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The role of reinforcement on cognitive control and the differences between adults and children

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THE ROLE OF REINFORCEMENT ON COGNITIVE CONTROL AND THE DIFFERENCES BETWEEN ADULTS AND CHILDREN

A Thesis

Presented to the

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ABSTRACT

Recently, there has been considerable interest in better understanding how components of cognitive control may be improved. One possible way that cognitive control may be improved relates to motivation. However, the degree to which motivation affects adults and children is uncertain. Moreover, limited research has been conducted on how motivation may affect cognitive control differently from adults to children. In the current study, the way that cognitive control may be affected by environmental reinforcements is examined in both children and adults. This issue was examined by measuring the error rates and reaction times of the adults and children during the administration of the AX-CPT. Undergraduate students from California State University, San Bernardino (*N* = 51) and third grade children from the Riverside Unified School District (*N* = 49) served as participants. Participants were randomly assigned to either an experimental or control condition. It was predicted that motivational reinforcement would yield larger differences in performance between the adult control group and experimental group than the children experimental and control group due to developmental differences in cognitive processing. There were four different trial types that analyzed: AX, AY, BX, and BY. Analyses indicated that children's performance on AY and BX trials did not improve from the control group to the experimental group. However, their performance did improve on the AX trials within the experimental group. Additionally, adult's accuracy improved across all trial types (AX, BX, AY, BY) within the experimental group. Implications of these findings are discussed.

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CHAPTER ONE

INTRODUCTION

The extent to which motivation affects performance in goal directed tasks needs to be further addressed. Considerable research has examined how motivation relates to various neuro-cognitive mechanisms. For example, there appears to be good understanding of the specific neurological mechanisms that respond to reinforcement which leads to motivation. In contrast, there is considerably less research that has examined possible associations between cognitive control and motivation in children and adults. The purpose of the present study was to examine the way in which motivation affects cognitive control in both children and adults.

CHAPTER TWO

LITERATURE REVIEW

Defining Cognitive Control

Cognitive control is a broad term that has been defined in many ways. For example, it has been defined simplistically as the "cognitive processes involved in goal-directed problem solving" (Marcovitch & Zelazo, 2009, p. 1). Additionally, it has been shown to play a critical role in planning and the ability to behave in a flexible manner, especially when dealing with new information (Bjorklund, 2012). More recently, cognitive control has been defined as the ability to represent and maintain goal information. Bjorklund (2012) explains that cognitive control involves basic processing abilities such as working memory (WM), inhibition, attention, and cognitive flexibility. Moreover, Blair, Zelazo, and Greenburg (2005, p. 561) defines executive control as the "maintenance of information in working memory, the inhibition of pre-potent responding, and the appropriate shifting and sustaining of attention for the purposes of goal directed action." Additionally, it must be noted that executive control, cognitive control, and executive functioning are all terms that may be used interchangeably.

Theories of Cognitive Control

Some theorists describe executive control as a family of constructs, whereas others believe it to be a single unitary process (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001; Brocki & Bohlin, 2004). Meaning, Barkley et al. (2001) theorizes that constructs within executive control are independent of one another. Whereas, Brocki and Bohlin (2004) argued that executive control is one process, in which constructs are dependent on one another and always working together as a single unit. It has also been postulated that executive functions are separable, but are connected by way of some underlying process (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). Miyake et al. (2000) broke down cognitive control into three "main" constructs (shifting, updating, and inhibition). Shifting has been described as the separation from an irrelevant task set and the later active engagement of a relevant task set. Updating and monitoring of WM representations ("updating") has been described as the monitoring and coding of incoming information for relevance to the task at hand. The updating function revises items held in WM by replacing older, no longer relevant, information with newer, more relevant information (Morris & Jones, 1990). Inhibitory control can be described as the ability to suppress pre-potent responses, irrelevant behavioral processes, impulses, and inappropriate thoughts (Leotti & Wager, 2009).

