3-2018

THE INFLUENCE OF CONTROL STRATEGY ON EVENT SEGMENTATION

Vanessa Carlos
California State University - San Bernardino

THE INFLUENCE OF CONTROL STRATEGY ON EVENT SEGMENTATION

A Thesis

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

in

General Experimental Psychology

by

Vanessa Carlos

March 2018

THE INFLUENCE OF CONTROL STRATEGY ON EVENT SEGMENTATION

A Thesis

Presented to the

Faculty of

California State University,

San Bernardino

by

Vanessa Carlos

March 2018

Approved by:

Jason Reimer, Committee Chair, Psychology

Eugene Wong, Committee Member

Matt Riggs, Committee Member

ABSTRACT

The dual mechanism of cognitive control framework (DMC) describes cognitive control via two strategies: proactive and reactive. Individuals using a proactive strategy, focus on actively maintaining goal-relevant information in memory, whereas reactive individuals store goal-relevant information and retrieve it when cues are present. Reimer and colleagues (2015, 2017) added cue-probe location shifts to the typical AX-CPT, as well as, a virtual-reality environment version of the AX-CPT. Through this, they found that the effect of location shifts vary depending on whether a proactive or reactive mode of control is utilized. Thus, the aim of the present study was to test whether the effect of location shifts on cognitive control depends on type of control strategy used. Two versions of the AX-CPT were used: shift alone and shift with no-go trials. The shift alone AX-CPT examined the influence of location shifts in proactively-biased young adults. The shift with no-go trials AX-CPT examined the influence of location shifts with a manipulation that is known to induce a reactive control strategy (Gonthier et al., 2016). It was hypothesized that cue-probe location shifts would have a differential effect on mode of control. Results demonstrated that type of AX-CPT given, cue-probe location, and type of trial presented individually influenced participant performance. There was also an interaction between AX-CPT type and trial type that provides evidence for a successful manipulation of mode of control. The hypothesized interaction between all variables, however,

was not found. Possible limitations of the present study, as well as, future direction were discussed.

ACKNOWLEDGEMENTS

I would like to thank Dr. Reimer for his thoughtful insight through each step of my thesis. I would also like to thank Dr. Riggs and Dr. Wong for their insight on various topics related to my thesis which brought about great improvements. Finally, I would like to thank all those who through each step of my thesis kept me in their thoughts and prayers, as they have been a tremendous source of support for me.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

COGNITIVE CONTROL

The ability to store and organize events in memory is a key element of the human experience. In order to effectively function, communicate, and learn, individuals must have the ability to store and manipulate past events and previously learned knowledge within memory. Effective functioning, communication, and multitasking require that individuals be able to reorganize or work with current and past information. This ability to update current information, organize memory, plan actions, and control thoughts and behavior is known by researchers as executive functions (see Cahn-Weiner, Boyle, & Malloy, 2002; Carlson, Moses, & Claxton, 2004; Isquith, Gioia, & Espy, 2004; Nelson et al., 2017; Richmond, Redick, & Braver, 2015). More simply, executive functions can be thought of as planning and organizing. However, to plan and organize, an individual must be able to control their thoughts to successfully complete a behavioral goal. This specific aspect of executive functions is known as cognitive control. Cognitive control can be simplified as the ability to regulate thoughts and behaviors to reach a particular goal (Braver, 2012).

Although cognitive control is necessary for general functioning, it is especially vital within a classroom setting. Classroom environments not only revolve around learning and memory, but many times depend on goal driven behavior to maintain attention for prolonged periods of time. Consequently, cognitive control (i.e., the ability to maintain a future goal in mind and thus control thoughts and avoid distractions to successfully complete the goal), is a skill that is especially necessary within classroom settings. Isquith et al. (2004) found that in both parent and teacher reports, preschoolers with clinical diagnoses (i.e., specifically attention deficit hyperactivity disorder, autism spectrum disorder, or language disorders) were shown to have more difficulties in inhibition, shifting tasks, emotional control, working memory, and planning than non-clinical children. Thus children with these specific diagnoses seem to struggle with cognitive control in both school and home environments (Isquith et al., 2004). Additionally, Carlson et al. (2004) found that control and inhibition predicted theory of mind in preschool-aged children, a skill necessary for perspective taking. Another main aspect of cognitive control necessary for classroom learning is that of inhibiting distractions and maintaining focus on what is being taught. Nelson et al. (2017) found that cognitive control predicted focused classroom engagement in first grade. This engagement in turn, predicted successful transition from preschool to first grade during the course of the year (Nelson et al., 2017).

Although much of the research relating to cognitive control has been constrained to school and laboratory settings, cognitive control is a skill that is highly important in daily functioning. Cahn-Weiner et al. (2002) found that cognitive shifting and complex sequencing most impacted daily functioning in elderly individuals living independently. This is because in order to plan a series of tasks or successfully shift from one task to another, an individual must control their thoughts and actions. Whether a situation involves taking medicine at an appointed time or managing finances, elderly individuals must be able to control their thoughts to maintain the goal in memory and avoid distractions.

Similarly, when thinking of a college student who needs to finish their study guide for a class two days away; a teacher who needs to prepare for a meeting with a parent after school; an adolescent who needs to buy his friend a birthday gift by the next day; an elderly woman who needs to take her medicine every day at 6pm; a parent who needs to stop for groceries after picking up their children from school; a schizophrenic who needs to take his medication every morning at 9am, cognitive control is necessary in each of these situations. In each of these examples, there is a goal behavior (e.g., finish a study guide, buy a present, take medicine, etc.). Cognitive control allows each individual to adjust their thoughts and actions to keep that goal in mind and allow it to come to completion (Braver 2012; Braver, Gray, & Burgess, 2007). There are two ways of regulating behavior. First by allocating attention to information that is relevant to a goal and second by inhibiting information that is not important and will only serve as a distractor (Reimer, Radvansky, Lorsbach, & Armendarez, 2015). In the cases mentioned above, cognitive control would be measured by one’s ability to block thoughts accumulated throughout the day and maintain in memory the mental note created to remind one of the goal behavior. If a person has good cognitive control, this will result in successful completion of the goal (e.g., finishing a study guide, taking medication, preparing a meeting, etc.).

CHAPTER TWO

MEASURING COGNITIVE CONTROL

Numerous studies attest to both the complexity of cognitive control and its importance in daily functioning (see Braver 2012; Braver et al., 2007; Burgess & Braver, 2010; Gonthier, Macnamara, Chow, Conway, & Braver, 2016; Jacoby, Kelley, & McElree, 1999; Richmond et al., 2015; Speer, Jacoby, & Braver, 2003). Nevertheless, the effects of cognitive control seem to vary widely between different tasks, individuals, and settings. This complexity and variability is what makes it difficult to test and measure cognitive control. In an effort to find a good way to measure such a highly complex structure, some have utilized tasks that measure participant expectation differences (e.g., high load vs low load expectancy: Speer et al., 2003), task switching costs (e.g., Stroop task: MacDonald, Cohen, Stenger, & Carter, 2000; semantic classification task: Braver, Reynolds, & Donaldson, 2003; Wisconsin card sorting task: Cahn-Weiner et al., 2002), and implicit strategy in a continuous performance task (e.g., AX-CPT: Gonthier et al., 2016; Locke & Braver, 2008; MacDonald & Carter, 2003; Redick, 2014; Reimer et al., 2015; Richmond et al., 2015).

From these forms of measuring cognitive control the most popular is the AX continuous performance task (AX-CPT). This task has been used consistently within the literature as way of measuring cognitive control (see Braver, 2012; Braver et al., 2007; Gonthier et al., 2016; Iselin & DeCoster, 2009; Locke &

Braver, 2008; Lorsbach & Reimer, 2008, 2010; MacDonald & Carter, 2003; Redick, 2014; Reimer et al., 2015; Richmond et al., 2015). One of the things that make this task so popular is its applicability towards a large range of populations and situations. Throughout the literature, the AX-CPT has been found appropriate for a wide range of ages (see Braver, 2012; Braver et al., 2001; Braver, Paxton, Locke, & Barch, 2009; Braver, Satpute, Rush, Racine, & Barch, 2005; Chatham, Frank, & Munakata, 2009; Iselin & DeCoster, 2009; Lorsbach & Reimer 2008, 2010; Paxton, Barch, Racine, & Braver, 2008; Paxton, Barch, Storandt, & Braver, 2006) and clinical groups (see Barch et al., 2001; Barch et al., 2009; Barch, Carter, MacDonald, Braver, & Cohen, 2003; Braver, 2012, Braver et al., 2005; Braver et al., 2007; Edwards, Barch, & Braver, 2010; Holmes et al., 2005; MacDonald, 2008; MacDonald & Carter, 2003; MacDonald et al., 2005; Robinson et al., 2013). The AX-CPT has also been shown to be sensitive to capture mood and reinforcement changes (see Braver, 2012; Braver et al., 2007; Chiew & Braver, 2013; Driesbach, 2006; Frober & Dreisbach, 2016; Locke & Braver, 2008; Wouwe, Band, & Ridderinkhof, 2011), environmental or instruction-related differences (see Gonthier et al., 2016; Reimer et al, 2015; Speer et al., 2003), and differences in individual capabilities (see Morales, Yudes, Gomez-Ariza, & Bajo, 2015; Redick, 2014; Richmond et al., 2015).

The AX version of the CPT task was first created to measure sustained attention in brain damaged participants (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956). Through time and experimentation, this task was modified to test cognitive control (see Cohen, Barch, Carter, & Servan-Schreiber, 1999; Servan-Schreiber, Cohen, & Steingard, 1996). Within this task participants are shown a series of letters (presented one at a time) and are asked to respond to pairs of letters (i.e., letter one shown first and letter two shown next) based on a rule given by the researcher. The rule consists of responding “Yes” to any X probe (i.e., the second letter) that is directly preceded by an A cue (i.e., the first letter). Any other combination of letters would require a “No” response. In the typical AX-CPT there are four trial types. There is one target trial: AX (i.e., target cue and target probe) and three non-target trials: AY (i.e., target cue and non-target probe), BX (i.e., non-target cue and target probe), and BY (i.e., non-target cue and non-target probe). The letters Y and B within the AY and BX trials may not be the exact letters the participants are shown, but for the explanation of the task only serve to represent any other letter in the alphabet that is neither A or X.

One important aspect of the AX-CPT is the frequency with which each trial type is shown. Specifically, the target trial (i.e., AX) is shown 70% of the time, whereas the non-target trials (i.e., AY, BX, and BY) are each shown 10% of the time. This frequency is important because by making most of the trials target trials, participants form an expectation that the letters A and X are typically seen together. Thus, every time they see an A cue they expect an X probe to follow and every time they see an X probe they expect an A cue to have come before. These frequencies are important because analysis of the AX-CPT involves looking for particular kinds of errors. Specifically, errors on AY trials (i.e., higher response times and error rates) indicate a stronger encoding of the cue, but not of the probe. On the other hand, errors on BX trials (i.e., higher response times and error rates) indicate a stronger encoding of the probe, but not of the cue. Within the AX-CPT, response time and accuracy rate of each trial type is used to measure cognitive control.

Previous accounts of cognitive control as measured by the AX-CPT described two distinct patterns of data corresponding to the level of cognitive control functioning. Specifically, higher cognitive control was characterized by a stronger focus and maintenance of the cue, whereas, lower cognitive control functioning was characterized by a stronger emphasis of the probe (see Barch et al., 2001; Barch et al., 2003; Holmes et al., 2005; Lorsbach & Reimer, 2008, 2010; Macdonald & Carter, 2003). According to these past interpretations of the AX-CPT an individual with higher cognitive control function showed a pattern of high error in AY trials, but high accuracy in BX trials. This is because when the cue comes up, these individuals maintain the cue in memory as they prepare a response. If they see an A as the cue, they prepare a target response increasing the likelihood that they make an incorrect target response in AY trials. If they see a B as the cue, they prepare a non-target response increasing the likelihood that they make a correct non-target response in BX trials. By contrast, an individual with lower cognitive control function showed a pattern of high error in BX trials, but high accuracy in AY trials. This is because when the cue comes up these individuals store the cue in memory, but do not actively maintain it. Rather, when the probe appears they use the information from the probe to retrieve the cue and make their response. Thus, if they see a B cue they store it, but do not actively maintain it. When the X probe comes up these participants are more likely to make an incorrect target response to BX trials. If they see an A cue, they again store it and do not maintain it, but as soon as they see a Y probe follow they react to the probe increasing the likelihood of correctly responding non-target to AY trials.

CHAPTER THREE

DUAL MECHANISMS OF COGNITIVE CONTROL FRAMEWORK

The AX-CPT has been used across many settings to gain a greater understanding of cognitive control as a whole. Nevertheless there is wide variability among the research findings that make it difficult to find a model that can accurately depict the cognitive control system. These efforts have led to multiple models that aim to explain the cognitive control system (Badre, 2008; Banich, 2009; Braver, 2012; Braver et al., 2007). For example, some have identified the cognitive control system as a unitary model explaining that cognitive control is a single system that functions with top-down processing (see Badre, 2008; Banich, 2009).

Others, however, identify the cognitive control system as a dual mechanism system (see Braver, 2012; Braver et al., 2007).Between these models, the model that most encompasses the research on cognitive control is the dual mechanisms of cognitive control (DMC) framework. Within this framework, there are two different modes of cognitive control (i.e., strategies) that can be used to reach a particular goal: proactive control (i.e., a goal maintenance approach) and reactive control (i.e., a context dependent approach) (see Figure 1) (Braver, 2012; Braver et al., 2007).

When using proactive control, an individual actively seeks to maintain the goal in memory (Braver et al., 2007). In this mode, the individual uses a preventative approach and is mentally prepared to perform the behaviors necessary to reach their goal (Braver, 2012; Braver et al., 2007). When given the example of a teacher that needs to prepare for a parent meeting, a teacher using a proactive mode of control would periodically remind themselves throughout the day that they need to prepare for their meeting. Thus, when the time comes, the teacher is mentally prepared to engage in behaviors that will allow them to be prepared for their meeting (i.e., to successfully complete their goal). On the other hand, an individual using a reactive mode of control does not actively maintain the goal in memory, but rather relies on contextual cues to remind them of their goal (Braver, 2012; Braver et al., 2007). Also, in the example mentioned above, a teacher using a reactive mode of control would not continuously remind themselves that they need to prepare for their parent meeting after school, but would rather rely on a sticky note on their desk to remind them of their meeting.

Much support has been found for the DMC framework within recent brain studies. Many of these studies have found some similarities indicative of general cognitive control (e.g., activation of the lateral pre-frontal cortex region) (Braver et al., 2003; Braver et al., 2007; Braver et al., 2009; Braver, 2012; Hikosaka & Isoda, 2010). Nevertheless, there are also clear distinctions in both the brain regions and the type and length of the signal activated between proactive and reactive modes of control (Braver, 2012; Braver et al., 2007). For example, some studies have found sustained activity in the lateral and anterior pre-frontal cortex (PFC) to be linked to behavioral indicators of proactive control (Braver, 2012;

Braver et al., 2003; Braver et al., 2007; Braver et al., 2009; Hikosaka & Isoda, 2010; Speer et al., 2003), whereas transient activity in the lateral PFC seems to indicate the use of a reactive mode of control (Braver, 2012; Braver et al., 2003; Braver et al., 2007; Braver et al., 2009; Hikosaka & Isoda, 2010; Speer et al., 2003). These findings support the DMC account of cognitive control because active maintenance of a task goal requires sustained activity, whereas retrieval of a task goal based on environmental cues would only need transient activation when the cue is present.

Furthermore, Braver and colleagues have argued for the importance of a phase-like activity of the dopamine (DA) neurotransmitter within the proactive mode of control. This DA activity serves to maintain the PFC activated, which allows the goal to be maintained continuously in memory (Braver, 2012; Braver & Cohen, 1999; Braver et al., 2007). Without the help of DA, the PFC would only show transient activity (Braver, 2012; Braver et al., 2007). Researchers have also found support for activity in the pre-supplementary motor area to be linked to a proactive mode of control by preparing for behavioral inhibition of action (Dove, Pollmann, Schubert, Wiggins, & Cramon, 2000; Hikosaka & Isoda, 2010; Rushworth, Hadland, Paus, Sipila, 2002).

