactive).

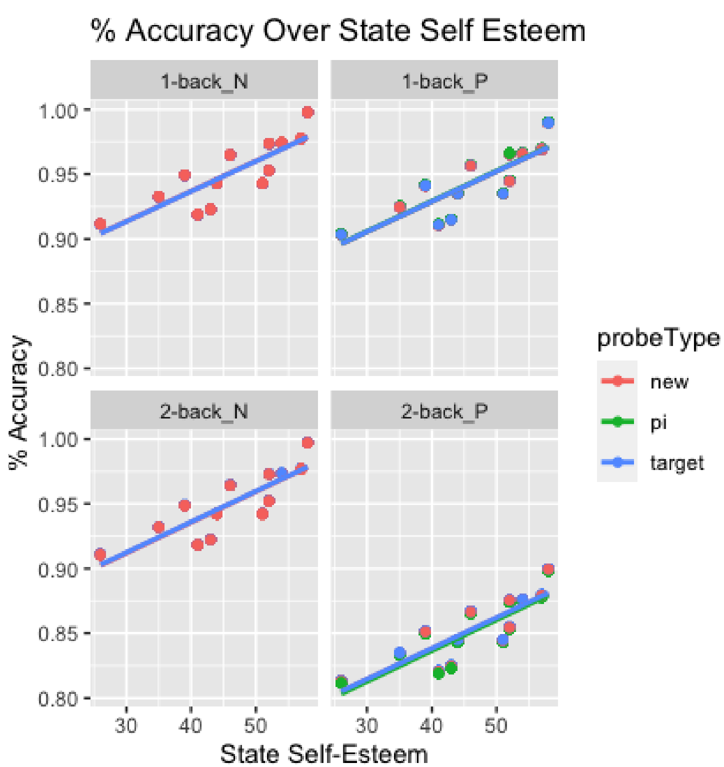


Figure 7: Percent Accuracy vs. State Self-Esteem: This graph indicates the overall relationship of state self-esteem and percent accuracy on all conditions (1-back Neutral and Proactive and 2-back Neutral and Proactive).

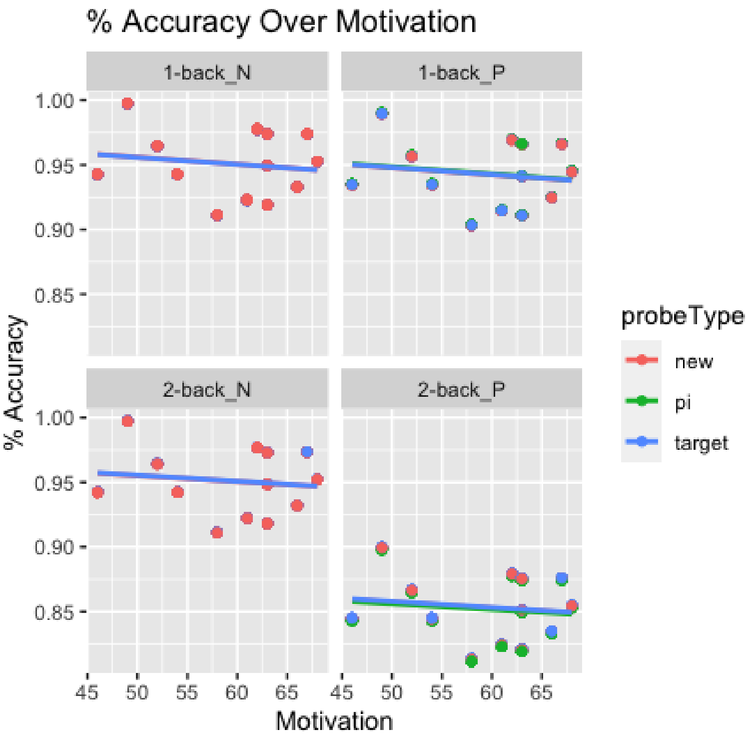


Figure 8: Percent Accuracy vs. Motivation: This graph indicates the overall relationship of motivation and percent accuracy on all conditions (1-back Neutral and Proactive and 2-back Neutral and Proactive).