Miyake et al. (2000) investigated performance across nine different tasks that are considered to primarily tap each of the three executive functions. Although each task that was chosen was proposed to tap only one specific cognitive control function, some overlap was observed. After investigating a three factor model based on the three target executive functions (shifting, updating, and inhibition), Miyake et al. found that there were significant correlations among the three latent variables. This suggests that these constructs are not completely independent of one another, but share some underlying commonality (Miyake et al., 2000). Additionally, it was also found that the shifting ability is needed for successful performance on the Wisconsin Card Sorting Task (WCST), while inhibition ability plays a crucial role in solving a Tower of Hanoi (TOH) puzzle. Finally, an operation span task (a measure used for verbal WM capacity) seemed to require primarily the updating ability. These results suggest that each of the target executive functions differ in their contributions to one's performance on commonly used executive functioning tasks. However, when combined with the results from the three factor model, they are also moderately correlated with one another. Therefore, these target executive functions are separate, but connected by some underlying commonality. Miyake et al. suggested that perhaps maintenance of goal information in WM could be the shared task requirements among the three target executive functions. This commonality could help explain the moderate correlation among the three target executive functions (Miyake et al., 2000). To support this proposal, Mikaye et al. noted that WM plays a significant role in several other theoretical accounts of executive functions. To summarize, several other theories propose that the frontal lobe plays an important role in the active maintenance of goals and other task-relevant information in WM (Engle et al., 1999a, 1999b; Kimberg & Farah, 1993; O'Reilly, Braver, & Cohen, 1999; Pennington, Bennetto, McAleer, & Roberts, 1996). Therefore, Miyake et al. suggested that the active maintenance and representation of goal information may be the underlying process that connects these three target executive functions together.

Collette, Van der Linden, and Laureys et al. (2005) took a physiological approach to help explain the unity and diversity of the three cognitive constructs examined in the study completed by Miyake et al. (2000). In their study, Collette et al. (2005) explored the unity and diversity of neural substrates that underlie cognitive control processes. The cerebral regions were examined with positron emission tomography (PET) while participants took part in different cognitive control tasks which tapped shifting, updating, and inhibition. Collette et al. found that each of the cognitive processes activated distinct cerebral regions. This suggests that only a specific area of the brain was activated during an inhibitory task, only a specific area of the brain was activated during an updating task, and only a specific area of the brain was activated during a shifting task. For the updating ability, the foci of activity were found in several frontal areas which included: frontopolar, superior, middle, inferior, and orbitofrontal cortices, and the intraparietal suclcus and the cerebellum. The shifting tasks reflected high activation in the right supramaginal gyrus, left precuneus, left superior parietal cortext, the intrapareital sulcus, and the left middle and inferior frontal gyri. Finally, the inhibitory tasks indicated increased activation in the right inferior frontal gyrus, right orbitofrontal gyrus, and the right middle superior frontal gyrus. However, it was also found that the posterior regions located in the left superiorparietal gyrus and in the right intraparietal sulcus were activated simultaneously during the shifting, updating, and inhibition processes. Therefore, it can be suggested that these three cognitive control constructs are separate, but can be connected by some underlying process. Moreover, these results make it clear that the parietal areas of the brain play a significant role in executive function abilities.

Cognitive Control as Goal Representation and Maintenance

Braver, Barch, and Cohen (1999) proposed a theory with some similar, but competing ideas to Collete et al. (2005). Braver et al. (1999) suggested the successful internal representation, maintenance, and updating of context information is central to the regulation of thoughts and behavior. Braver, Barch, and Keys (2001) defined context as "any task-relevant information that is internally represented in such a form that it can bias processing in the pathways responsible for task performance" (pg. 747). This type of information includes representations that have an influential impact on the early stages of cognitive processing that may involve interpretive or attentional processes. According to Braver et al.'s (2001) theoretical framework, the control of thought and behavior in WM is reliant on the use of context, or internal representations. Stemming from a connectionist model, Braver et al.'s (2001) theory integrates the idea of context representation and maintenance with functional interactions of particular neural systems. Therefore, Braver et al.'s theory used the connectionist framework to unite the psychological and biological properties of cognitive control.