For the reactive mode of control, studies support activity in the anterior cingulate cortex (ACC) (Braver, 2012; Braver et al., 2007; Hikosaka & Isoda, 2010; Williams, Bush, Rauch, Cosgrove, Eskandar, 2004). In these studies, the ACC seems to serve as a system that monitors conflict (Braver, 2012; Braver et al., 2007; Botvinick, Braver, Barch, Carter, & Cohen, 2001; Hikosaka & Isoda, 2010; Williams et al., 2004). This understanding of the ACC fits well within the DMC's description of the reactive mode of control because when the probe appears, in the AX-CPT, the reactive mode of control must resolve the interference created between the bias of seeing the probe and the stored cue information. Furthermore, in their chapter, Braver et al. (2007) discuss how activity in the medial temporal lobe within the hippocampus serves to store goal information into memory (Braver et al., 2007). Storage of the goal plays an important role in reactive mode of control, as described by the DMC account, because it frees cognitive resources until an environmental cue activates the retrieval of the goal. Additionally, Braver et al. (2003) found activity in the parietal cortex to be present during the utilization of a reactive mode of control. This also makes sense in light of the DMC account. The reactive mode of control depends on environmental cues to reactivate the goal in memory. Thus, the parietal cortex, which is in charge of consolidating sensory input within the brain, seems to play an important role in attending to environmental cues within the reactive mode of control (Braver et al., 2003).

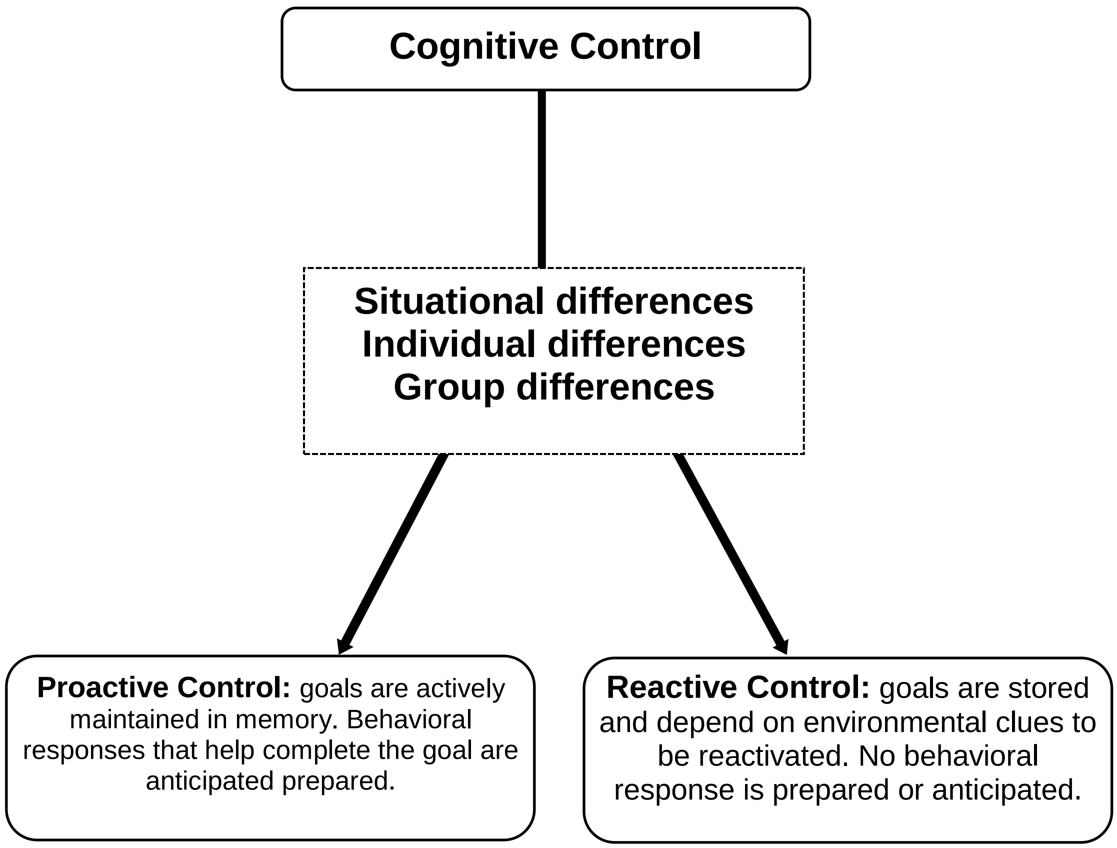

Figure 1. Dual Mechanisms Framework Based on Braver (2012).

CHAPTER FOUR

PROACTIVE AND REACTIVE MODES OF CONTROL IN THE AX-CPT

The DMC account has led to a more complete understanding of cognitive control. Specifically, the DMC account has helped to change our identification of cognitive control from a simple higher and lower pattern to a more complete two strategies understanding. Thus, cognitive control is now identified by the type of control strategy that each participant engages in (i.e., a proactive or a reactive mode of control) (Braver, 2012; Braver et al., 2007; Jacoby et al., 1999; Redick, 2014; Reimer et al., 2015; Richmond et al., 2015). The AX-CPT can sensitively identify both of these strategies and the degree to which participants engage in each (Gonthier et al., 2016; Redick, 2014; Reimer et al., 2015; Richmond et al., 2015). By comparing the response time and accuracy rate of each trial type researchers can easily identify participant’s mode of cognitive control.

An individual using a proactive mode of control, for example shows a pattern identical to what was previously considered to be high cognitive control function (i.e., high error in AY trials, but high accuracy in BX trials). Although the pattern of data is identical, the present understanding of this mode of control is qualitatively different. When utilizing this strategy, individuals maintain the goal of the task in memory as a high priority. Thus, when the cue comes up, these individuals engage in task-relevant behaviors that will increase the likelihood of successful completion of the task (i.e., maintain the cue in memory as they prepare a response). Thus, seeing an A as the cue increases the likelihood that participants prepare a target response ahead of time making it more likely to incorrectly respond target to an AY trial. By the same logic, seeing a B as the cue, means the participant will likely prepare a non-target response ahead of time increasing the likelihood of correctly responding non-target to a BX trial.

In the case of reactive mode of control, the pattern is identical to what was previously considered to be low cognitive control function (i.e., high error in BX trials, but high accuracy in AY trials). In the case of reactive mode of control, rather than actively maintaining the goal of the task in memory, individuals use clues in the environment to remind them of the goal and react whenever those clues come up. Thus, when the cue comes up, these individuals store the cue in memory, but do not actively maintain it. When the probe appears, however, they use the information from the probe to help them retrieve the cue and make their response. Thus, upon seeing a B cue they store it, but do not actively maintain it. When the X probe comes up, however, these participants use the probe information to attempt to retrieve the cue from memory, making it more likely to incorrectly respond target to BX trials. Seeing an A cue, they again store it and do not maintain it, but as soon as they see a Y probe follow they quickly react to the non-target probe increasing the likelihood of making a correct non-target response to AY trials.

CHAPTER FIVE

SWITCHING BETWEEN MODES OF CONTROL

As is evident, there are clear benefits and costs to using either a proactive or reactive mode of control. Benefits of using a proactive mode of control includes being mentally prepared and engaging in behaviors that increase the possibility of completing one's goal (Braver et al., 2007). In tasks that measure cognitive control, this means that participants prepare a behavioral response ahead of time based on a predicted pattern of results that maximizes the possibility of correctly responding to a task. This behavioral preparation results in the complete suppression of any context related interference (Braver et al., 2007). Since thoughts and behaviors are concentrated from the very beginning to any task-related information that will result in successful completion of the goal, any non-task related interference is blocked from even entering thought.

Beyond these benefits, there are great costs that come from using a proactive mode of control. One such cost is the depletion of cognitive resources (Braver et al., 2007). Since the PFC must be continuously active in order to maintain the goal in mind, many cognitive resources are used. Consequently, many resources must be available in order for this kind of cognitive control to be considered. Additionally, a proactive mode of control cannot be utilized over long periods of time, as this kind of resource intensive activity cannot be maintained for prolonged periods of time (Braver et al., 2007). Thus, any goal that must be maintained for more than a few minutes must rely on an alternative control strategy (i.e., a reactive mode of control). This behavioral preparation is not only resource intensive, but also relies on the contextual cues. Braver and colleagues (2007) discuss how a proactive mode of control depends on the predictability of contextual cues. Specifically, a proactive mode of control depends on a predictable pattern of results in order to prepare a behavioral response ahead of time. Thus, contextual cues must be both predictable and reliable in order for a proactive mode of control to be engaged. Additionally, proactive mode of control depends on various neural mechanisms to function properly (e.g., the DA neurotransmitter allowing the PFC to be continuously activated) (Braver et al., 2007). Thus, in order for a proactive mode of control to be available these specific neural mechanisms must be fully functional.

Benefits to using a reactive mode of control involve limiting the resources used within the cognitive system. Thus, the reactive mode of control provides the optimal solution for the cognitive system (Braver et al., 2007). Given that automatic processes are the most efficient within the cognitive system, there is a natural tendency to automatize processes whenever possible. The reactive mode of control facilitates the cognitive system’s natural transition from an actively involved cognitive process to a more automatic process (Braver et al., 2007). Although the proactive mode of control fights against this automatization, the reactive mode allows automatization by using resources only when necessary. Furthermore, by utilizing resources only when necessary it frees the cognitive system to engage in cognitive control even when there are limited resources. Thus, there is wide flexibility within the reactive mode to be available in many contexts.

As with proactive control, there are also costs associated with using a reactive mode of control. Although a reactive mode of control is the optimal solution to the cognitive system, within cognitive control it is not the optimal control strategy (Braver et al., 2007). Given that the reactive mode of control limits the cognitive control system to only using resources when necessary, there is the possibility of engaging in behaviors that may delay or be detrimental to the completion of the goal (Braver et al., 2007). Since the reactive mode of control uses resources only when necessary, there is no early preparation for a behavioral response. Thus, there is a higher possibility for error (i.e., engaging in behaviors that decrease the likelihood of successfully responding to a goal). If this is the case, the individual must then correct for the interference when contextual cues remind them of the goal. Consequently, the reactive mode of control is more vulnerable to the influence of interference than the proactive mode of control (Braver et al., 2007).

Whether an individual engages a proactive or reactive mode of control, there are clear costs and benefits associated with each. According to the DMC account, the cognitive control system weighs each of these costs and benefits, and biases which control strategy is used (Braver, 2012; Braver et al., 2007). Within the DMC account, Braver and colleagues discuss three categories of differences that can account for changes from one mode of control to another. These categories include: individual differences, group differences, and situational differences (Braver, 2012; Braver et al., 2007). These differences have been able to account for many of the contradicting findings in the cognitive control literature.

Individual Differences

Within the DMC account, individual differences refer to each person's unique experience or capacity. This unique experience or capacity seems to highly influence which mode of control is adopted. Research has found, for example, that individuals with low working memory capacity have a tendency to use a reactive mode of control much more than a proactive mode of control (Redick, 2014; Richmond et al., 2015). Conversely, individuals with a high working memory capacity have a much higher tendency to use a proactive mode of control than a reactive mode of control (Redick, 2014; Richmond et al., 2015). According to the DMC account, these findings are explained by differences in capacity (Braver, 2012; Braver et al., 2007; Redick, 2014; Richmond et al., 2015). Using a proactive mode of control requires more cognitive resources which an individual with a low working memory capacity does not have available. As a consequence, individuals with a low working memory capacity lean more towards using a reactive mode of control, whereas individuals with a high working memory capacity have more resources available and thus are able to engage a proactive mode of control (Redick, 2014; Richmond et al., 2015).

General fluid intelligence seems to also influence the mode of control an individual adopts (Burgess & Braver, 2010). Burgess and Braver (2010) found that general fluid intelligence was correlated with mode of control, such that high general fluid intelligence individuals showed more proactive control, whereas low general fluid intelligence individuals showed more reactive control. This again can be explained by capacity. Whereas an individual with a high general fluid intelligence counts on many cognitive resources to utilize a proactive mode of control, an individual with low general fluid intelligence does not have as many resources available and thus must utilize a reactive mode of control (Braver, 2012; Braver et al., 2007).

Experience also seems to influence mode of control. Anxiety, for example seems to play a major role in determining which mode of control is adopted (Fales et al., 2008; Schmid, Kleiman, & Amodio, 2015). In one study, highly anxious participants showed brain activity indicating the use of a reactive mode of control (i.e., transient activity in the dorsolateral PFC), whereas low anxiety participants showed brain activity more indicative of a proactive mode of control (i.e., sustained activity in the dorsolateral PFC) (Fales et al., 2008). After watching an anxiety inducing video, high anxiety individuals maintained their pattern or a reactive mode of control. Low anxiety individuals, however switched from a proactive pattern of activity (i.e., sustained PFC activity) to a more reactive pattern of activity (i.e., transient PFC activity) (Fales et al., 2008). Schmid et al. (2015) found similar patterns of brain activity in socially anxious individuals. Specifically, low social anxiety individuals showed stable patterns of dorsolateral PFC activity (Schmid et al., 2015). On the contrary, high social anxiety individuals showed unstable patterns of dorsolateral PFC activity, but stable patterns of activity in the dorsal ACC. These findings are consistent with the DMC framework's account of PFC and ACC functioning within cognitive control. Specifically, sustained or stable activity within the PFC reflects active maintenance of the goal (i.e., proactive control), whereas transient or unstable activity within the PFC reflects activation of the control system only when necessary (i.e., reactive control) (Braver, 2012; Braver et al., 2007). Additionally, activity within the ACC is associated with conflict monitoring (Botvinick et al., 2001; Hikosaka & Isoda, 2010; Williams et al., 2004). Given that the reactive mode of control is more subject to interference, the ACC serves to detect this interference and activate the control system (Braver, 2012; Braver et al., 2007). This is important to consider when measuring and manipulating cognitive control in a laboratory setting. If a laboratory setting produces feelings of anxiety within an individual, their performance, rather than reflect their capacity or an experimental manipulation of the task, will more realistically reflect their anxiety and result in their use of a reactive control strategy.

Another factor of experience that has been studied is motivation. When discussing individual differences it is important to consider individual distinctions in the importance of the goal behavior. In some cases the goal behavior could be considered by the individual to be of high importance (e.g., a student who considers an upcoming test to be both difficult and important), whereas in others the behavior could be considered less important (e.g., a student who considers an upcoming test to be either easy or unimportant). If an individual considers the goal behavior to be very important, then great effort will be given to engage in behaviors that will allow them to continuously remember the goal (i.e., utilize a proactive control strategy). If, on the other hand, the goal behavior is not considered to be very important, then not much effort will be given to engage in behaviors that will allow them to continuously remember the goal (i.e., utilize a reactive control strategy). Studying motivation, Locke and Braver (2008) found that when given incentives for correct responses, students were more likely to engage in a proactive control strategy (i.e., associated with sustained PFC activity) when compared to tasks where students were not given incentives. This is important to consider when measuring and manipulating cognitive control in a laboratory setting. If a participant feels that the experimental task they are performing is important or meaningful, the participant is more likely to engage behavior that will optimize the possibility for correct responses and thus engage in the optimal cognitive control strategy (i.e., a proactive mode of control).

Group Differences

The DMC account discusses group differences as involving differences between people categorized into distinct groups. These can include developmental differences, as well as differences between individuals with different types of clinical diagnosis (e.g., schizophrenia).

Within the developmental field, cognitive control has been widely studied across multiple ages. In children, there is a clear developmental pattern of cognitive control. That is when comparing younger and older groups of children, the younger groups show behavioral indications of using a reactive control strategy within the AX-CPT (i.e., better performance on AY trials and worse performance on BX trials), whereas the older groups show behavioral indications of using a proactive control strategy (i.e., better performance on BX trials and worse performance on AY trials) (Chatham, et al., 2009; Lorsbach & Reimer, 2008, 2010). This pattern of development continues into adolescence with adolescents showing a more reactive pattern of brain activity (i.e., decreased activity within the lateral PFC) compared to young adults who show a more proactive pattern of brain activity (i.e., increased activation within the lateral PFC) (Andrews-Hanna et al., 2011). Furthermore, this pattern of brain activity in adolescents was confirmed by self-report measures of impulse control, foresight, and peer pressure (Andrews-Hanna et al., 2011). Within older adults, studies show a greater tendency to use a reactive mode of control compared to young adults which show a more proactive tendency (Barch et al., 2001; Braver et al., 2009; Czernochowski, Nessler, & Friedman, 2010; Paxton et al., 2007; Schwarzkopp, Mayr, & Jost, 2016). This pattern has been observed in both behavioral (i.e., within the AX-CPT older adults show better performance in AY trials and worse performance in BX trials relative to young adults) (Barch et al., 2001) and brain patterns of activity (i.e., within the AX-CPT older adults show decreased lateral PFC activity during the cue and cue-probe delay, but increased activity during the probe) (Braver et al., 2009; Paxton et al., 2007). Further studies of brain activity within older adults have found that the process of filtering out distractors is delayed for older adults compared to young adults (Schwarzkopp et al., 2016). Specifically, older adults seem to store distractors first and then filter them out at a later time (Schwarzkopp et al., 2016). This later filtering process is indicative of a reactive control strategy (Braver, 2012; Braver et al., 2007). Out of each of these developmental stages, studies consistently find that young adults have a much higher tendency to use the proactive control strategy when compared to children, adolescents, and older adults (Andrews-Hanna et al., 2011; Barch et al., 2001; Braver et al., 2009; Lorsbach & Reimer, 2008; Paxton et al., 2007). The DMC framework accounts for these differences because out of each of these groups, young adults have the highest availability of cognitive resources. Conversely, children, adolescents, and older adults seem to have reduced cognitive resources due to continued development or age-related decline. Thus, when it comes time to engage in cognitive control, children, adolescents, and older adults tend to utilize the strategy that uses less cognitive resources (i.e., a reactive control strategy).