Table 3: Results of Accuracy Model

Fixed Effects	Estimate	SE	t	p
Intercept	0.754	0.009	80.967	<.001*
New probe	0.001	0.004	0.362	0.717
1-back Neutral	0.098	0.004	25.145	<.001
Target Probe	0.002	0.004	0.443	0.658
1-back Proactive	0.092	0.004	23.623	<.001*
2-back Neutral	0.097	0.004	24.804	<.001*
Waugh's Motivation	-0.000	0.000	-1.760	0.078
Rosenberg Self-Esteem	-0.004	0.000	-13.747	<.001*
State Self-Esteem	0.004	0.000	24.644	<.001*
Age	0.035	0.003	11.232	<.001*
New probe*1-back N	0.000	0.005	0.084	0.933
New probe*1-back P	-0.002	0.006	-0.341	0.733
Target probe*1-back P	-0.002	0.034	-0.375	0.707
New probe*2-back N	0.000	0.005	0.023	0.155

Discussion

The present study aimed to explore the relationship between both self-esteem and academic motivation on cognitive control. The extent to which a student values learning and is intrinsically motivated to succeed academically may be associated with pursuit of higher education, higher paying occupations, and lower drop-out rates (Fan & Wolters, 2014; Hardre 2012). The EVC framework offers explanations as to how individuals decide to engage cognitive control in an effortful task and the manner in which cognitive resources are directed to accomplish a task (Shenhav et al, 2013). Furthermore, several factors shape and influence motivation and thus, may also influence cognitive control. These factors include beliefs about competence, autonomy, interest, experiences, self-esteem and developmental, social, and emotional challenges (Ditzfeld & Showers, 2013; Ryan ad Deci 2000, 2017; Schwann, 2016; Usher & Kober 2012). In the present study, we focused on global and state self-esteem and its relation to both motivation and cognitive control.

There are four main findings from this experiment. First, set size in the n-back task predicted both response time and accuracy, however, there was no difference across the different probe types when looking at accuracy. Participants performed at high accuracy with each probe type across conditions. Second, global self-esteem had a significant negative relationship with reaction time, but a positive relationship with accuracy. Third, overall state self-esteem overall had significant positive relationships with reaction time, but no significant relationship with accuracy. Fourth, academic achievement motivation resembled state self-esteem in that it exhibited a positive relationship with reaction time. However, its relationship with accuracy was not significant.

The first main finding was expected and consistent with the literature on the effects of set size and working memory (Oberauer et al., 2016). Specifically, it is known that there is a relationship between the amount of content held in working memory with both response times and accuracy such that when the amount of content is increased, response times are longer and less accurate (Oberauer et al, 2016). Thus, in the case of the n-back task, response time would increase, and accuracy would decrease with increased set size. In the present study, there were no differences in accuracy across probe types. This could be a result of the participant's performing at high accuracy throughout all tasks. Further increases in set size (e.g. 3-back, 4-back) may reveal decreases in accuracy and differentiation across item types.

The second finding was that global self-esteem had a significant relationship with both reaction time and accuracy on the n-back task. While the relationship with reaction time was negative, the relationship with accuracy was positive. This means that higher global self-esteem scores predicted quicker reaction times and higher accuracy. This is consistent with evidence that a higher self-esteem is related to positive academic outcomes and achievements (Ditzfeld & Showers, 2013Schwann, 2016; Usher & Kober 2012, 2014). As stated in the discussion of self-esteem, individuals with higher self-esteem may apply more effort and persevere when encountered with failure (Ditzfeld & Showers, 2013). In the present study, it is possible that participants reporting a higher self-esteem applied more effort following an error, compared to those with lower self-esteem that may have been discouraged. Furthermore, a higher self-esteem has been correlated with high self-efficacy, which has been found to be influential in academic motivation and related to academic achievement (Afari, Ward & Khine, 2012; Ryan and Deci 2000;2012). Thus, perhaps higher self-efficacy of the participants could have contributed to the present study such that those with higher global self-esteem felt a greater competence in the n-back task, resulting in better performance overall. In the context of the EVC framework, it is possible that increased self-esteem, and thus, self-efficacy may increase the value of exerting control in the cost-benefit analysis.