Psychologically, cognitive control is regulated by representations of context which help resolve conflicts that occur at various stages of cognitive processing in task relevant pathways. That is, individuals use context information as active representations in WM in order to correctly respond to an incoming stimuli, and to overcome any prepotent tendencies. Biologically, this theory suggests that context information is found within the dorsolateral region of the prefrontal cortex, where it can be actively maintained for a short duration of time, and then accessed when faced with a task that requires the relevant context information. Being able to link the biological and psychological components of cognitive control together allows researchers to explain both how context representations and maintenance shape neurobiological constraints, while also explaining how neurobiological components may influence behavioral outcomes. Overall, Braver et al.'s (1999) theory suggests that the central underlying mechanism of cognitive control is the representation and active maintenance of context information.

Braver et al. (2001) argued that this single context processing mechanism controls the three cognitive control constructs that are often seen as independent from one another (attention, active memory, and inhibition). Braver et al. explained that in other theories, when a task involves task-irrelevant processes, inhibitory control is typically the function that is described to override these task irrelevant processes. But in Braver et al.'s model, there was no specific mechanism for inhibition. Instead, context representations complete the same function by providing the support that is needed to override task-irrelevant processes. This is accomplished with the successful active maintenance of information in the PFC, which can then facilitate control of the PFC by biasing the processing of task-relevant information (Braver & Cohen, 1999)

Similarly, context representations provide the same kind of support for tasks that typically require working memory. In a task that involves a delay between a cue and a future contingent response, WM is often assumed to be involved. However, in Braver et al.'s model, context representations are held in WM, so that task relevant information is maintained in order to inhibit a prepotent response when faced with conflicting and interfering information. Moreover, context representations serve as an attentional function by helping to select the correct task-relevant information over other competing sources of information. Therefore, context representation are held in WM and are used for tasks that are thought to involve both "inhibition" and "attention" functions. Because these two functions may be facilitated by the same underlying mechanism (context representation), they are brought together as one. However, each of these functions have been operationally defined differently based on the behavioral condition of the situation (Braver & Cohen, 1999).

In Braver et al. (2001)'s study, they investigated the physiological processes by which cognitive control constructs are regulated and activated within the brain. Braver et al. (2001) argued that problems found in cognitive control in older adults are related to the functioning between the dopamine (DA) system and the dorsolateral prefrontal cortex (DL-PFC). Therefore, cognitive control is dependent on the dynamic interaction of the DL-PFC and the DA system. It was stated that neuroimaging research provides evidence that DL-PFC remains active even during the maintenance period of different WM tasks (Braver & Cohen, 2001; Cohen et al. 1997; Courtney, Ungerleider, Keil, & Herby, 1997). In addition, Braver et al. explained that other studies have investigated how the DA system interacts with the DL-PFC, in that the DA system regulates the projections of inhibitory and excitatory afferents that are sent to the DL-PFC (Chiodo & Berger, 1986; Penit-Soria, Audinat & Crepel, 1987). During this process of regulating the projections, the DA acts as a sort of barrier, which gates all the incoming context information in different situations. Therefore, only task relevant information is being maintained by the individual if the DA system produces enough projections into the DL-PFC. If this does not occur, then it is likely that the individual may have difficulty exhibiting cognitive control. (Rush, Barch, & Braver, 2006).