When looking at individuals with schizophrenia, research has found illness specific deficits within the cognitive control system. Specifically, individuals with schizophrenia show deficits in activation of the dorsolateral PFC (Barch et al., 2003; MacDonald & Carter, 2003). MacDonald & Carter (2003) found that while control participants showed increased dorsolateral PFC activation during the cue in order to prepare a behavioral response, participants with schizophrenia showed no differences in activation. Furthermore, these dorsolateral PFC deficits correspond with behavioral indicators of a reactive mode of control (i.e., within the AX-CPT better performance in AY and worse performance in BX) within participants who have schizophrenia compared to controls (Barch et al., 2001; Barch et al., 2003). A decreased performance in the AX-CPT can be observed even after four weeks of medication (Barch et al., 2003).Within the DMC framework, the lateral PFC plays a vital role in contributing to which mode of control is adopted. Specifically, continuous activation within the PFC is necessary in order to engage a proactive mode of control (Braver, 2012; Braver et al., 2007). Thus, individuals with schizophrenia are unable to engage a proactive mode of control given their deficits within the lateral PFC.

Situational Differences

Within the DMC framework situational differences relate to differences in the context, whether environment or task related, in which cognitive control is engaged. Situational differences could include differences in the types of instructions given to participants, differences in the incentives provided, differences within the task itself, or differences in the expected difficulty of the task. These differences have been shown to drastically change the mode of control adopted by participants (Braver et al., 2009; Edwards et al., 2010; Gonthier et al., 2016; Paxton et al., 2006; Speer et al., 2003).

Inducing Proactive Mode of Control

Given recent findings of contextual influences on mode of control, Braver and colleagues examined the possibility of training individuals with a typical reactive pattern of cognitive control to have a more proactive pattern of cognitive control (Braver et al., 2009; Edwards et al., 2010; Paxton et al., 2006). Several studies found that participants could be trained to utilize a more proactive control strategy by simply changing the instructions given to them on the AX-CPT (Braver et al., 2009; Edwards et al., 2010; Gonthier at al., 2016; Paxton et al., 2006). In these studies, participants were instructed to pay attention to the cue and to use the cue information to mentally prepare a response before the probe appears. By simply changing the instructions to have participants focus more on the cue, training effects were observed in older adults (Braver et al., 2009; Paxton et al., 2006) and in participants with schizophrenia (Edwards et al., 2010). Specifically, each of these groups was observed to shift from a reactive to a more proactive pattern of cognitive control after the training (Braver et al., 2009; Edwards et al., 2010; Paxton et al., 2006). Furthermore, within young adults an already identified pattern of proactive control at baseline was made more visible after being instructed to focus on the cue (Gonthier et al., 2016).

Inducing Reactive Mode of Control

After being able to manipulate reactive individuals to use a more proactive strategy, Braver and colleagues wondered if there are situations in which an individual engaging a proactive strategy might switch to a reactive strategy

(Braver et al., 2009; Gonthier et al., 2016; Speer et al., 2003). Given that previous studies have found young adults to typically adopt a proactive mode of control (Andrews-Hanna et al., 2011; Lorsbach & Reimer, 2008; Paxton et al., 2007), Speer et al. (2003) sought to investigate the influence of expected difficulty on mode of control. Speer et al. (2003) found that regardless of the actual difficulty level of the task, when expected difficulty was high participants showed a greater inclination to use a reactive mode of control. Conversely, when expected difficulty was low participants showed a greater inclination to use a proactive mode of control (Speer et al., 2003). According to the DMC framework, when the difficulty of a task increases more cognitive resources are necessary to engage in the task (Braver, 2012; Braver et al., 2007). Thus, fewer resources are available to use within cognitive control. As a consequence, a less resource intensive strategy must be utilized (i.e., a reactive mode of control). This is true even when the difficulty of the task is only expected, as the cognitive system prepares for expected patterns of difficulty.

In another study, Braver et al. (2009) manipulated both the task and the type of incentive given to participants to see if these contextual manipulations led to a behavioral shift in control strategy. Specifically, Braver et al. (2009) predicted that if the cue was less able to predict the probe and if incorrect responses were penalized, then participants might be less likely to prepare a response ahead of time and thus less likely to use a proactive control strategy. This manipulation was carried out by adding random no-go trials to a typical version of the AX-CPT.

The no-go trials consisted of a cue (either target or non-target) and a number in place of a probe. Participants were instructed that any time they saw a number in place of a probe, they should not respond in any way (i.e., not press any response button). Additionally, any incorrect response was followed by a monetary penalty. Through these manipulations, Braver et al. (2009) found that young adult participants shifted from a proactive control strategy, observed during the baseline measure, to a reactive control strategy during the manipulated measure. In a following study, Gonthier et al. (2016) investigated whether a similar pattern of results could be achieved through the no-go manipulation, but without the monetary penalties. This was done by adding 24 no-go trials to a less predictable version of the AX-CPT (i.e., the AX-CPT-40). During this version of the AX-CPT, the proportion of each trial is manipulated such that AX and BY appear an equal number of times (i.e., 40% of trials) and AY and BX appear an equal number of times (i.e., 10% of trials). By adding these 24 no-go trials to the AX-CPT 40, Gonthier et al. (2016) found that participants were much less likely to use a proactive control strategy and much more likely to use a reactive control strategy when compared to their baseline scores. Gonthier et al. (2016) concluded that by introducing no-go trials into the AX-CPT 40, participants were less likely to engage in preparatory behavior (i.e., proactive control) and more likely to engage in reactionary behavior (i.e., reactive control) even without the monetary penalties. This pattern of findings can be accounted for by understanding the behavior of proactive control within the DMC framework.

A proactive mode of control relies on patterns of contextual cues (Braver, 2012; Braver et al., 2007). When these patterns become less reliable (e.g., in the AX-CPT 40) or when there are high costs to predicting an upcoming probe and preparing a behavioral response (e.g., no-go manipulation and monetary penalties) the cognitive system becomes more likely to engage a reactive rather than a proactive mode of control.

CHAPTER SIX

EVENT SEGMENTATION AND COGNITIVE CONTROL

Another possible situational difference within cognitive control is how the event was encoded into memory. A single event, although seemingly continuous, is in reality separated into many smaller events (Zacks & Swallow, 2007; Radvansky & Zacks, 2011). Evidence of event segmentation has been consistently found in studies where participants segment a filmed event into smaller events (Swallow, Zacks, & Abrams, 2009) and in reading studies that find slowed reading times during a textual transition into a new event (Radvansky & Copeland, 2010; Zwaan, Magliano, & Graesser, 1995; Zwaan, Radvansky, Hilliard, & Curiel, 1998). Although event segmentation has been long researched in the cognitive field, a recent model (the Event Horizon Model) accounts for both positive and negative influences that event segmentation can have on memory (Radvansky, 2012).

The Event Horizon Model (Radvansky, 2012) identifies event encoding through five principles. The first of these principles is that a long seemingly continuous event is segmented into many smaller events through event boundaries. Support for this principle has been shown widely in both film and reading segmenting studies (Swallow et al., 2009; Zwaan et al., 1995; Zwaan et al., 1998). The second principle of event segmentation is that information within a current event model (i.e., before the event boundary) is more available than information from a previous event model (Radvansky, 2012). Evidence for this principle can be found in reading studies that measure both reading time and memory of a sentence, within a story, that refers to an item that is either spatially related (i.e., within the same event model) or unrelated (i.e., from a different event model) to the main character in the story (Glenberg, Meyer, & Lindem, 1987; Radvansky & Copeland, 2001). These studies found that reading times were slower and memory performance was worse for spatially unrelated items compared to spatially related items (Glenberg et al., 1987; Radvansky & Copeland, 2001). A third principle within the Event Horizon Model is that a single causal link is created between event boundaries that serves to connect one event to another and help with retrieval whenever possible (Radvansky, 2012). Investigating causality in reading, Zwaan et al. (1995) found that participant reading times were slower whenever sentences lacked a causal link within a short story. The fourth and fifth principles of the Event Horizon Model both relate to the influence of interference on memory for segmented events. The fourth principle states that whenever retrieval is wholesome and noncompetitive, information across multiple event models become more accessible (Radvansky, 2012). Conversely, as mentioned in the fifth principle, whenever retrieval is partial and thus competitive, information across multiple event models become less accessible (Radvansky, 2012). This was confirmed in studies that looked at retroactive interference on list learning. These studies found that when there was a context change between the learning of two word lists participants were able to recall more words from both lists than when there was no context change (Strand, 1970). Given that the retrieval of these lists was noncompetitive (i.e., retrieve all words), a change of context (i.e., a new event model) served to reduce retroactive interference and thus proved helpful for memory (Radvansky, 2012; Strand, 1970). There are situations, as mentioned in the fifth principle, where a change of context can be detrimental to memory (Radvansky, 2012). For example, Radvansky & Copeland (2006) found that when moving items from one table to another in a virtual environment, participants remember those objects less if they walked from one room to another then if they walked the same distance within one room (Radvansky & Copeland, 2006). In this study, retrieval for the items was partial (i.e., retrieve one item) and competitive. Thus, a change of context (i.e., a new event model) increased interference at the moment of retrieval and thus proved harmful for memory (Radvansky, 2012; Radvansky & Copeland, 2006).

The Event Horizon Model has proved useful for understanding the event segmentation literature. Recent studies on cognitive control have used this model to investigate possible influences of event encoding on cognitive control (Reimer et al, 2015, 2017). Specifically, these investigate the influence of spatial shifts on event structure and cognitive control.

Event Segmentation and Proactive Control

Studies on event segmentation have long found that spatial shifts not only provide clear event boundaries (Magliano, Kopp, McNerney, Radvansky, &

Zacks, 2012; Zacks, Speer & Reynolds, 2009), but also clearly influence memory for event models (Radvansky & Copeland, 2006, 2010). Given recent findings on the differential effects of event segmentation on memory at the time of retrieval (Radvansky, 2012; Radvansky & Copeland, 2006, 2010), Reimer et al. (2015) investigated the possibility that mode of control could be influenced by creating distinct event models within a cognitive control task. Through a series of studies, Reimer et al (2015) explored the effect that adding a location shift (i.e., a change between the location of the cue and the probe) to the typical AX-CPT paradigm, had on mode of control. The purpose behind the shift was to separate the cue and the probe into different event models. Thus, for half of the trials the cue and the probe appeared on the same location (i.e., same condition) and for the other half of trials the cue and the probe appeared on opposite sides of the screen (i.e., the different condition). Reimer et al. (2015) found that the behavioral signature of a proactive mode of control (i.e., improved performance on BX trials and worse performance on AY trials) was significantly larger in the shift than in the no shift condition. Thus, shifts within a single cue-probe trial led to a stronger representation of the cue by distinguishing it from the probe (Reimer et al, 2015). This stronger representation of the cue in memory made a proactive control strategy, which places greater emphasis on the maintenance of the cue during delay, easier to use. Furthermore, these findings were true for both short (i.e., 1,000 ms) and long (i.e., 5,000 ms) cue-probe delays (Reimer et al., 2015).

In a series of follow-up studies, Reimer et al. (2015) considered the possibility that these benefits of the shift on control strategy were simply due to a change or movement between the cue and the probe. If this is true, any non-event related change (e.g., color change) or movement (e.g. movement within a box) in the cue and probe might also show benefits of the shift on control strategy. To test this possibility, Reimer et al. (2015) manipulated the color of the cue and the probe such that for half of the trials the cue and the probe were the same color (i.e., same condition), whereas for the other half of trials they were a different color (i.e., different condition). In a separate study Reimer et al. (2015) divided the screen into two separate sides by a line in the middle. Reimer et al. (2015) then used this separation of the screen to manipulate the location of the cue probe shift such that for half of the trials the cue-probe shift happened within the same side of the screen (i.e., same condition) and for the other half of trials the cue-probe shift happened across two different sides of the screen (i.e., different condition). By manipulating the color of cues and probes in one study and location of the shift in another study, Reimer et al. (2015) found the behavioral indicator of a proactive control strategy (i.e., better performance on BX trials and worse performance on AY trials) typical of young adults (see Andrews-Hanna et al., 2011; Barch et al., 2001; Braver et al., 2009; Lorsbach & Reimer, 2008; Paxton et al., 2007). This performance, however, did not interact with the cue-probe color change (i.e., same or different color condition). In contrast, there was a considerable interaction between performance on the AX-

CPT and the type of cue-probe location shift (i.e., same side vs different side cue-probe shift). Specifically, a proactive mode of control (i.e., improved performance on BX trials and worse performance on AY trials) was visible in the different side shift (i.e., different condition) compared to the same side shift (i.e., same condition). These findings are consistent with Reimer and colleague's (2015) explanation of the role of event segmentation in increasing the representation of the cue in memory by making it distinct from the probe. More precisely, changes that did not lead to the creation of an event boundary between the cue and the probe (i.e., color changes or shifts within the same side) did not lead to a better representation of the cue in memory, which in turn did not benefit proactive performance. On the other hand, changes that led to the creation of an event boundary between the cue and the probe (i.e., shifts across two different sides) meant that the cue was better represented in memory, which further promoted proactive performance.

In another study Reimer et al. (2015) wanted to provide further proof that cue probe shifts were what led to the creation of an event boundary which served to separate the cue and the probe into two distinct event models. Since this event segmentation process requires cognitive resources (Radvansky, 2012), adding a distractor task, which further drains cognitive resources, might block the formation of an event boundary and thus cancel any enhancement to proactive performance through a stronger representation of the cue (Reimer et al., 2015). To test this, Reimer et al. (2015) maintained the cue-probe shift seen in the first two studies, but between the cue and the probe a distractor task was added. If the event segmentation account proposed by Reimer and colleagues (2015) is correct, then the distractor task will block the formation of a new event boundary between the cue and the probe and thus cancel all benefits gained by the cue-probe shift. This proved successful, as the results demonstrated a proactive behavior pattern (typical of young adults) that no longer interacted with cue-probe shifts (Reimer et al., 2015). Thus, any benefit of the shift seen in an enhanced proactive behavioral pattern in previous studies was canceled out by the distractor task (Reimer et al., 2015).

Finally, it must be noted that Reimer et al. (2015) used young adults through all five studies. As evidenced by previous findings (see Andrews-Hanna et al., 2011; Barch et al., 2001; Braver et al., 2009; Lorsbach & Reimer, 2008; Paxton et al., 2007), young adults are biased to using a proactive mode of control. Thus, rather than claim that location shifts can change mode of control, through a series of studies, Reimer and colleagues (2015) established that location shifts between the cue and the probe benefit a proactive control strategy by strengthening the representation of the cue (Reimer et al., 2015).

Event Segmentation and Reactive Control

In a second study, Reimer, Radvansky, Lorsbach, and Armendarez (2017) examined whether the shift effects would remain when participants were placed in a more cognitively challenging environment. To test this, Reimer et al. (2017) had participants complete a version of the AX-CPT within an interactive, virtual reality environment. In these experiments, location shifts consisted of walking from one room to another (i.e., the different room condition) versus walking the same distance within a single room (i.e., the same room condition). When placing young adults who are typically biased towards a proactive mode of control in a virtual reality environment, Reimer et al (2017) found that participants showed an increased tendency to use a reactive control strategy than in a typical laboratory-based AX-CPT setting. This was noticeable in a lack of difference between AY and BX in both response time and accuracy. These findings are consistent with previous studies that discovered that when task difficulty increased young adult participants were more likely to use a reactive control strategy than a proactive control strategy (Speer et al., 2003). Navigating through a virtual reality environment can be both challenging and cognitively depleting, making a proactive mode of control (which is dependent on high amounts of resources) less likely to be used (Reimer et al., 2017). Moreover, when shifts were added to the virtual reality AX-CPT (i.e., walking from one room to another versus walking the same distance through a single room), rather than benefiting from the shift participants seemed to struggle even more to access the cue information (Reimer, et al., 2017). Specifically, in comparing AY and BX trials to shift type, Reimer et al. (2017) found evidence for a reactive control strategy (i.e., improved performance in AY and worse performance in BX trials) within the different room (i.e., different location) compared to the same room (i.e., same location) condition.