The third finding demonstrated that state self-esteem had a significant positive relationship with both reaction time and accuracy. This means that higher state self-esteem predicted higher accuracy and increased reaction times. Recall that individuals in this study completed the state self-esteem scale performance and social subsets. The reversed pattern of reaction time observed with state self-esteem compared with global self-esteem may best be explained by the nature of the questions in each of the questionnaires and the fact that each questionnaire is capturing a different concept. For example, the Rosenberg self-esteem scale is comprised of questions meant to capture an individual's overall self-worth but is not intended to capture one's performance or achievement self-esteem. In contrast, the state self-esteem scale emphasizes performance and social comparison self-esteem that are relevant to the lab setting and contingent on the individual's feeling during a lab visit in which they were asked to complete standardized tests and a computer task. Moreover, state self-esteem has been shown to be a better predictor of school performance, while global self-esteem has been shown to be a better predictor of psychological well-being. This finding further supports that these two ideas capture different types of self-esteem, thus possibly explaining their reversed relationships with reaction time on the n-back task (Rosenberg et al, 1995) .

Fourth, like state self-esteem, academic achievement motivation also exhibited a significant positive relationship with response time. Similar to state self-esteem, it is likely that the questions on Waugh's Scale of Academic Motivation capture a concept that is more relevant to the n-back task. Specifically, the scale contains questions regarding an individual's efforts to succeed and achieve goals, intrinsic motivation to learn and solve problems, and the extent to which one finds intellectual challenges intrinsically rewarding. Thus, the extent to which one is intrinsically motivated to solve intellectual challenges and succeed may directly impact the allotment of cognitive resources and effort that an individual applied on the n-back task, as is suggested in the EVC framework (Shenhav et al., 2013). This is also consistent with the observed pattern of increased reaction time. More specifically, some animal models indicate that when an animal is in the process of learning a new task, they tend to behave in a goal directed manner that enhances flexibility but generally slows responses (Keramati, Dezfouli, Piray, 2011). Thus, highly motivated individuals may exchange quick response times for slower responses that go with increased flexibility during the n-back task.

One surprising finding was that academic motivation was not found to be significantly correlated with accuracy on the n-back task. As the literature review indicated, individuals with higher academic motivation predicted better performance (Deci et al, 1996; Domenico, 2017; Ryan and Deci, 2000). However, this was not the case in the present study. This could be due to the fact that this study had a small sample size, and thus, we cannot clearly see a significant correlation yet. Another explanation for this finding is that participants may not exhibit significant changes in accuracy levels between 1- and 2-back, but still have slower response times as a result of the set size difference, consistent with the effects of set size on response times (Oberauer,2016). Overall, we find that self-esteem—both global and state—and academic motivation are significantly related to performance on a task of working memory updating. However, the exact nature of these effects may depend on the questionnaire and what domain of self-esteem or motivation the questionnaires target.

The n-back task requires the involvement of various cognitive processes for successful performance. Participants must actively hold items in memory, update new items, bind the items to their order of presentation and resist interference from proactive items (Chatham et al., 2012). Thus, context representations of the items are essential for completion of this task. The processes of maintaining and updating these representations to afford the flexibility of cognitive control in different contexts are thought to involve the PFC and the neurotransmitter DA (Braver and Cohen, 2001; Yee and Braver, 2018). Previous studies have specifically looked at the role of the PFC in the n-back task and have concluded that the ventrolateral PFC and dorsolateral PFC are recruited during this task. Furthermore, the dorsolateral PFC and the medial PFC has been found to have increased sensitivity to cognitive load (Hautzel et al., 2002; Tsuchida & Fellows, 2008). DA involvement has also been investigated in this specific task. In the previous review, DA was shown to be involved in the maintenance of representations as well as being involved in motivation. In line with this evidence, Salami and colleagues (2019) recently investigated DA activity during the n-back task and found that DA activity increased with task demand, resulting in larger activity with 3-back compared to the 1 and 2-back conditions, demonstrating that increased DA regulation may be required for more demanding and effortful tasks (Salami et al., 2019). This evidence further supports the importance of the PFC and DA in cognitive control and demonstrates some of the processes involved in the current study. Specifically, this evidence further supports the importance of the PFC in the maintenance of context representations and how this is sensitive to set size. Recall also that DA is also thought to play a role in the encoding of task rules in the PFC which facilitates enhanced control (Yee and Braver, 2018). This enhanced control, which is particularly necessary with larger set sizes in the n-back task, is thus related to an increase in DA, demonstrating the important role that DA plays in the orientation of cognitive control.