The DA system is a key component in the regulation of activity that occurs in the DL-PFC. Additionally, the DL-PFC is essential in the processing of cognitive control functions. Studies have been conducted that help establish that the DA system serves as both gating and learning functions (Braver & Cohen, 2000; Braver, Cohen, & Barch, 2002). Braver and Cohen (2000) suggest that DA projections into the PFC act as a gating function, which helps determine what context information needs to be accessed and what context information needs to be stored (Braver & Cohen, 2000). Moreover, the gating function of the DA system can be facilitated by reinforcement learning (Braver & Cohen, 2000). In other words, stimuli are paired with a predictive reward so that dopaminergic activity can be used as a gating signal to help move context representation into active memory. Braver and Cohen (2000) have found that the midbrain DA neurons simulate vital reward-related information that can be paired with a stimulus situation through phasic bursts of activity. The neurons fired during these bursts of activity show temporary stimulus specific responses to particular stimuli that have been found to help predict future rewards during the task being presented (Braver & Cohen, 2000). With these responses, signaling to update representations in the PFC will occur, and as a result, it will be more likely for an individual to follow through with a behavior related to current goal state (Braver & Cohen, 2000). Therefore, frequently updating PFC representations by pairing cues that signal availability of a reward will help insure that the behavior they demonstrate will guide the individual towards the obtainment of the predicted reward (Braver & Cohen, 2000).

AX-CPT

The AX-CPT, a variant of the continuous performance task, is used as a way to measure an individual's ability to represent and maintain goal information in WM (Lorsbach & Reimer, 2010). Braver and Cohen (2001) suggest that inhibitory, attentional, and WM functions are all at work in the AX-CPT. In the AX-CPT, participants are presented with a series of letters as cue-probe pairs. Participants are instructed to make a target response to the letter "X", but only if it is preceded by the letter "A". Success in this task depends on one's ability to represent and maintain context information in WM (Braver & Cohen, 2001). Successful updating, representing, and active maintenance of context information of the cue are essential for an accurate response for the upcoming probe. When this occurs, the DA system regulates the access of the context information from the cue stimulus to the DL-PFC. This regulation process provides flexible updating and interference protection when completing the AX-CPT. Context information provided by the cue stimulus provides inhibitory and attentional functions. In this task, 70% of trials administered are target (AX) trials. During AX trials, first an A probe will appear on the computer screen, then an X probe will appear on the screen following the A cue. The target (AX) trials are the trials in which the participants are aiming to correctly respond to. However, since there is a high occurrence of the target (AX) trials, an expectancy bias is created in a couple of different ways. The high frequency of the AX trials helps the participant to represent and maintain the context information of the cue so that the participant is able to make an accurate response for the upcoming probe. However, with the high frequency of the target AX trials, the participant may draw attention to only the valid cue (A). With the focus on the valid cue (A), the representation and maintenance of the context information becomes much stronger. Therefore, participants perform well on the target (AX), but it may have a negative impact on the non-target (AY) trials. The cue (A) primes the target probe (X), and therefore, it becomes more difficult for participants to reject the non-target (AY) trials. Overall, the high frequency of target trials is beneficial for the representing and maintaining of the valid cue (A) for AX trials, but comes at a cost (i.e., slower reaction time, higher error rates) for the non-target (AY) trials. In addition, the high frequency of AX trials also creates a bias that leads participants to make a target response when the "X" probe is presented. Therefore, the participant must be able to inhibit the prepotent tendency to make a target response on BX trials. On BX trials, the participant must represent and maintain the invalid cue (B) to inhibit the dominant tendency to make a target response. Taken together, the biases that are created from the high frequency of AX trials can be measured within both the BX and AY trials.

As stated earlier, Braver and Cohen (2001) have proposed that the AX-CPT taps several constructs of cognitive control, which include: inhibition, attention, and WM. AY trials measure attentional control because the participant needs to pay close attention to the next letter presented after the target cue (A) is given (Braver et. al, 1999). This is because there is a high frequency of target (AX) trials, which creates the expectancy that an "X" will follow an "A" cue. Attending to a valid target cue (A) facilitates an accurate response for a target probe (X) on target (AX) trials. However, attending to a valid target cue (A) for non-target trials (AY), where the probe is a non-target letter (e.g., Y), may lead to more errors and slower reaction times. Performance on BX trials is based on inhibitory control because the context information from the cue must be maintained in order respond correctly to the probe (Braver et. al, 1999). With decreased inhibitory control, it is possible that the participant will respond incorrectly because they are unable represent the current relevant context information of the B cue. Therefore, with 70% of the trials being target (AX) trials, it becomes difficult to overcome a prepotent tendency to make a target response on the BX trials. WM comes into play with the AX-

CPT in that context information must be maintained and represented within active memory across the cue-probe delay (Braver et al., 2001). Shorter cue-probe delay conditions are typically 1 second, which place a lower demand on WM. Longer delay conditions are 5 seconds, which place a higher demand on WM, and are suggested to involve the maintenance of context information.