In a follow-up experiment, the task difficulty was increased to asses shift effects in a more reactively biased group (Reimer et al., 2017). Thus, the same virtual reality environment with the shifts from the previous study was used; the only difference was the way in which the various trials were identified. Specifically, instead of seeing different letters and identifying the letters as different trial types, target and non-target cues and probes were identified by color (i.e., target trials were now a blue X followed by a red X and non-target trials consisted of a green X or yellow X together or mixed with target colors). This increased the difficulty of the task by making cues and probes more difficult to maintain in memory and thus raising the cognitive demands of the task (Reimer et al., 2017). This manipulation proved successful, as participants showed behavioral indicators of a reactive mode of control (i.e., better performance in AX and AY and worse performance in BX). Moreover, shifts between the cue and probe furthered this reactive control strategy by showing an even greater separation between the different compared to the same location condition (i.e., greater performance for AX and AY trials and worse performance for BX trials during the different rooms compared to the same room condition).

In both experiments, the separation of the cue from the probe (i.e., the shift) rather than improve the representation of the cue as distinct from the probe in memory, placed the cue farther away during the moment of retrieval because of the probe focused strategy that was used (i.e., the reactive control strategy). This made the cue information more difficult to retrieve when the probe was presented, and thus, resulted in a greater inclination to use a reactive control strategy. When considered together, the experiments provided evidence that environmental demands can influence the mode of cognitive control that one adopts, and that the mode of control moderates the effect of event structure on the ability to represent context information.

CHAPTER SEVEN

PRESENT STUDY

Recent studies examining the differential effects of location shifts on cognitive control have found that shift effects vary depending on whether an individual has adopted a proactive or a reactive control strategy (Reimer et al., 2015, 2017). Whereas proactively-biased participants seemed to benefit from a location shift (Reimer, et al., 2015), reactively-biased participants seemed to suffer from a cue-probe location shift (Reimer, et al., 2017). These differential effects of the shift can be better understood by considering the role of event segmentation on the representation of the cue in both types of control strategies. Within the typical AX-CPT, the cue and the probe are meant to be one continuous event, separated only by their identity. When location shifts are added between the cue and the probe, however, the location shift forms an event boundary (Reimer et al., 2015). Thus, the cue and the probe become separated into two distinct events.

When using a proactive control strategy, participants focus on maintaining the cue in memory (Braver, 2012). Thus, a cue-probe location shift serves to categorize continuously maintained information. That is, the cue and the probe are placed into distinct categories within a continuously maintained set of information. This categorization serves to increase the representational quality of the cue, as distinct from the probe. Furthermore, given the proactive approach, this categorized cue information is maintained in active memory. Consequently cue-probe location shifts seem to increase memory for the cue by increasing the representation of the cue and distinguishing it from the probe in memory (Reimer et al., 2015).

When using a reactive control strategy, participants store the cue in memory and use the information gathered from the probe to retrieve the cue information from memory (Braver, 2012). Thus, during a reactive control strategy participants place high emphasis on the probe which allows them to retrieve cue information (Braver, 2012). Consequently, a cue-probe location shift within a reactive control strategy serves to further separate the cue from the probe. That is, the shift serves to separate the cue from the probe into two distinct event models. If the cue, rather than being maintained, is stored in memory and retrieved later on, then the shift will push the cue even farther from the probe during the moment of retrieval. This separation will thus serve to decrease the availability of the cue's representation in working memory. Consequently cue-probe location shifts seem to decrease memory for the cue by decreasing the availability of the cue in memory and increasing interference at the moment of retrieval (Reimer et al., 2017).

It appears that cue-probe location shifts within an adopted proactive control strategy serve to increase the availability of the cue in memory (Reimer et al., 2015). On the other hand, cue-probe location shifts within an adopted reactive control strategy appear to decrease the availability of the cue in memory

(Reimer et al., 2017). Given these findings, the purpose of the present study is to further investigate the manner in which mode of control influences the effect of location shifts on the representation of the cue within the AX-CPT. Furthermore, previous studies examining the influence of event segmentation on control strategy have utilized mixed methodology (i.e., AX-CPT presented on a computer compared to in a virtual reality environment) (Reimer et al., 2015; 2017). Thus, it is unknown whether the differential effects of location shifts on control strategy reflect true processing differences or methodological differences. The present study, therefore, directly tested whether the effect of event structure on cognitive control is dependent on the mode of control that is engaged. This was done by using two versions of the AX-CPT: a shift alone version of the AX-CPT and a shift with no-go trials version of the AX-CPT. The shift alone version of the AX-CPT examined the influence of cue-probe location shifts on a population that is typically biased to using a proactive control strategy (i.e., young adults). The shift with no-go trials version of the AX-CPT examined the influence of cue-probe location shifts with a manipulation that has been shown to induce a reactive mode of control in young adult populations (see Gonthier et al., 2016). Recall that in the Gonthier et al (2016) study, no-go trials consisted of target or non-target cues that were followed by a number. On such trials participants were instructed to withhold their response (i.e., not press anything) (Gonthier et al., 2016). By adding no-go trials to the AX-CPT, the costs associated with preparing a response ahead of time (i.e., using a proactive control strategy) were increased.

This is the case because the inclusion of no-go trials reduced the predictive nature of the cue. Thus, participants were more likely to use a reactive control strategy (Gonthier et al., 2016).

Within the present study, the presence of no-go trials is expected to change young adults' mode of control from a primarily proactive mode to a reactive mode. Furthermore, cue-probe location shifts are expected to have a differential effect on mode of control. Specifically, when an individual has engaged a proactive mode of control, shifts in the location of cues and probes should increase the ability to represent cues. Thus, young adults are expected to perform better in target AX trials and non-target BX trials, but worse on non-target AY trials (indicating the use of a proactive strategy) to a greater degree when there were shifts (i.e., different location condition) compared to when there were no shifts (i.e., same location condition). However, when individuals adopt a more reactive mode of control, shifts should decrease the availability of the cue in memory. Thus, the presence of shifts, within an adopted reactive control strategy, is expected to further increase a participant's use of a reactive mode of control, as indicated by greater performance on non-target AY trials, but worse performance on target AX trials and non-target BX trials during the different compared to the same location condition.

CHAPTER EIGHT

METHOD

Participants

A total of 80 participants took part in the present study. However, 14 participants were removed from all subsequent analysis. Thus, the final sample included 66 participants (*M* age = 20 years, 53 females and 13 males) with the following ethnicity breakdown: 62.12% Hispanic, 10.61% African American, 9.09% White, 7.58% Asian, 3.03% Middle Eastern, and 7.58% Mixed race. All participants were undergraduate students attending California State University, San Bernardino (CSUSB) (*M* yrs in college = 2, *M* GPA = 3.03). Participants were treated according to the Ethical Principles of Psychologists and Code of Conduct (American Psychological Association, 2017). In return for their participation, students received extra credit points applicable to any course that offers extra credit. All participants had normal or corrected to normal vision.

Design

The current study used a 2 (AX-CPT type: shift alone vs shift with no-go trials) x 2 (cue-probe location: same vs different) x 4 (trial type: AX vs AY vs BX vs BY) within participant design. AX-CPT type, cue-probe location, and trial type were all varied within participants. Response time (RT) and error rate (ER) on the AX-CPT 40 served as dependent variables.

Materials/Apparatus

Cognitive control was measured using the AX-CPT 40 (i.e., a modified version of the typical AX-CPT). On the typical AX-CPT, 70% of trials are target trials (i.e., AX), whereas non-target trials (i.e., AY, BX, and BY) each make-up 10% of trials. This is done in order to ensure that participants form an expectancy that A and X will very likely be together. In the AX-CPT 40, however, trial type frequencies are manipulated such that each type of cue (i.e., A, B) and probe (i.e., X, Y) are seen an equal number of times (see Gonthier et al., 2016; Richmond et al., 2015). Specifically, target AX trials make-up 40% of trials, non-target BY trials make-up 40% of trials, and non-target AY and BX trials each make up 10% of trials (Gonthier et al., 2016; Richmond et al., 2015). Previous studies have found this modified version of the AX-CPT to more accurately measure type of control strategy than the typical AX-CPT 70 (Gonthier et al., 2016; Richmond et al., 2015).

With the exception of the trial type frequency (i.e., AX-CPT 40 was used instead of the typical AX-CPT 70), materials for the present study were heavily based on Reimer et al. (2015). E-Prime software (Schneider, Eschman, and Zuccolotto, 2002) was used to create the AX-CPT 40 for the present study. The software recorded RT and accuracy rates within the AX-CPT. Participants were presented with pairs of letters appearing one at a time on a 15-inch computer monitor screen. The letters were presented in red 28pt uppercase Arial font on a black background to allow maximum contrast between the letters and the background. Letters always appeared vertically centered. The pairs of letters were presented in a cue-probe format with the cue being the first letter and the probe being the second letter. The cue and the probe appeared 31.5 cm apart. Cues and probes were always presented on either the far-left or the far-right side of the screen. Shifts between the cue and the probe occurred within each trial and were manipulated based on cue-probe location (i.e., same vs different). For half of the trials, the cue and the probe was presented in the same location, for the other half of trials, the cue and the probe was presented in different locations (see Figure 2). During the same cue-probe location trials, cues and probes appeared on the same side of the screen (e.g., both in the far-left side) (see Figure 2). Furthermore, same location trials were counterbalanced in such a way that half of the trials appeared on the far-left side of the screen and the other half appeared on the far-right side of the screen. During the different cue-probe location trials, cues and probes appeared on opposite sides of the screen (e.g., cue appeared on the far-left and probe on the far-right side of the screen) (see Figure 2). Moreover, different location trials were counterbalanced such that on half of the trials the shift occurred from left to right and on the other half of trials the shift was from right to left.

Trials were presented sequentially to create the illusion of one continuous event. In response to previous research showing no difference between short (i.e., 1000 ms) and long (i.e., 5000 ms) cue-probe delays (Reimer et al., 2015), the present study utilized a 2500 ms cue-probe delay. Furthermore and in response to previous studies using the AX-CPT 40 (Gonthier et al., 2016; Richmond et al., 2015), a 1000 ms inter-trial interval was used. Each trial consisted of the following: a cue presented for 500 ms, a blank cue-probe delay screen presented for 2500 ms, a probe for 500 ms, and finally a blank inter-trial interval screen presented for 1000 ms. Between the probe screen and the inter-trial interval screen participants were given 1500 ms to make their response (see Figure 2). Furthermore, after each response participants were given immediate feedback on the accuracy of their response. Feedback was given through a sound indicating correct (i.e., bing sound) or incorrect (i.e., buzzer sound) responses. Whenever participants did not make their response within the allotted time (i.e., 1500 ms) they received an error message asking them to respond faster and they did not receive any sound feedback. Target and non-target responses were made on a computer keyboard. Regardless of handedness, participants used their index finger to make target responses (i.e., used the J key for both left and right-handed participants) and their middle finger to make non-target responses (i.e., used the L key for right-handed participants and the G key for left-handed participants). Buttons were labeled target and non-target on the specified keys according to handedness.

Participants were given two versions of the AX-CPT (i.e., the shift alone version and the shift with no-go trials version). During the shift alone version of the AX-CPT, participants were presented with four trial types: one target trial AX (i.e., containing a target cue and a target probe) and three non-target trials AY (i.e., containing a target cue and a non-target probe), BX (i.e., containing a non-target cue and a target probe), and BY (i.e., containing a non-target cue and a non-target probe). It must be noted that Y and B in the AY and BX trials were not the exact letters the participants were shown, but in the present explanation of the task only served to represent any other letter in the alphabet that was neither A or X. Furthermore, and in agreement with previous studies (e.g., Braver et. al, 2001; Reimer, et al., 2015; Richmond et al., 2015), the letters K and Y were not used because of their visual similarity to the target letter X. In the shift with no-go trials version of the task a fifth trial type was added and consisted of a cue (i.e., target: A or non-target: B) and a random number instead of the probe.

Following the AX-CPT 40 modified task used in previous studies (see Gonthier et al., 2016; Richmond et al., 2015), stimuli was counterbalanced to ensure that participants saw A, Y, B, and X, an equal number of times (i.e., 80 times or 50% of trials). There were a total of 160 trials in the shift alone version of the AX-CPT 40 and 200 trials in the shift with no-go trials version of the AX-CPT 40. Within each type of task, 64 of the total trials were AX (i.e., 40% of trials), 16 were AY (i.e., 10% of trials), 16 were BX (i.e., 10% of trials), and 64 were BY (i.e., 40% of trials) (see Table 1). In addition to these trials, during the shift with no-go trials version of the AX-CPT, participants were presented with 40 no-go trials (i.e., as with Gonthier et al., 2016 approximately 25% of trials). Although specific trial types were shown a set number of times for counterbalancing purposes (see Table 1), the trials themselves were presented in random order.

As a method of checking our AX-CPT type manipulation, a single score of Proactive Behavioral Index (PBI) was calculated. PBI was calculated for each type of task using means from AY and BX trials. The following formula was used to calculate the PBI score: (AY-BX)/(AY+BX). This score has been used in previous studies (Braver et al., 2009; Gonthier et al., 2016) as a measure of control strategy. A positive score indicates the use of a proactive control strategy, whereas a negative score indicates the use of a reactive control strategy. A PBI score was calculated for mean RTs and accuracy within each AX-CPT.

Procedure

Participants were tested in groups of up to four in a well-lit room. Both AX-CPTs (i.e., shift alone and shift with no-go trials) were completed in a single session that took approximately 75 minutes to administer. The AX-CPTs were counterbalanced such that for half of the participants the shift alone version came first and the shift with no-go trials version came second, whereas for the other half of participants the shift with no-go trials version came first and the shift alone version came second.

Participants received the same instructions for both versions of the AX-CPT 40 with slight additional instructions for the no-go trials. Participants were instructed to look for a specific target pair (i.e., AX). However, the letters themselves appeared one at a time on the computer screen and participants were asked to respond to each letter they saw on the screen (i.e., both the cue and the probe) to ensure that both the cue and the probe were equally encoded (see Gonthier et al, 2016). Participants were instructed to press the “Yes” button for every target trial (i.e., AX) and the “No” button for every non-target trial (i.e., AY, BX, and BY). Participants were told about the shifting locations of the cue and probe letters, but were instructed to only pay attention to the actual pairs of letters. Researchers emphasized to the participants the importance of responding as quickly and as accurately as possible multiple times throughout the instructions. Target and non-target responses were made using the G, J, and L keys on the keyboard, everything else (e.g., moving through the instructions) used the spacebar button on the keyboard. After receiving instructions for the task, participants completed 10 practice trials. During the practice trials the researcher went through each of the trials with the participant and participants were encouraged to verbalize any confusion of the task instructions. In addition to the AX-CPT instructions, for the no-go task participants were told that randomly throughout the task they may encounter a number in place of the second letter (i.e., the probe). For these particular trials, participants were instructed to not press anything.

Given that the order of the AX-CPTs was counterbalanced half of the participants received the typical AX-CPT instructions and complete the first task (i.e., 160 AX-CPT trials). These participants then reviewed the AX-CPT instructions and were told about the no-go trials and how to respond (i.e., not press anything). Next participants completed the second task with no-go trials (i.e., 160 AX-CPT trials and 40 no-go trials). For the other half of participants, the instructions for the AX-CPT with no-go trials came first along with the completion of the first task (i.e., 160 AX-CPT trials and 40 no-go trials). These participants then received instructions for completing the AX-CPT only task (i.e., without any no-go trials). Afterwards participants completed the second task (i.e., 160 AX-CPT trials). Each AX-CPT version was broken up into four blocks of 40 trials each (for the shift alone version of the AX-CPT) or 50 trials each (for the shift with no-go trials version of the AX-CPT) with an optional break between each block. Furthermore, between the two tasks there was a mandatory five-minute break during which the participants were asked to provide demographic information. The researcher remained in the room with the participant throughout the instructions and completion of the task to ensure each participant's proper understanding and engagement in the task.