The present study has a few limitations to note. First, the size and nature of sample size is limiting. Specifically, the small sample size does not allow us to observe the full extent of the effects that self-esteem may have on motivation. Additionally, it is important to note that the majority of participants in this study were currently enrolled in a higher education program or interested in pursuing higher education in the future. Thus, these individuals likely have a higher academic achievement motivation to begin with, which could also impact self-esteem. Related to the previous point, the directionality of the relationship between self-esteem and academic performance is unclear. More specifically, some researchers have argued that self-esteem may serve as a consequence of academic achievement (Ditzfeld & Showers, 2013). Thus, it is possible that the individuals in this sample have had high rates of academic success, leading to higher rates of self-esteem. It is also quite possible that the relationship is bidirectional. The exact nature of this relationship may be of interest for additional studies. Furthermore, additional studies will benefit from a larger and more diverse sample. A wider range of scores on the self-esteem measures, for example, could provide a more in depth look at how self-esteem interacts with cognitive performance. Additionally, future studies could investigate the relationship of self-esteem with scores on measures of intelligence and gender in order to provide further insight as to what other factors may interact with self-esteem and how this may predict cognitive performance.

Conclusions

To conclude, the findings demonstrate that self-esteem and academic motivation are related to performance on a computerized task of working memory. Specifically, all concepts were found to be related to reaction time; all, but motivation were found to be related to accuracy. The differences in directionality of these relationship may reflect the difference between global self-esteem and domain specific self-esteem and motivation. Overall, the results indicate that increased self-esteem and academic motivation do have significant effects on an increasingly difficult task of working memory, demonstrating the orienting effects that both self-esteem and academic motivation can have on the orientation of cognitive resources. These results have relevance in the area of education, as it may allow us to improve interventions for students lacking motivation.

APPENDIX A

The Rosenberg Self-Esteem Scale

Reference:

Rosenberg, M. (1965). Society and the adolescent self-image. Princeton, NJ: Princeton University Press.

Below is a list of statements dealing with your GENERAL feelings about yourself. If you strongly Agree, please select "strongly agree", if you agree, please select "agree", if you disagree, circle "Disagree", if you strongly disagree, circle "strongly disagree".

1. I feel that I am a person of worth, at least on an equal plane with others

3	2	1	0
Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**

2. I feel that I have a number of good qualities.

3	2	1	0
Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**

3. All in all, I am inclined to feel that I am a failure

3	2	1	0
Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**

4. I am able to do things as well as most people

3	2	1	0
Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**

5. I feel I do not have much to be proud of

3	2	1	0
Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**

6. I take a positive attitude toward myself

3	2	1	0
Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**

7. On the whole, I am satisfied with myself

3	2	1	0
Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**

8. I wish I could have more respect for myself

3	2	1	0
Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**

9. I certainly feel useless at times

3	2	1	0
Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**

10. At times I think that I am no good at all

3	2	1	0
Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**

APPENDIX B

The State Self-Esteem Scale

Reference:

Heatherton, T. F. & Polivy, J. (1991). Development and validation of a scale for measuring state self-esteem. Journal of Personality and Social Psychology, 60, 895-910.

This is a questionnaire designed to measure what you are thinking at this moment. There is of course, no right answer for any statement. The best answer is what you feel is true of yourself at the moment. Be sure to answer all of the items, even if you are not certain of the best answer. Again, answer these questions as they are true for you RIGHT NOW.