Overall, Bràver and Cohen (1999) theorized that both the attentional and inhibitory functions needed are for successful completion of the AX-CPT. Furthermore, they propose that these functions are facilitated by the same underlying mechanism- the internal representation of context information within the PFC. Braver and Cohen predict that on BX trials, the internal representation of context should improve participants performance. This improvement in performance is formed by an expectancy bias, which is created by the high frequency of AX trials (70%). Therefore, if the participants internally represent the context information of the cue, they will perform well on the BX trials. On the other hand, on AY trials, it was predicted that representation of context should actually impair performance. Braver and Cohen hypothesize that this is due to the formation of in inappropriate expectancy bias. Therefore, if there are no problems with the individual's context representations, AY performance should be worse than BX performance, with relation to the number of errors and with reaction time (RT). In opposition to this, if context representations are impaired, then BX performance should be poorer than the AY performance. Similarly, AX target trials should yield poor performance as well. Braver and Cohen predict that this would occur because the decision making of target responses will be dependent upon the context that is provided by the cue.

Developmental Differences with the AX-CPT

Braver et al. (2001) conducted a study that looked at the differences in cognitive processing of older and younger adult's performance on the AX-CPT. The predictions for this study were based off a connectionist computational model. Specifically, this model suggests that the internal representation of context information is the underlying mechanism which connects the constructs of cognitive control. Braver et al. argued that older adults suffer from disturbances in the processing of context information. As a result, older adults have impaired cognitive control across several different constructs. It was hypothesized that the impairment of cognitive control seen in healthy older adults may be due to a decline in the function of the dopamine (DA) system in the PFC. Braver et al. found that older adults performed better on certain trials (AY), but worse on other trials (BX). These results are inconsistent with the results of the younger adults. Additionally, it was found that older adults had faster RTs on AY trials when compared to younger adults. Braver et al. 2001 noted that most of the cognitive aging literature supports a positive relationship between RT and age. Braver et al. proposed that this may be because they have a decline in overall functioning in the (DA) system at an older age. Therefore, they may have disturbances in the context processing, due to developmental differences in the ability to represent context cue information. As a result, older adults would have difficulties on specific trials that require the representation and maintenance of context information.

Paxton, Barch, Storandt, and Braver (2006) conducted a study that investigated why older adults may have developmental differences on cognitive control tasks when compared to young adults. Paxton et al. (2006) found that older adults use different strategies than younger adults when completing the AX-CPT task. The results from this study indicated that older adults do not use the cue information to bias their responses in the same way as young adults (Braver et al., 2001; Paxton et al., 2006). In Experiment 1, older adults were administered the AX-CPT with different delay periods between the presentation of the cue and the probe. There was a low maintenance condition (1000 ms cue-probe delay) and a high maintenance condition (5000 ms cue-probe delay). It was predicted that older adults would have more difficulty in the high maintenance condition because they would have more difficulty maintaining the context information of the cue. Therefore, it was predicted that the older adults would make more BX errors, relative to the number of AY errors, since the AY trials are thought to impair the ability to represent context information (Braver et al., 2001). In addition to the high maintenance condition, Paxton et al. (2006) manipulated how long the cue appeared on the screen during the delay period. It was thought that having access to the cue for a longer period of time would help improve the older adult's performance in retrieving the context information to make correct responses when presented with the probe. However, the results indicated that older adults showed fewer AY errors with longer reaction times during BX trials even with the accessibility of the cue during the delay periods (Paxton et al. 2006). Paxton et al. suggests that when a participant commits an AY error, they are maintaining the context information of the target cue, but are not attending to the target or non-target probes. When a BX error is committed, they have difficulty with inhibiting a prepotent tendency to respond to a target (X) probe. Therefore, since less AY errors and more BX errors with longer reaction times were found, having access to the context information over a delay did not help improve their performance. This indicates, older adults did not use the representation of context information, even with increased exposure to the context information over the delay between the cue and the probe. This pattern of results suggests that older adults may not use context information in the same way younger adults do. One explanation for these results could be because older adults take longer to form an expectancy bias based on the context information of the cue from the differential frequency of trials (70% of target (AX) trials) (Paxton et al.). As explained earlier, when an inappropriate expectancy bias is formed during this task, more AY errors will be committed