Table 1:

Number and Percentage of Times Each Trial Type Appeared During the AX-CPT

Trial type	Times appeared	Percent appeared
AX	64	40%
AY	16	10%
BX	16	10%
BY	64	40%
No-go trials	40	25%

Note. No-go trials will only appear during the shift with no-go trials version of the AX-CPT

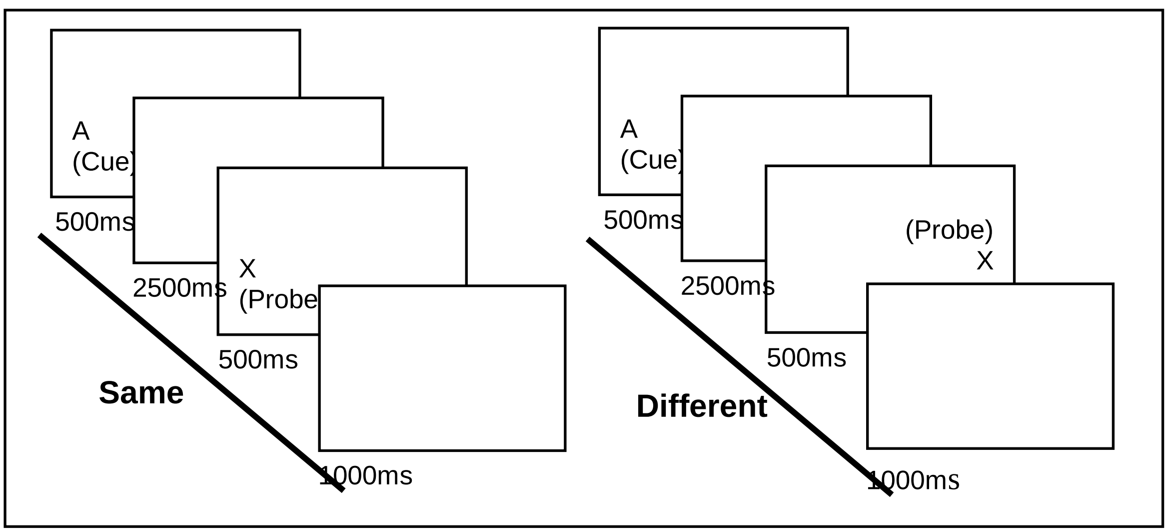

Figure 2. Timeline of a Single AX-CPT Trial for Same and Different Cue-Probe Location Conditions

CHAPTER NINE

ANALYSIS AND RESULTS

A total of fourteen participants were removed from all subsequent analyses. Two participants were removed due to computer error. Two more participants were removed due to experimenter error. One participant was removed because of non-compliance with experiment instructions. Seven participants were removed because their performance was not above chance level within the task (i.e., two participants had an ER > 50% on AY trials and five participants had an ER > 50% on BX trials). This performance pattern suggests that these participants did not understand the task instructions. Consequently, these participants were removed from further analyses. Two more participants were identified as having extreme scores (i.e., $Z > 3.4$) with undue influence on the group of scores (i.e., Cook's distance >1). Thus, these two participants were also removed from further analyses. For response time data, only correct responses were analyzed. Furthermore, only trials with response times greater than 200 ms were analyzed. During the task itself participants were given a total of 1500 ms to respond to each cue-probe pair. Thus, no response time exceeded 1500 ms. The final sample included 66 participants. Means RT and ER were calculated for each condition (see Table 2). An alpha level of .05 was adopted for all tests. Furthermore, standard rules for reporting effect size were used in both

Cohen's *d* (i.e., 0.2 is small, 0.5 is medium, and 0.8 is large) and η^2 (i.e., 0.01 is small, 0.09 is medium, and 0.25 is large).

PBI Scores

In order to test our AX-CPT type manipulation, a Proactive Behavioral Index (PBI) score was calculated for each type of task. The following formula used means from AY and BX trials to calculate the PBI score: (AY-BX)/(AY+BX). A paired samples t-test was conducted to evaluate the difference in PBI scores for the shift alone compared to the shift with no-go trials version of the AX-CPT. Analysis of PBI scores for RT showed that participants were significantly more likely to engage a proactive control strategy within the shift alone version of the AX-CPT (M = .123, SE = .013) compared to the shift with no-go trials version of the AX-CPT (M = .007, SE = .009), $t(65) = 8.53$, $p < .001$, $d = 1.05$ (large effect). Thus, when participants did the shift alone compared to the shift with no-go task, their PBI score increased by 1.05 standard deviations. This analysis was not significant within ER scores, $t(65) = -1.73$, $p = .089$, $d = -.212$ (small effect).

Target Trials (AX)

A 2 (AX-CPT Type: shift alone vs. shift with no-go trials) x 2 (Cue-Probe Location: same vs. different) repeated measures ANOVA was conducted on target trials (i.e., AX). In the RT data, there was a main effect of AX-CPT type such that participants responded significantly faster when completing the shift alone version of the AX-CPT (M = 558, SE = 10.70) compared to the shift with no-go version of the AX-CPT (*M* = 637, *SE* = 10.56), $F(1, 65) = 86.17$, $p < .001$, $\eta^2 = .047$ (small to medium effect). This effect was not significant with the ER data, $F(1, 65) = .074$, $p = .786$, $\eta^2 = .000$ (small effect).

There was also a significant main effect of cue-probe location such that participants responded significantly faster to trials in which the cue and the probe appeared in different locations (*M* = 585, *SE* = 10.11) than in the same location (*M* = 610, *SE* = 9.69), $F(1, 65) = 46.94$, $p < .001$, $\eta^2 = .047$ (small to medium effect). This effect was not found to be significant in the ER data, $F(1, 65) = .608$, $p = .438$, $\eta^2 = .003$ (small effect).

Finally, no significant interaction between type of task and cue probe location was found in either the RT, $F(1, 65) = 2.08$, $p = .154$, $\eta^2 = .001$ (small effect) or ER data, $F(1, 65) = .856$, $p = .358$, $\eta^2 = .004$ (small effect).

Non-target Trials (BY)

Although no specific hypotheses were made regarding BY trials, a 2 (AX-CPT Type: shift alone vs. shift with no-go trials) x 2 (Cue-Probe Location: same vs. different) repeated measures ANOVA was conducted on these trials.

A main effect of AX-CPT type was found with the RT data such that participants responded significantly faster when completing the shift alone version of the AX-CPT (*M* = 466, *SE* = 13.14) compared to the shift with no-go version of the AX-CPT (*M* = 639, *SE* = 11.11), $F(1, 65) = 227.68$, $p < .001$, $\eta^2 = .734$ (large effect). This effect was not found in the ER data, $F(1, 65) = .163$, $p = .687$, $\eta^2 = .001$ (small effect).

There was also a significant main effect of cue-probe location such that participants responded significantly faster to trials in which the cue and the probe appeared in different locations (*M* = 546, *SE* = 11.03) when compared to trials in which the cue and the probe appeared in the same location (*M* = 559, *SE* = 10.90), $F(1, 65) = 8.34$, $p = .005$, $\eta^2 = .004$ (small effect). This effect was not significant in the ER data, $F(1, 65) = 1.96$, $p = .166$, $\eta^2 = .012$ (small effect).

Furthermore no significant interaction between type of task and cue-probe location was found in either the RT, $F(1, 65) = .474$, $p = .493$, $\eta^2 = .000$ (small effect) or ER data, $F(1, 65) = .009$, $p = .927$, $\eta^2 = .000$ (small effect).

Non-target Trials (AY and BX)

A 2 (AX-CPT Type: shift alone vs. shift with no-go trials) x 2 (Cue-Probe Location: same vs. different) x 2 (Trial Type: AY vs. BX) repeated measures ANOVA was conducted with non-target trials (AY and BX). With the RT data, a significant main effect of AX-CPT type was found such that when completing the shift alone version of the AX-CPT participants responded significantly faster (*M* = 578, *SE* = 12.40) than when completing the shift with no-go trials version of the AX-CPT (*M* = 731, *SE* = 10.59), $F(1, 65) = 193.55$, $p < .001$, $\eta^2 = .380$ (large effect). This effect was not significant for ER data, $F(1, 65) = 1.32$, $p = .255$, $\eta^2 = .003$ (small effect).

There was also a significant main effect of cue-probe location with the RT data such that participants responded significantly faster when the cue and the probe were presented in different locations (*M* = 639, *SE* = 10.29) compared to when they were presented in the same location (*M* = 670, *SE* = 11.02), $F(1, 65) = 21.48$, $p < .001$, $\eta^2 = .015$ (small effect). This effect was not significant for ER data, $F(1, 65) = .385$, $p = .537$, $\eta^2 = .001$ (small effect).

With RTs, a third main effect was found in type of trial such that participants responded significantly faster when presented with BX trials (*M* = 621, *SE* = 12.86) than when presented with AY trials (*M* = 688, *SE* = 10.04), $F(1, 65) = 37.71$, $p < .001$, $\eta^2 = .074$ (small to medium effect). However, the opposite effect was found in the ER data, such that participants responded significantly more accurately to AY (*M* = .025, *SE* = .004) compared to BX trials (*M* = .063, *SE* = .008), $F(1, 65) = 15.26$, $p < .001$, $\eta^2 = .062$ (small to medium effect).

Furthermore, a significant interaction between type of task and type of trial was found in the RT data, $F(1, 65) = 58.97$, $p < .001$, $\eta^2 = .058$ (small to medium effect) (see Figure 3 for means and Figure 4 for residuals in Appendix A). Specifically, when completing the shift alone version of the AX-CPT, participants responded faster to BX trials (*M* = 578, *SE* = 17.26) compared to AY trials (*M* = 638, *SE* = 9.98). By contrast, when completing the shift with no-go version of the AX-CPT there was no meaningful difference between AY (*M* = 592, *SE* = 12.19) and BX (*M* = 651, *SE* = 12.95) trials. The interaction between type of task and type of trial was not found in the ER data, $F(1, 65) = 3.30$, $p = .074$, $\eta^2 = .008$ (small effect). Furthermore, no other interaction was found to be significant (i.e., all *F*s < 1) or meaningful in its effect (i.e., $\eta^2 < .001$).

Task Order

Due to the nature of the design (i.e., within participants), the present study counterbalanced the order in which the tasks were presented. Thus, it was necessary to test whether the order of the tasks had an influence on participant performance. To this end, a 2 (Task Order: shift alone then shift with no-go vs. shift with no-go then shift alone) x 2 (AX-CPT Type: shift alone vs. shift with no-go) x 2 (Cue-Probe Location: same vs. different) mixed ANOVA was conducted on target trials (AX). No significant main effect of task order was found in either the RT, $F(1, 64) = 2.17$, $p = .146$, $\eta^2 = .033$ (small to medium effect) or ER data, $F(1, 64) = 1.00$, $p = .321$, $\eta^2 = .015$ (small effect). Furthermore, no significant interaction was found between task order and type of AX-CPT presented in either RT, $F(1, 64) = 1.46$, $p = .232$, $\eta^2 = .008$ (small effect) or ER data, $F(1, 64) = .018$, $p = .893$, $\eta^2 = .000$ (small effect). Finally, no other interaction related to task order was found to be significant (i.e., all Fs < 1) or meaningful in its effect (i.e., $\eta^2 < .004$).

Similarly, a 2 (Task Order: shift alone then shift with no-go vs. shift with no-go then shift alone) x 2 (AX-CPT Type: shift alone vs. shift with no-go) x 2 (Cue-Probe Location: same vs. different) mixed ANOVA was conducted within non target trials (BY). The analysis showed no significant main effect of task order in either RT, $F(1, 64) = .648$, $p = .424$, $\eta^2 = .010$ (small effect) or ER data, $F(1, 64) = .005$, $p = .943$, $\eta^2 = .000$ (small effect). Furthermore, no significant interaction was observed between task order, type of AX-CPT, and cue-probe location within either RT, $F(1, 64) = 2.94$, $p = .091$, $\eta^2 = .003$ (small effect) or ER data, $F(1, 64) = .008$, $p = .927$, $\eta^2 = .001$ (small effect). Moreover, no other task order related interaction was found to be significant (i.e., all *F*s < 1) or meaningful in its effect (i.e., $\eta^2 < .001$).

Finally a 2 (Task Order: shift alone then shift with no-go vs. shift with no-go then shift alone) x 2 (AX-CPT Type: shift alone vs. shift with no-go) x 2 (Cue-Probe Location: same vs. different) x 2 (Trial Type: AY vs. BX) mixed ANOVA was conducted within non target trials (AY and BX). Results showed a significant main effect of task order the ER data, such that when presented with the shift alone AX-CPT first and the shift with no-go trials AX-CPT second participants responded significantly more accurately ($M = .965$, $SE = .006$) compared to when they were presented with the shift with no-go trials AX-CPT first and the shift alone AX-CPT second ($M = .947$, $SE = .006$), $F(1, 64) = 5.03$, $p < .05$, $\eta^2 = .073$ (small to medium effect). This effect was not found significant in the RT data, $F(1, 64) = 1.35$, $p = .249$, $\eta^2 = .021$ (small to medium effect).

No significant interaction was observed between task order and type of trial presented in both the RT, $F(1, 64) = 2.24$, $p = .140$, $\eta^2 = .004$ (small effect), and the ER data, $F(1, 64) = 1.32$, $p = .254$, $\eta^2 = .005$ (small effect). Moreover, there was no significant interaction between task order, type of AX-CPT, and type of trial presented, in either RT, $F(1, 64) = 2.43$, $p = .124$, $\eta^2 = .002$ (small effect), or ER data, $F(1, 64) = 1.11$, $p = .296$, $\eta^2 = .003$ (small effect). In RT data, no significant interaction was found between task order and type of AX-CPT, *F*(1,

64) = 1.87, p = .176, η^2 = .004 (small effect). Likewise, no significant interaction was found between task order, type of AX-CPT presented, and cue-probe location in RTs, $F(1, 64)$ = 1.52, p = .223, η^2 = .001 (small effect). In ER data, a non-significant interaction was observed between task order, cue-probe location, and type of trial presented, $F(1, 64)$ = 1.11, p = .296, η^2 = .002 (small effect). Furthermore, the interaction between tasks order, type of task, cue probe location, and type of trial presented, also resulted non-significant within ER data, $F(1, 64)$ = 1.37, p = .246, η^2 = .001 (small effect). Finally, no other interaction was found to be significant (i.e., all *F*s < 1) or meaningful in its effect (i.e., η^2 < .002).

First and Second Task

Given the significant main effect of task order found in the ER data of AY and BX trials, it is possible that the first task participants completed had an influence over the way in which they responded during the second task (i.e., there were carryover effects). Thus, a final 2 (AX-CPT Type: shift alone vs. shift with no-go trials) x 2 (Cue-Probe Location: same vs. different) x 2 (Trial Type: AY vs. BX) repeated measures ANOVA was conducted separately for the first task participants completed (i.e., ignoring scores from the second task) and the second task participants completed (i.e., ignoring scores from the first task). Analysis for the first task alone was done to examine any possible interaction between the variables when these were free from any carryover effects. By contrast, analysis for the second task alone was done to examine any differences from the first task analysis (i.e., the influence of any carryover effects).

Furthermore, all subsequent analyses were carried out within the ER data because the effect of task order was found only within the ER data.

<u>First Task</u>

Analysis of first task alone indicated a significant main effect of AX-CPT type such that when completing the shift alone version of the AX-CPT participants responded significantly more accurately (*M* = .033, *SE* = .008) than when completing the shift with no-go trials version of the AX-CPT (*M* = .059, *SE* = .008), $F(1, 64) = 5.70$, $p = .020$, $\eta^2 = .082$ (small to medium effect). There was also a significant main effect of trial type such that participants responded significantly more accurately in AY (*M* = .023, *SE* = .005) compared to BX trials (*M* = .069, *SE* = .011), $F(1, 64) = 13.97$, $p < .001$, $\eta^2 = .098$ (medium effect). No other main effect was significant (i.e., all *F*s < 1) or meaningful in its effect (i.e., $\eta^2 < .000$).

Furthermore, a significant interaction between type of task and type of trial presented was found, $F(1, 64) = 3.99$, $p < .05$, $\eta^2 = .028$ (small to medium effect) (see Figure 5 for means and Figure 6 for residuals in Appendix A). Specifically, when completing the shift with no-go trials version of the AX-CPT, participants responded with more accuracy to AY trials (*M* = .014, *SE* = .007) compared to BX trials (*M* = .050, *SE* = .015). By contrast, there was no meaningful difference between AY (*M* = .038, *SE* = .007) and BX (*M* = .025, *SE* = .015) trials found for the shift alone version of the AX-CPT. No significant interaction was found between cue-probe location and type of trial presented, $F(1, 64) = 1.19$, $p = .279$,

$\eta^2 = .003$ (small effect). Moreover, there was no significant relationship between AX-CPT type, cue-probe location, and type of trial presented, $F(1, 64) = 2.06$, $p = .156$, $\eta^2 = .005$ (small effect). No other interaction was found to be significant (i.e., all *F*s < 1) or meaningful in its effect (i.e., $\eta^2 < .001$).