1. I feel confident about my abilities

1	**2**	**3**	**4**	**5**
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

2. I am worried about whether I am regarded as a success or failure

1	**2**	**3**	**4**	**5**
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

3. I feel satisfied with the way my body looks right now.

1	**2**	**3**	**4**	**5**
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

4. I feel frustrated or rattled about my performance

1	**2**	**3**	**4**	**5**
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

5. I feel that I am having trouble understanding things that I read.

1	**2**	**3**	**4**	**5**
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

6. I feel that others respect and admire me.

1	**2**	**3**	**4**	**5**
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

7. I am dissatisfied with my weight.

1	**2**	**3**	**4**	**5**
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

8. I feel self-conscious.

1	**2**	**3**	**4**	**5**
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

9. I feel as smart as others.

1	**2**	**3**	**4**	**5**
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

10. I feel displeased with myself.

1	**2**	**3**	**4**	**5**
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

11. I feel good about myself.

1	2	3	4	5
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

12. I am pleased with my appearance right now.

1	2	3	4	5
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

13. I am worried about what other people think of me.

1	2	3	4	5
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

14. I feel confident that I understand things.

1	2	3	4	5
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

15. I feel inferior to others at this moment.

1	2	3	4	5
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

16. I feel unattractive.

1	2	3	4	5
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

17. I feel concerned about the impression I am making.

1	2	3	4	5
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

18. I feel that I have less scholastic ability right now than others.

1	2	3	4	5
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

19. I feel like I'm not doing well

1	2	3	4	5
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

20. I am worried about looking foolish.

1	2	3	4	5
Not At All	**A Little Bit**	**Somewhat**	**Very Much**	**Extremely**

Performance Self-esteem items: 1, 4, 5, 9, 14, 18 ,19
Social Self-esteem items: 2, 8, 10, 13, 15, 17, 20
Appearance self-esteem items: 3, 6, 7, 11, 12, 16

APPENDIX C

Waugh's Motivation to Achieve Academically

Reference:

Waugh, R. F. (2002). Creating a scale to measure motivation to achieve academically: Linking attitudes and behaviours using Rasch measurement. *British journal of educational psychology*, *72*(1), 65-86.

Please rate the following 24 items according to the following response format and place a number corresponding to What I aim for and What I actually do on the appropriate line opposite each statement.

In all or nearly all my subjects	**Put 3**
In most, though not all, my subjects	**Put 2**
In some, though not most, of my subjects	**Put 1**
In none or only one of my subjects	**Put 0**

<u>**Example:**</u> If you aim to set high standards in academic work for all your subjects put 3, and if this only happens in some subjects, put 1.
Item 1. I set high standards in academic work 3 1

Item no.	**Item wording**	**What I aim for**	**What I actually do**
1.	I do my best to reach the academic standards that I set for myself		
2.	I evaluate my performance against the academic standards that I set myself		
3.	I try different strategies to achieve my academic goals when I have difficulties.		
4.	I set myself realistic but challenging academic goals		
5.	I seek some average academic tasks in which I think I can succeed		
6.	I seek some difficult academic tasks in which I believe I can succeed		
7.	I seek some difficult academic tasks which I might be able to do		
8.	I make strong demands on myself to achieve in. academic work		
9.	When I am given an academic task or assignment, I make a strong effort to find the		

right answers

10. I write and rewrite my academic assignments in order to achieve
11. When I have conflicts about time to be spent on achieving, I re-think my values (social, parental, dates versus achievement)
12. I show interest in a number of academic topics
13. I read widely on a number of academic topics
14. I think about solving problems, with which others have difficulty, because I am interested
15. I participate in class discussions to improve my understanding in academic matters
16. I ask questions of others to improve my understanding in academic matters
17. I learn from others with more knowledge than I have.
18. I aim to learn from an expert in at least one academic area
19. I take personal responsibility for my academic learning
20. I plan to seek out information when necessary and take steps to master it
21. I like the interaction with peers in solving problems in academic work
22. I try to achieve academically because I like the challenges it brings
23. I like the intellectual challenge of academic work
24. Like the social relationships involved in academic work

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