(Braver et al., 2001). The alternate explanation for the results is that older adults are able to form expectancies similar to younger adults, but they use different strategies when responding. Paxton et al. conducted a second experiment to determine if older adults do use different strategies, or if they simply take longer to form expectancies about the frequency of differential trials types.

In Experiment 2, Paxton et al. (2006) altered the type of strategy that the older adults were using in order to make it more similar to the strategy used by the younger adults. In order to accomplish this, the experimenter used training and practice procedures in the administration of the AX-CPT for one of the conditions. These training and practice procedures involved reinstruction concerning the task rules, increasing awareness of the differential frequency of trials, specific strategy training, increasing awareness on what was being manipulated throughout the task, increased interaction, nonspecific encouragement during practice blocks, and longer practice. For the strategy training, the older adults were asked to pay attention for the letter A. If they saw the letter A, they were encouraged to press the red (target response) button, no matter what letter the probe was. If the cue was not an A, they were asked to press the yellow (non-target response) button. By doing this, experimenters expected that the older adults would be able to better attend to the context information of the cue. In addition to this group, there were also two control groups. The first control group was identical to the training and practice group, except the experimenters did not provide information about the differential frequency of trial types, and it did not provide strategy training. The second control group only included extended practice for the participants. In all three conditions, the older adults made more AY errors, fewer BX errors, and their BX reaction time increased, relative to the previous results of the first experiment. These results were consistent with the error and reaction times to that of the younger adults. However, no significant differences were found between the three conditions. Therefore, since extended practice was the only common aspect among the three conditions, this would offer the best explanation for the improved performance on their context processing.

Lorsbach and Reimer (2008) compared the performance of children with young adults on the AX-CPT to investigate developmental differences in cognitive control. For Lorsbach and Reimer's study, the theory offered by Braver and Cohen (2001) was applied. To review, this theory posits that context processing is the underlying mechanism that is responsible for the performance and functioning of cognitive control. Lorsbach and Reimer wanted to determine whether this theory could account for the developmental differences seen in cognitive control from childhood to adulthood. In this study, children and adults were administered the AX-CPT to determine if developmental differences in the ability to represent context information does exist between adults and children. Lorsbach and Reimer proposed that if developmental differences did exist, then children would likely have difficulty inhibiting prepotent responses to make valid target responses when an X probe appears. Moreover, they predicted that children would not be able to attend to the context information of the cue to prepare them for a target response. Therefore, it was hypothesized that they would make more BX errors and less AY errors when compared to the adult participants.

The results from this study confirmed that children do differ from young adults in their ability to use context information in order to regulate their behavior. Children had increased difficulty representing and/or maintaining prior context information when compared to adults. That is, relative to adults, children were less successful at using context cues (A or non-A) when responding to X probes. Lorsbach and Reimer also found that there were significant differences in performance on the non-target trials (BX, AY, BY) across age groups. For the AY trial types, young adults produced longer reaction times than the children. The longer response rates demonstrated by young adults during AY trials, relative to BY trials, suggests that they were using representations of the A cues to a produce a strong expectation that X would appear as the probe. In addition, when an X did not follow the A cue, but they did respond correctly, it took longer to process because they were accessing the context information from active memory.