Second Task

Analysis of second task alone indicated a significant main effect of trial type such that participants responded significantly more accurately when presented with AY trials ($M = .027$, $SE = .005$) compared to BX trials ($M = .057$, $SE = .010$), $F(1, 64) = 6.31$, $p < .05$, $\eta^2 = .048$ (small to medium effect).

No significant main effect of AX-CPT type was found, $F(1, 64) = 1.02$, $p = .317$, $\eta^2 = .016$ (small effect). No other main effect was significant (i.e., *F*s < 1) or meaningful in its effect (i.e., $\eta^2 < .002$). Furthermore, none of the observed interactions was found significant (all *F*s < 1) or meaningful in its effect (i.e., $\eta^2 < .003$).

Table 2:

Mean Correct Response Times (RT in Milliseconds) and Error Rates (ER in Percentage) by Trial Type, Task Type, and Cue-Probe Location

		Trial Type							
		AX		AY		BX		BY	
Task Type	Cue-probe Location	RT	ER	RT	ER	RT	ER	RT	ER
Shift Alone	Same	543	3.6	630	3.1	499	5.4	460	0.2
	Different	572	2.8	653	2.4	530	5.1	471	0.1
Shift With no-go	Same	627	3.3	718	2.0	709	7.9	632	0.3
	Different	647	3.4	752	2.4	745	6.9	647	0.1

CHAPTER TEN

DISCUSSION

The present study aimed to investigate the way in which mode of control and location shifts interact to influence the representation of the cue within the AX-CPT. More specifically, the present study manipulated mode of cognitive control in people to directly test whether the effect of event structure on cognitive control is dependent on mode of control.

Past research has found that the presence of no-go trials during the AX-CPT changes the mode of cognitive control young adult participants engage in, from a primarily proactive control strategy to a reactive control strategy (Gonthier et al., 2016). Thus, the present study predicted a shift in the control strategy used by participants from a primarily proactive control strategy (i.e., during the shift alone version of the AX-CPT) to a more reactive control strategy (i.e., during the shift with no-go trials version of the AX-CPT). In accordance with what was hypothesized, results showed a difference between the PBI scores in the shift alone compared to the shift with no-go trials version of the AX-CPT, with the shift alone version of the AX-CPT showing more proactive patterns of behavior and the shift with no-go trials version showing more reactive patterns of behavior. Thus, a shift in control strategy across both versions of the AX-CPT happened, as was expected.

Additionally, previous studies have found that within an adopted proactive control strategy, location shifts increase the availability of the cue in memory (Reimer et al., 2015), whereas within an adopted reactive control strategy, location shifts decrease the availability of the cue in memory (Reimer et al., 2017). Thus, in the present study, a AX-CPT type, cue-probe location, and type of trial was expected to interact in such a way that cue-probe location shifts differentially affected target AX trials and non-target AY and BX trials depending on which mode of control was engaged. Specifically, when engaging a proactive control strategy (i.e., when completing the shift alone version of the AX-CPT), shifts in the location of cues and probes were expected to increase the availability of the cue in memory. Thus, the behavioral pattern indicating the use of a proactive control strategy (i.e., better performance on AX and BX trials and worse performance on AY trials) was expected to a greater degree when the cue and the probe were in a different location compared to when they were in the same location. Furthermore, when engaging a reactive control strategy (i.e., when completing the shift with no-go trials version of the AX-CPT), shifts in the location of cues and probes were expected to increase the availability of the cue in memory. Thus, the behavioral pattern indicating the use of a reactive control strategy (i.e., better performance on AY trials and worse performance on AX and BX trials) was expected to a greater degree when the cue and the probe were in a different compared to the same location.

Analysis of target trials (i.e., AX) produced a significant main effect of AX-CPT type. That is, participants responded significantly faster when completing the shift alone version of the AX-CPT compared to the shift with no-go trials version of the AX-CPT. Results also showed a significant main effect of cue-probe location. Specifically, participants responded significantly faster when the cue and the probe were in a different compared to the same location. However, a significant interaction was not found between type of task and cue-probe location. With non-target trials (i.e., AY and BX), results showed a significant main effect of AX-CPT type. Specifically, participants responded significantly faster when completing the shift alone version of the AX-CPT compared to the shift with no-go trials version of the AX-CPT. There was also a significant main effect of cue-probe location. That is, participants responded significantly faster when the cue and the probe appeared in a different location compared to when they appeared in the same location. Additionally, a significant main effect of trial type was found in both RT and ER data. This main effect of trial type, however, is non-interpretable due to the presence of a potential speed/accuracy trade-off. With the RT data, participants responded significantly faster when presented with BX trials compared to AY trials. On the other hand, with the ER data, participants responded with significantly more accuracy when presented with AY trials compared to BX trials. Results also showed a significant interaction between type of AX-CPT performed and type of trial presented in the RT data (see Figures 3 and 4 in Appendix A). Specifically, AY and BX trials differed significantly during the shift alone version of the AX-CPT. This difference, however, disappeared when participants completed the shift with no-go trials version of the AX-CPT. Finally, no significant interaction was found between type of task, cue-probe location, and type of trial.

The present study was able to replicate past differences in PBI scores between the two versions of the AX-CPT (see Gonthier et al., 2016), with the typical version of the AX-CPT showing more proactive patterns of behavior in young adult populations (i.e., higher PBI score), and the version of the AX-CPT with added no-go trials showing a more reactive pattern of behavior (i.e., lower PBI score). Furthermore, the present study was also able to replicate previous research that found improved performance for the typical AX-CPT compared to the AX-CPT with no-go trials (Gonthier et al., 2016). These findings concur with the behavioral patterns expected by the manipulation of mode of control from each type of task. More specifically, proactive young adults completing the typical version of the AX-CPT maintained their proactive behavioral pattern (i.e., show faster RTs during the task), whereas proactive young adults completing the version of the AX-CPT with added no-go trials switch to a more reactive behavioral pattern (i.e., show slowed RTs during the task) (Gonthier et al., 2016). This switch in the overall performance between both AX-CPT types was replicated in the present study.

The present study was also able to partially replicate previous research that found improved performance when the cue and the probe appeared in different locations compared to when they appeared in the same location (Reimer et al., 2015). Reimer and colleagues (2015) attributed this improved performance to event segmentation. That is, shifts in the location of cues and probes created a boundary that placed cues and probes into different event models (Reimer et al., 2015). This boundary helps distinguish the cue from the probe and thus enhances the representation of the cue (Reimer et al., 2015). The general improved performance due to a shift in the location of cues and probes found in the present study shows an enhancement in the representation of the cue when there is a shift in location. Nevertheless, Reimer and colleagues (2015) only found shift-related improvements with BX trials, but not AY trials. In the Reimer et al (2015) study this indicated an enhancement in the use of a proactive control strategy due to the improved representation of the cue. The present study, however, found shift-related enhancements, in the representation of the cue, for both AY and BX trials. Therefore, the present findings within the BX trials (i.e., improved performance due to location shifts) were consistent with the findings in Reimer and colleagues (2015). By contrast, the present findings for the AY trials (i.e., improved performance due to location shifts) were inconsistent with the findings in Reimer and colleagues (2015). Thus, the present study was only able to partially replicate the findings in Reimer et al (2015).

Furthermore, an interesting interaction was captured between non-target trials (i.e., AY vs. BX) and type of AX-CPT (i.e., shift alone vs. shift with no-go trials) in RT data (see Figures 3 and 4 in Appendix A). This interaction replicates previous studies that found large differences between the AY and BX trials during the typical version of the AX-CPT, but not during the AX-CPT with added no-go trials (Gonthier et al., 2016). Within the AX-CPT, the use of a proactive control strategy is generally characterized by large differences in performance between AY and BX trials (Reimer et al., 2015). More specifically, the use of a proactive mode of control renders better performance in BX trials and worse performance in AY trials (Gonthier et al., 2016; Reimer et al., 2015). By contrast, the use of a reactive control strategy can be characterized by no difference between AY and BX trials, or when there is a difference, that difference is depicted by better performance in AY trials and worse performance in BX trials (Gonthier et al., 2016; Reimer et al., 2015). Thus, the interaction between AX-CPT type and trial type found in the present study serves to provide further evidence for the manipulation of control strategy across both types of AX-CPT. Specifically, the significant difference between the AY and BX trials (with better performance in BX trials and worse performance in AY trials) found in the shift alone version of the AX-CPT testifies to the use of a proactive control strategy. In contrast, the non-significant difference between the AY and BX trials found in the shift with no-go trials version of the AX-CPT testifies to the use of a reactive control strategy.

Finally, and contrary to what was hypothesized, we did not find that AX-CPT type, cue-probe location, and trial type interacted in any way (see Figures 7 and 8 in Appendix A). These findings suggest that although there are clear improvements in the representation of the cue when there are shifts in location, as well as, a clear difference in the control strategy utilized between type of task, these factors did not interact to influence each other.

The present study used a within subjects design. Thus, the order in which each type of AX-CPT was presented was counterbalanced across participants. Therefore, half of the participants completed the shift alone version of the AX-CPT first and the shift with added no-go trials AX-CPT second, whereas the other half of participants completed the shift with no-go trials version of the AX-CPT first and the shift alone AX-CPT second. Analysis of the effects of task order rendered no significant main effect or interactions with the RT data. With the ER data, however, there was a significant main effect of task order with non-target AY and BX trials. Thus, the order in which the tasks were given to participants seemed to influence the accuracy with which participants responded to AY and BX trials. Separate analyses of first task alone (i.e., the first task participants received regardless of task order) and second task alone (i.e., the second task participants received regardless of task order) were conducted to further investigate how task order influenced participant responses. Analysis of first task alone rendered significant main effects of AX-CPT type and trial type. Thus, the previously discovered effect of trial type where participants performed more accurately when presented with AY trials compared to BX trials was further fortified in the first task analysis. More interestingly, a previously missing main effect of AX-CPT type was now found in the ER data for first task alone. This effect of task type was previously discovered with the RT data, but was missing in the ER data. Analysis of first task alone for ER data, repeated the pattern found in the RT data where participants performed significantly more accurately in the shift alone AX-CPT compared to the shift with no-go trials AX-CPT.

Furthermore, an interesting interaction between type of AX-CPT and type of trial presented was found within the first task alone analysis (see Figures 5 and 6 in Appendix A). This interaction complements the interaction found in the RT data. That is, within the RT data there was a clear proactive pattern (i.e., increased performance for BX trials and decreased performance for AY trials) found in the shift alone version of the AX-CPT, but no difference was found for the shift with no-go trials version of the AX-CPT (see Figures 3 and 4 in Appendix A). Continuing with that trend, in the first task alone analysis of the ER data there was a clear reactive pattern (i.e., increased performance for AY trials and decreased performance for BX trials) found in the shift with no-go trials version of the AX-CPT, but no large enough difference was found for the shift alone version of the AX-CPT. No other interaction was found to be significant within the first task alone analysis. Analysis of second task alone only produced a significant effect of trial type previously found in ER data, where participants performed more accurately when presented with AY compared to BX trials. No other interaction was found to be significant within the second task alone analysis.

The present study found an interesting contrast with the analyses on trial type. That is, there were contradicting patterns between the RT and ER data on the effect of trial type. Within the RT data participants responded significantly faster when completing BX trials compared to AY trials. In contrast, participants responded with significantly more accuracy to AY trials compared to BX trials within the ER data. These contradicting patterns made the effect of trial type non-interpretable. However, since RT and ER were the measures used to assess AX-CPT performance in the present study, it is possible that these measures themselves contributed to the contradicting findings within type of trial. Namely, RT measures the speed with which participants responded, whereas ER measures the accuracy with which participants responded. During task instructions, participants were told to respond as quickly and as accurately as possible. Some researchers have agreed that these instructions guide participants down a nearly impossible path to balance speed and accuracy (Edwards, 1961; Seli, Cheyne, & Smilek, 2012). Thus, many participants engage in a speed-accuracy trade-off. That is, in trials where they perform faster, participants also perform with less accuracy, whereas trials in which participants perform more accurately, they perform with slowed response times. Future studies could alter the instructions for the AX-CPT to avoid possible trade-off between speed and accuracy. Another possibility is for researchers to take into consideration a possible trade-off between speed and accuracy within participant responses and control for that error within the analyses. Beyond the observed speed-accuracy tradeoff, a possible limitation of the present study was that participants were tested in groups of up to four. The group set-up may have led to a possible decrease in the motivation level of participants to follow task instructions. Locke and Braver (2008) found that motivation level plays a significant role in determining participant performance in cognitive control tasks. Thus, future studies should consider the influence of a group versus individual participant set-up when examining cognitive control.

Additionally, the present study used a within participants design. Thus, the order in which the two types of AX-CPT were presented was counterbalanced equally across participants. In some cases participants received the shift alone version of the AX-CPT alone first and the shift with no-go trials version second, whereas in other cases participants received the shift with no-go trials version of the AX-CPT first and the shift alone version second. Within the research field, investigators generally view within participant designs as very beneficial, as long as there is counterbalancing within the design (Charness, Gneezy, & Kuhn, 2011). Within participant designs benefit from increased internal validity and statistical power (Charness et al., 2011). Increased internal validity is linked to a decrease in between participant error because each participant serves as its own control across each variable (Charness et al., 2011). Statistical power is increased because more individual error is accounted for and sample size is no longer cut in half by the between participant nature of the variables (i.e., each participant experiences every level of the variable). Nevertheless, there are some concerns surrounding the use of within participant designs. Specifically, the effect of fatigue, practice, and carrying over the experience of one level of the variable to another has been a constant concern within the field of psychology (Charness et al., 2011).

Within the present study the order of the tasks was counterbalanced. Nevertheless, there was evidence that the order in which each AX-CPT was experienced did influence the accuracy with which participants responded during the study. Analyses of first task alone and second task alone within the ER data showed an interesting pattern. For one, the previously discovered main effect of trial type was still there, but now a previously undiscovered main effect of task type was found within the first task alone analysis. In the first set of analyses this effect of AX-CPT type was found in the RT data, but not in the ER data. Moreover, an additional interaction was discovered between type of AX-CPT and type of trial (see Figures 5 and 6 in Appendix A). Again, this AX-CPT type by trial type interaction was previously found in the RT data (see Figures 3 and 4 in Appendix A), but not in the ER data. Analysis of first task alone, however, uncovered this previously missing main effect and interaction. Furthermore, analysis of second task alone showed no significant interactions or main effects other than the constant effect of trial type. This difference between the pattern of data observed between analyses of the first task alone and the second task alone provides further evidence of the presence of carry-over effects within the present study. That is, experiencing one type of AX-CPT first (i.e., the first task) influenced the way in which participants responded when presented with the second type of AX-CPT (i.e., the second task). Future studies could take this into consideration when deciding whether to use a within participant design or a between participant design with the altering versions of the AX-CPT.

Furthermore, these same carry-over effects contribute to the cognitive control field by improving our understanding of the way in which participants switch from one control strategy to the next. It seems that the switch from one control strategy to the next does not happen instantaneously, but rather when there is a switch, there remains a small level of influence from the previously used strategy. Additionally, past studies have found that participants could be trained to use a proactive control strategy (Gonthier et al., 2016) These findings, along with those of the present study, open up many possibilities within education. Specifically, when students are trained in one task to use a proactive control strategy this may extend to other tasks. Future research within cognitive control could focus on the process that the cognitive system goes through to switch from one control strategy to the next.

In a series of studies, Reimer and colleagues (2015) discovered an interesting relationship between two seemingly distinct theories: mode of control and event segmentation. This led to the proposal of a structured relationship between cognitive control and event segmentation. Namely, that the segmentation of an event influenced that way in which information about a relevant task was processed within the cognitive control system. Specifically, the segmentation of an event within the context of a proactive control strategy seemed to strengthen task relevant information and thus further promote the use of a proactive control strategy (Reimer et al., 2015). Recent findings by Reimer and colleagues (2017) further informed the systematic relationship between event segmentation and cognitive control. A series of studies in Reimer et al. (2017) found that in a virtual reality environment, participants switched to a more reactive control strategy. Furthermore, within the context of a reactive control strategy, the segmentation of an event seemed to weaken task relevant information and thus further promote the use of a reactive control strategy (Reimer et al., 2017). Neither the original analyses nor the separate first and second task alone analyses, produced any replication of the findings in Reimer et al. (2015). Furthermore, the present study did not produce any of the expected patterns hypothesized from the Reimer et al. (2017) study. There are many limitations within the present study. Thus, a lack of the hypothesized findings could be due to the error caused by these limitations. It is also possible, however, that that the theory proposed by Reimer and colleagues is more complex than what was originally proposed within the present study. Furthermore, it is possible that the behavior caused by the complexities of a virtual reality environment do not easily translate to a computer task. Thus, future research could further explore the complex relationship between cognitive control and event segmentation.

APPENDIX A

FIGURES

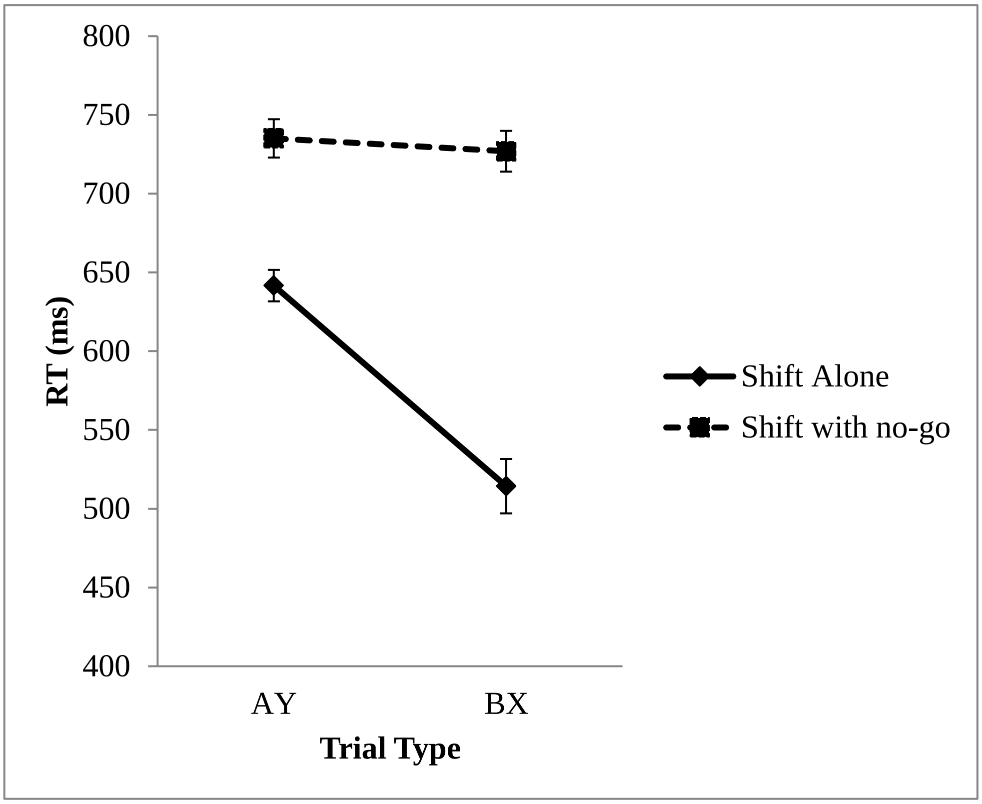

Figure 3. Significant Task Type by Trial Type Interaction in RT Based on Means

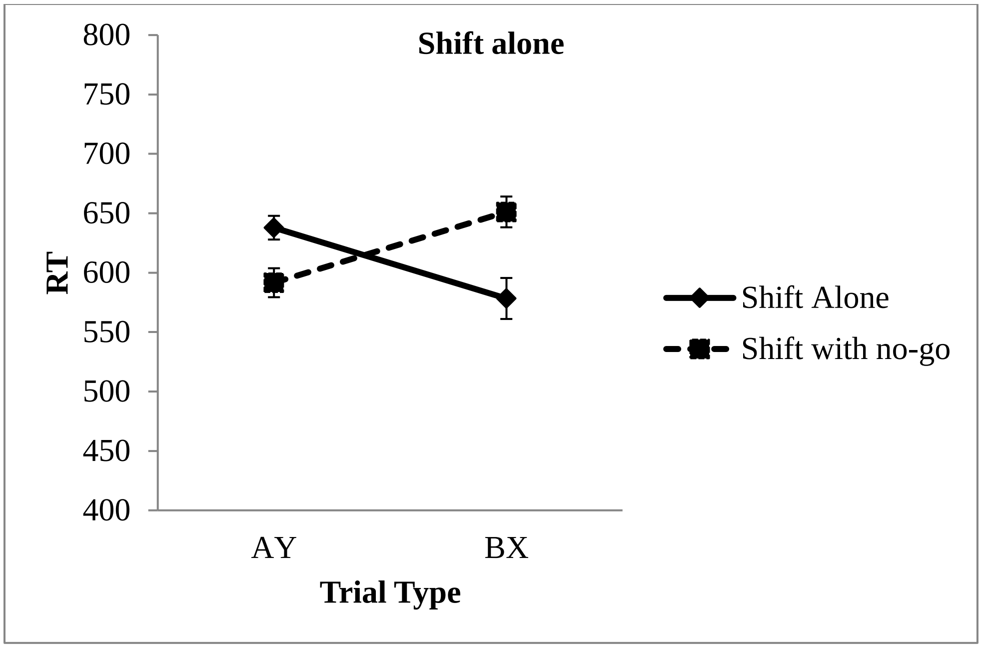

Figure 4. Significant Task Type by Trial Type Interaction in RT Based on Residual Means

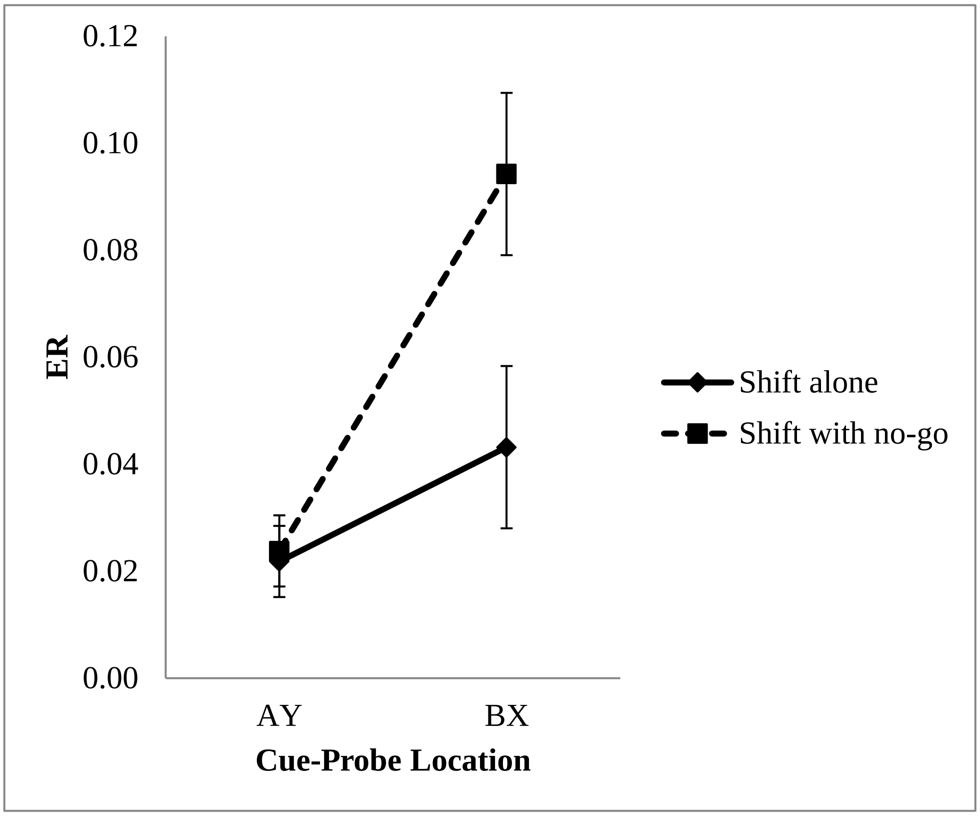

Figure 5. Significant Task Type by Trial Type Interaction in ER for First Task Alone Based on Means

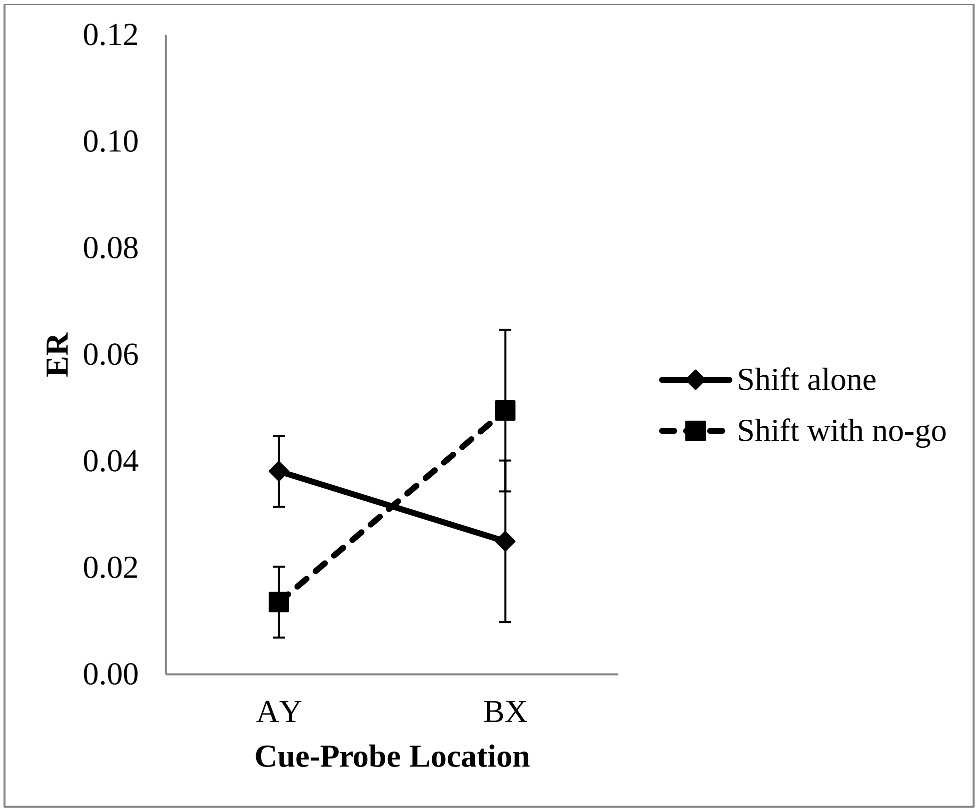

Figure 6. Significant Task Type by Trial Type Interaction in ER for First Task Alone Based on Residual Means

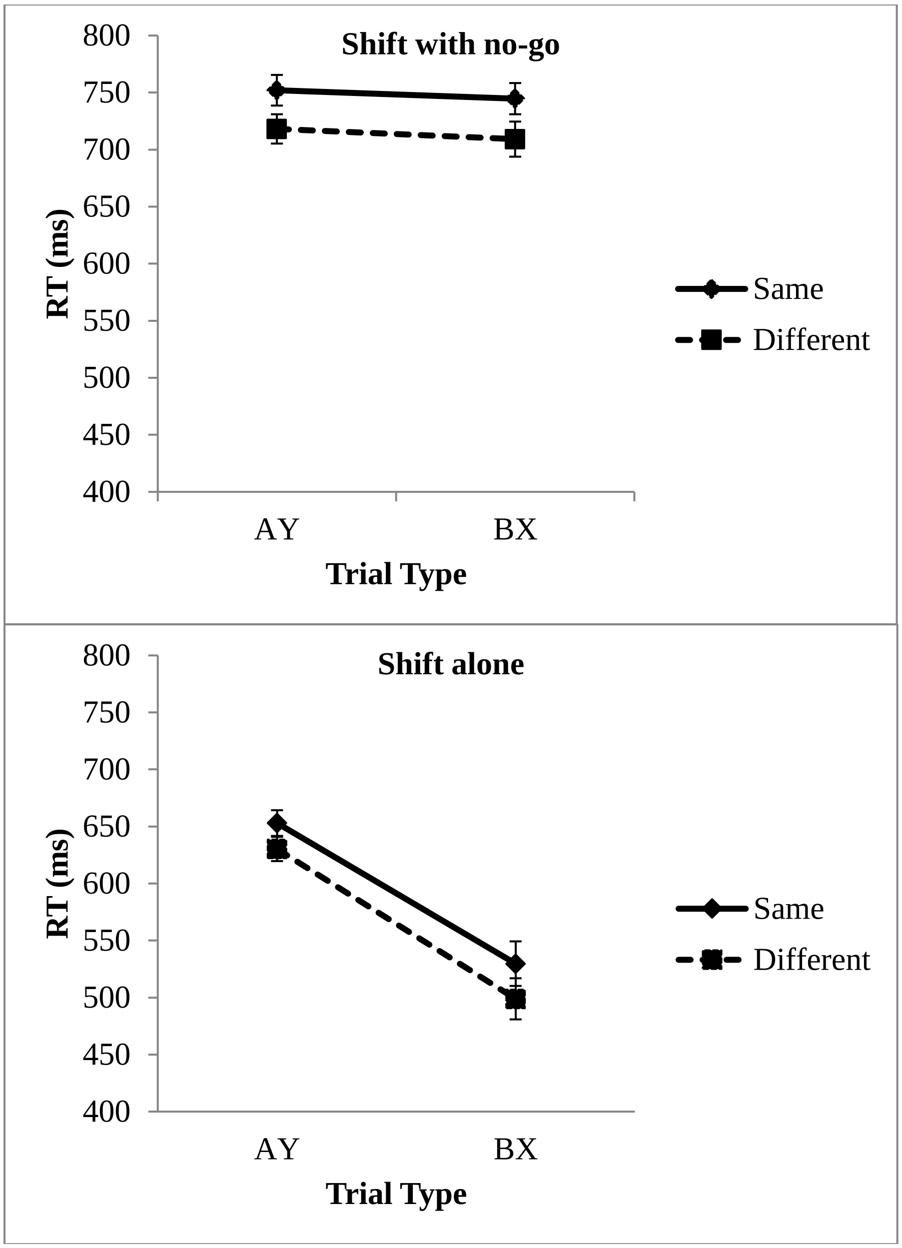

Figure 7. Non-Significant Task Type by Cue-Probe Location by Trial Type Interaction for Non-Target Trials (AY and BX) Within Reaction Time (RT)

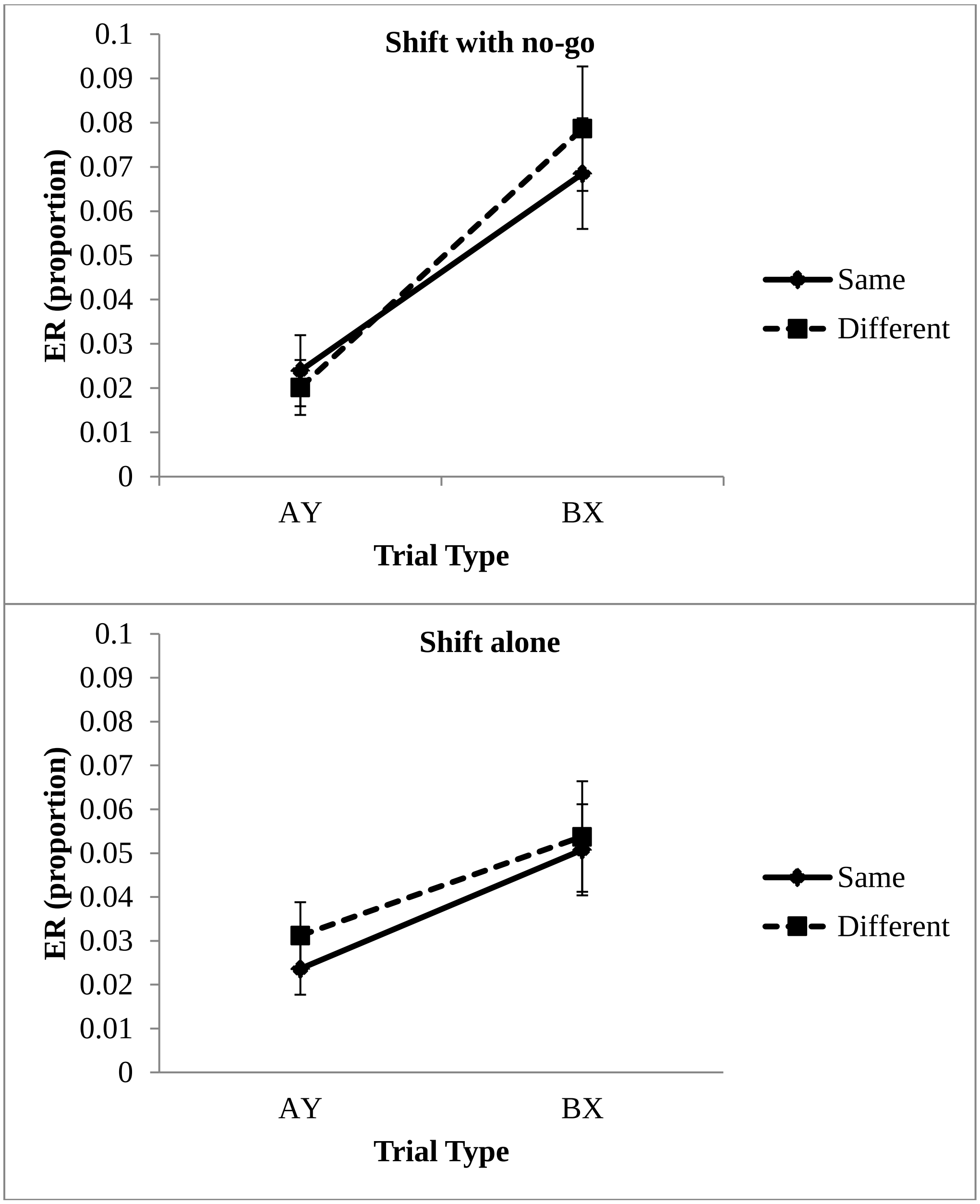

Figure 8. Non-Significant Task Type by Cue-Probe Location by Trial Type Interaction for Non-Target Trials (AY and BX) Within Error Rate (ER)

REFERENCES

American Psychological Association. (2017). Ethical Principles of Psychologists and Code of Conduct. Retrieved from < https://www.apa.org/ethics/code/ethics-code-2017.pdf>

Andrews-Hanna, J. R., Seghete, K. L. M., Claus, E. D., Burgess, G. C., Ruzic, L., & Banich, M. T. (2011). Cognitive control in adolescence: neural underpinnings and relation to self-report behaviors. *PloS one*, *6*(6), e21598. https://doi.org/10.1371/journal.pone.0021598

Badre, D. (2008). Cognitive control, hierarchy, and the rostro-caudal organization of the frontal lobes. *Trends in Cognitive Sciences, 12*(5), 193–200.