The next major finding from this study comes from the BX condition, which provides information regarding developmental differences in inhibition. Because target trials appear frequently in the AX-CPT, participants form a prepotent tendency to make target responses whenever the X probe appears. Lorsbach and Reimer (2008) found that children produced significantly more errors than adults in the BX condition, relative to the BY condition. This finding suggests that children had more difficulty representing and/or maintaining context information and use it to inhibit a prepotent tendency and make a target response to the X probe.

The impact of the context processing mechanism was also reflected in Lorsbach and Reimer (2008)'s study when the demands for WM became higher. To increase the demands of working memory, a 5 second cue-probe delay was used. Lorsbach and Reimer (2008) indicated that this delay requires the active maintenance of context representations in WM. Children were found to have increased difficulty with the 5 second cue-probe delay, when compared to the adults. However, Lorsbach and Reimer clarify that although the results of the study suggest developmental differences in the maintenance of context information, they feel as though they were limited in their ability to explain the differences that were seen between adults and children. This is because these differences could have been seen either because children failed to maintain context information *or* because they were unable to form a representation of the context.

In addition to examining developmental differences between young adults and children, Lorsbach and Reimer

(2010) also conducted a study using the AX-CPT that tested third grade children and sixth grade children. Lorsbach and Reimer found it particularly important to compare the performance of these two age groups because there are significant developments in the PFC that occur during early and middle childhood. As a result, there is typically a significant increase in the performance of executive functioning from early to middle childhood. Lorsbach and Reimer argued that comparing these two age groups of children is appropriate since previous research suggests that populations with dysfunctions or an underdeveloped PFC or DA systems have difficulties in the representation and maintenance of goal information (Braver et al., 2001). Anderson (2002) explained that there is rapid growth in the frontal lobes between 7-9 years of age and again at 11-13 years of age, which may have a direct impact on children's executive functioning as well. Additionally, it has been found that the DA system and the PFC do not typically reach full maturity until early adulthood, so it is reasonable to predict that there will be improvements in performance of tasks requiring the representation and maintenance of goal-related context information.

The purpose of Lorsbach and Reimer's (2010) study was to examine developmental differences between younger and older children in their ability to represent and/or maintain the cue's goal information. Lorsbach and Reimer conducted two experiments, with each utilizing a different version of the AX-CPT. In Experiment 1, a standard version of the AX-CPT was used with a long cue probe delay (5500 ms). In the second experiment, a shorter cue probe delay was used (1000 ms), and both cue color (red or green) and cue identity (A and non- A) were manipulated within the AX-CPT. Using a shorter delay places less demand on WM for the participant because they don't have to maintain the goal information for as long as they would with the longer delay. Additionally, since the color of the cue varied with each trial, it altered the level of difficulty for the participant to represent the context information in order to respond correctly to the target. Increased difficulty occurs from the alteration of colors because now the participant not only needs to attend to the letter of the cue to prepare themselves for a target response, but also the color of the letter. In other words, the participant is required to represent more context information in order to prepare themselves for a target response.

In Experiment 2, Lorsbach and Reimer (2010) found that third grade children have greater difficulty maintaining the representation of the context information over the long delay in comparison to the sixth graders. Third grade children had much higher error rates on AX trials of the AX-CPT. Additionally; sixth graders had significantly higher error rates and longer RT's on the AY trials when compared to the third graders. These results are consistent with Paxton et al. (2006)'s study, which compared the performance of young adults and older adults on the AX-CPT. In this study, younger adults made more AY errors, and older adults less AY errors, but more BX errors. This suggests that both younger children and older adults have difficulty with maintaining the representation of context information of the target cue, so they commit more BX errors. Conversely, younger adults and older children are able to represent and maintain the context information, but they form an inappropriate expectancy bias from the differential frequency of trial types. Therefore, they commit more AY errors.