Banich, M. T. (2009). Executive function: the search for an integrated account. *Current Directions in Psychological Science 18*(2), 89–94.

Barch, D. M., Berman, M. G., Engle, R., Jones, J. H., Jonides, J., MacDonald, A. I., et al. (2009). CNTRICS final task selection: working memory. *Schizophrenia Bulletin, 35*(1), 136–152.

Barch, D. M., Carter, C. S., Braver, T. S., McDonald, A., Sabb, F. W., Noll, D. C., & Cohen, J. D. (2001). Selective deficits in prefrontal cortex function in medication-naive patients with schizophrenia. *Archives of General Psychiatry, 58*(3), 280–288.

Barch, D. M., Carter, C. S., MacDonald, A. W., Braver, T. S., & Cohen, J. D. (2003). Context-processing deficits in schizophrenia: Diagnostic specificity, 4week course, and relationships to clinical symptoms. *Journal of Abnormal Psychology, 112* (1), 132–143.

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological review*, *108*(3), 624-652.

Braver, T. S. (2012). The variable nature of cognitive control: A dual mechanisms framework. *Trends in Cognitive Sciences, 16*, 106-113.

Braver, T. S., & Cohen, J. D. (1999). Dopamine, cognitive control, and schizophrenia: the gating model. *Progress in brain research*, *121*, 327-349.

Braver, T. S., Barch, D. M., Keys, B. A., Carter, C. S., Cohen, J. D., Kaye, J. A., … Reed, B. R. (2001). Context processing in older adults: Evidence for a theory relating cognitive control to neurobiology in healthy aging. *Journal of Experimental Psychology: General, 130*, 746-763.

Braver, T. S., Gray, J. R., & Burgess, G. C. (2007). Explaining the many varieties of working memory variation: Dual mechanisms of cognitive control. In A. R. A. Conway, C. Jarrold, M. J. Kane, A. Miyake, & J. N. Towse (Eds.), *Variation in Working Memory* (pp. 76–106). New York, NY: Oxford University Press.

Braver, T. S., Paxton, J. L., Locke, H. S., & Barch, D. M. (2009). Flexible neural mechanisms of cognitive control within human prefrontal cortex. *Proceedings of the National Academy of Sciences, 106*, 7351-7356.

Braver, T. S., Reynolds, J. R., & Donaldson, D. I. (2003). Neural mechanisms of transient and sustained cognitive control during task switching. *Neuron*, *39*(4), 713-726.

Braver, T. S., Satpute, A. B., Rush, B. K., Racine, C. A., & Barch, D. M. (2005). Context processing and context maintenance in healthy aging and early stage dementia of the Alzheimer's type. *Psychology and Aging, 20*(1), 33–46.

Burgess, G. C., & Braver, T. S. (2010). Neural mechanisms of interference control in working memory: effects of interference expectancy and fluid intelligence. *PloS one*, *5*(9), e12861. https://doi.org/10.1371/journal.pone.0012861

Cahn-Weiner, D. A., Boyle, P. A., & Malloy, P. F. (2002). Tests of executive function predict instrumental activities of daily living in community-dwelling older individuals. *Applied neuropsychology*, *9*(3), 187-191.

Carlson, S. M., Moses, L. J., & Claxton, L. J. (2004). Individual differences in executive functioning and theory of mind: An investigation of inhibitory control and planning ability. *Journal of experimental child psychology*, *87*(4), 299-319.

Charness, G., Gneezy, U., & Kuhn, M. A. (2012). Experimental methods: Between-subject and within-subject design. *Journal of Economic Behavior & Organization, 81*(1), 1-8.

Chatham, C. H., Frank, M. J., & Munakata, Y. (2009). Pupillometric and behavioral markers of a developmental shift in the temporal dynamics of cognitive control. *Proceedings of the National Academy of Sciences, 106*(14), 5529–5533.

Chiew, K.S., & Braver, T.S. (2013). Temporal dynamics of motivation-cognitive control interactions revealed by high-resolution pupillometry. *Frontiers in Psychology 4*(15). doi: 10.3389/fpsyg.2013.00015

Cohen, J. D., Barch, D. M., Carter, C., & Servan-Schreiber, D. (1999). Context-processing deficits in schizophrenia: Converging evidence from three theoretically motivated cognitive tasks. *Journal of Abnormal Psychology, 108*(1), 120–133.

Czernochowski, D., Nessler, D., & Friedman, D. (2010). On why not to rush older adults—relying on reactive cognitive control can effectively reduce errors at the expense of slowed responses. *Psychophysiology*, *47*(4), 637-646.

Dove, A., Pollmann, S., Schubert, T., Wiggins, C. J., & von Cramon, D. Y. (2000). Prefrontal cortex activation in task switching: an event-related fMRI study. *Cognitive brain research*, *9*(1), 103-109.

Dreisbach, G. (2006). How positive affect modulates cognitive control: the costs and benefits of reduced maintenance capability. *BrainCognition, 60*, 11-19.

Edwards, B.G., Barch, D.M., & Braver, T.S. (2010). Improving prefrontal cortex function in schizophrenia through focused training of cognitive control. *Frontiers in Human Neuroscience*, 4(32). doi:10.3389/fnhum.2010.00032

Edwards, W. (1961). Costs and payoffs are instructions. *Psychological Review, 68*(4), 275.

Fales, C. L., Barch, D. M., Burgess, G. C., Schaefer, A., Mennin, D. S., Gray, J. R., & Braver, T. S. (2008). Anxiety and cognitive efficiency: differential modulation of transient and sustained neural activity during a working memory task. *Cognitive, affective, & behavioral neuroscience*, *8*(3), 239-253.

Fröber, K., & Dreisbach, G. (2016). How performance (non-)contingent reward modulates cognitive control. *Acta Psychol, 168*, 65–77.

Glenberg, A. M., Meyer, M., & Lindem, K. (1987). Mental models contribute to foregrounding during text comprehension. *Journal of Memory and language*, *26*(1), 69-83.

Gonthier, C., Macnamara, B. N., Chow, M., Conway, A. R. A., & Braver, T. S. (2016). Inducing proactive control shifts in the AX-CPT. *Frontiers in psychology, 7*, 1-14.

Hikosaka, O., & Isoda, M. (2010). Switching from automatic to controlled behavior: cortico-basal ganglia mechanisms. *Trends in cognitive sciences*, *14*(4), 154-161.

Holmes, A. J., MacDonald, A., III, Carter, C. S., Barch, D. M., Stenger, V. A., & Cohen, J. D. (2005). Prefrontal functioning during context processing in schizophrenia and major depression: An event related fMRI study. *Schizophrenia Research, 76*(2), 199–206.

Iselin, A. M. R., & DeCoster, J. (2009). Reactive and proactive control in incarcerated and community adolescents and young adults. *Cognitive development*, *24*(2), 192-206.

Isquith, P. K., Gioia, G. A., & Espy, K. A. (2004). Executive function in preschool children: Examination through everyday behavior. *Developmental neuropsychology*, *26*(1), 403-422.

Jacoby, L. L., Kelley, C. M., & McElree, B. D. (1999). The role of cognitive control: Early selection versus late correction. In S. Chaiken & Y. Trope (Eds.), *Dual-process theories in social psychology* (pp. 383-400). New York: Guilford Press.

Locke, H.S., & Braver, T.S. (2008). Motivational influences on cognitive control: Behavior, brain activation, and individual differences. *Cognitive, Affective, and Behavioral Neuroscience, 8*(1), 99–112.

Lorsbach, T. C., & Reimer, J. F. (2008). Context processing and cognitive control in children and young adults. *The Journal of Genetic Psychology, 169*, 34-50.

Lorsbach, T. C., & Reimer, J. F. (2010). Developmental differences in cognitive control: Goal representation and maintenance during a continuous performance task. *Journal of Cognition and Development, 11*, 185-216.

MacDonald, A. W. (2008). Building a clinically relevant cognitive task: case study of the AX paradigm. *Schizophrenia Bulletin, 34*(4), 619–628.

MacDonald, A. W., & Carter, C. S. (2003). Event-Related fMRI Study of context processing in dorsolateral prefrontal cortex of patients with Schizophrenia. *Journal of Abnormal Psychology, 112*(4), 689–697.

MacDonald, A. W., Cohen, J. D., Stenger, V. A., & Carter, C. S. (2000). Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control. *Science*, *288*(5472), 1835-1838.

MacDonald, A. W., Goghari, V. M., Hicks, B. M., Flory, J. D., Carter, C. S., & Manuck, S. B. (2005). A convergent–divergent approach to context processing, general intellectual functioning, and the genetic liability to schizophrenia. *Neuropsychology, 19*(6), 814–821.

Magliano, J., Kopp, K., McNerney, M. W., Radvansky, G. A., & Zacks, J. M. (2012). Aging and perceived event structure as a function of modality. *Aging, Neuropsychology, and Cognition*, *19*(1-2), 264-282.

Morales, J., Yudes, C., Gómez-Ariza, C. J., & Bajo, M. T. (2015). Bilingualism modulates dual mechanisms of cognitive control: Evidence from ERPs. *Neuropsychologia*, *66*, 157-169.

Nelson, T. D., Nelson, J. M., James, T. D., Clark, C. A., Kidwell, K. M., & Espy, K. A. (2017). Executive control goes to school: Implications of preschool executive performance for observed elementary classroom learning engagement. *Developmental psychology*, *53*(5), 836-844.

Paxton, J. L., Barch, D. M., Racine, C. A., & Braver, T. S. (2008). Cognitive control, goal maintenance and prefrontal function in healthy aging. *Cerebral Cortex, 18*, 1010–1028.

Paxton, J. L., Barch, D. M., Storandt, M., & Braver, T. S. (2006). Effects of environmental support and strategy training on older adults' use of context. *Psychol and Aging, 21*, 499–509.

Radvansky, G. A. (2012). Across the event horizon. *Current Directions in Psychological Science*, *21*(4), 269-272.

Radvansky, G. A., & Copeland, D. E. (2001). Working memory and situation model updating. *Memory & Cognition*, *29*(8), 1073-1080.

Radvansky, G. A., & Copeland, D. E. (2006). Walking through doorways causes forgetting: Situation models and experienced space. *Memory & cognition*, *34*(5), 1150-1156.

Radvansky, G. A., & Copeland, D. E. (2010). Reading times and the detection of event shift processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*(1), 210-216.

Radvansky, G. A., & Zacks, J. M. (2011). Event perception. *Wiley Interdisciplinary Reviews: Cognitive Science*, *2*(6), 608-620.

Redick, T. S. (2014). Cognitive control in context: Working memory capacity and proactive control. *Acta Psychologica, 145*, 1–9.

Reimer, J. F., Radvansky, G. A., Lorsbach, T. C., & Armendarez, J. J. (2015). Event structure and cognitive control. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41*, 1374-1387.

Reimer, J. F., Radvansky, G. A., Lorsbach, T. C., & Armendarez, J. J. (2017) *Walking through doorways and cognitive control.* Manuscript in preparation.

Richmond, L. L., Redick, T. S., & Braver, T. S. (2015). Remembering to prepare: The benefits (and costs) of high working memory capacity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41*, 1764-1777.

Robinson, L. J., Thompson, J. M., Gallagher, P., Gray, J. M., Young, A. H., & Ferrier, I. N. (2013). Performance monitoring and executive control of attention in euthymic bipolar disorder: Employing the CPT-AX paradigm. *Psychiatry Research, 210*, 457-464.

Rosvold, K. E., Mirsky, A. F., Sarason, I., Bransome, E. D., & Beck, L. H. (1956). A continuous performance test of brain damage. *Journal of Consulting Psychology*, *20*, 343–350.

Rushworth, M. F. S., Hadland, K. A., Paus, T., & Sipila, P. K. (2002). Role of the human medial frontal cortex in task switching: a combined fMRI and TMS study. *Journal of neurophysiology*, *87*(5), 2577-2592.

Schmid, P. C., Kleiman, T., & Amodio, D. M. (2015). Neural mechanisms of proactive and reactive cognitive control in social anxiety. C*ortex*, *70*, 137-145.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime reference guide*. Psychology Software Tools, Incorporated.

Schwarzkopp, T., Mayr, U., & Jost, K. (2016). Early selection versus late correction: Age-related differences in controlling working memory contents. *Psychology and aging*, *31*(5), 430-441.

Seli, P., Cheyne, J. A., & Smilek, D. (2012). Attention failures versus misplaced diligence: Separating attention lapses from speed–accuracy trade-offs. *Consciousness and cognition, 21*(1), 277-291.

Servan-Schreiber, D., Cohen, J. D., & Steingard, S. (1996). Schizophrenic deficits in the processing of context. A test of a theoretical model. *Archives of General Psychiatry*, 53, 1105–1112.

Speer, N. K., Jacoby, L. L., & Braver, T. S. (2003). Strategy-dependent changes in memory: Effects on behavior and brain activity. *Cognitive, Affective, & Behavioral Neuroscience*, *3*(3), 155-167.

Strand, B. Z. (1970). Change of context and retroactive inhibition. *Journal of Verbal Learning and Verbal Behavior*, *9*(2), 202-206.

Swallow, K. M., Zacks, J. M., & Abrams, R. A. (2009). Event boundaries in perception affect memory encoding and updating. *Journal of Experimental Psychology: General*, *138*(2), 236-257.

Williams, Z. M., Bush, G., Rauch, S. L., Cosgrove, G. R., & Eskandar, E. N. (2004). Human anterior cingulate neurons and the integration of monetary reward with motor responses. *Nature neuroscience*, *7*(12), 1370-1375.

Wouwe, N. C., Band, G. H., & Ridderinkhof, K. R. (2011). Positive affect modulates flexibility and evaluative control. *Journal of Cognitive Neuroscience*, *23*, 524–539.

Zacks, J. M., & Swallow, K. M. (2007). Event segmentation. *Current Directions in Psychological Science*, *16*(2), 80-84.

Zacks, J. M., Speer, N. K., & Reynolds, J. R. (2009). Segmentation in reading and film comprehension. *Journal of Experimental Psychology: General*, *138*(2), 307-327.

Zwaan, R. A., Magliano, J. P., & Graesser, A. C. (1995). Dimensions of situation model construction in narrative comprehension. *Journal Of Experimental Psychology: Learning, Memory, And Cognition, 21*(2), 386-397.

Zwaan, R. A., Radvansky, G. A., Hilliard, A. E., & Curiel, J. M. (1998). Constructing multidimensional situation models during reading. *Scientific studies of reading*, *2*(3), 199-220.