In Experiment 2, it was found that the third graders could only partially represent the context information of the cue. For example, they had highest error rates on

$A_{green}/B_{red}X$ trials, where $A_{red}X$ is the target cue-probe pair. Lorsbach and Reimer argued that this was because these trial types ($A_{green}/B_{red}X$) place the greatest representational demands on the children. With these high demands, the third graders were only able to represent the cue information about the correct letter, but the not the correct color, or vice versa. Taken together, the results of Experiments 1 and 2 suggest that the developmental differences in cognitive control exist between younger and older children when there are high demands placed on goal representation or maintenance.

Development of Anterior Cingulate Cortex and Dorsolateral-Prefrontal Cortex

As mentioned previously, it has been widely recognized that the PFC displays the most activity in the brain during cognitive control processes (Gilbert, Bird, Brindley, 2009). Specifically, the dorsolateral (DL-PFC) and ventral lateral (VL-PFC) regions of the prefrontal cortex are regions that are highly involved in the maturity of cognitive control (Liddle, Kiehl, & Smith, 2001). Liddle et al. (2001) conducted an event related fMRI study that compared cerebral activity in two different trials (go and no go trials) within the Go/No-go task. In this task, participants are asked to respond or refrain from responding to designated items of presented stimuli (e.g., A for Go trials, and X for No-go trials). Liddle et al. found that there was increased activity in the DL-PFC and VL-PFC during No-go trials, while activation of the anterior cingulate cortex (ACC) was found during both Go and No-go trials. Liddle et al. concluded that the ACC is responsible for decision formation and monitoring that is required in both types of trials, while the DL-PFC and VL-PFC has specific control over response inhibition that is required on No-go trials. In a similar study, Carter and vanVeen (2007) proposed that the ACC's primary role in cognitive control is to identify conflict between competing representations and to communicate with the DL-PFC. Carter and vanVeen suggested that the ACC may resolve conflict between competing representations by engaging attentional control mechanisms within the DL-PFC. Therefore, the ACC acts as a conflict monitor, while the DL-PFC acts as the controlling mechanism.

Based on fMRI studies, children's brains, particularly the PFC, continue to develop throughout childhood and into young adulthood (Montgomery & Koeltzow, 2010). In addition, it has been found that the PFC develops from the anterior regions to posterior regions, from ventral to dorsal regions, and from medial to lateral regions. Therefore, the ACC is among the first prefrontal regions to mature. However, research indicates that the development of the ACC is essential to the overall performance of advanced cognitive control, and is thought to act as a controlling mechanism that slows down constant or on-going responses of an individual (Montgomery & Koeltzow, 2010). This is consistent with the findings of Liddle et al. (2001) in that the ACC is thought to have control over decision formation and monitoring during the engagement of cognitive control. Brain imaging studies have found that in younger children, the ACC has been found to have increased activation, particularly during tasks that involve response conflict such as the Stroop color-naming task (Marsh, Schultz, Quackenbush, Royal, & Skudlarski et al., 2006). Therefore, poor performance on this task does not demonstrate a failure to activate the ACC. Rather, it was suggested that greater activation of this brain region in children may reveal a general lack of maturity in cognitive control, particularly in behavioral inhibition (Montgomery & Koeltzow, 2010). Montgomery and Koeltzow (2010) theorized that when a child is trying to respond correctly during a cognitive control task, they have increased difficulty in putting a stop to a prepotent response when compared to adults. Montgomery and Koeltzow proposed that this is because their behavioral inhibition systems are still in the process of developing in childhood. Therefore, greater effort must be put forth by the inhibitory function in order to "brake" a prepotent response.

The DL-PFC becomes activated when a task is completed that involves a change from repeated behavioral strategies (i.e., inhibiting a prepotent response) (Montgomery & Koeltzow, 2010). The DL-PFC receives neuronal excitatory drive from the ACC, and from there, it is projected to the basal ganglia, where these neuronal circuits control voluntary motor outputs (Yeterian & Pandya, 1991). Montgomery and Koeltzow indicate that any task that involves conflict (e.g., AX-CPT) will increase activation not only in the ACC, but also in the DL-PFC. Moreover, past studies have found that there was higher activation of the DL-PFC during the go/no go task in children when compared to adults (Casey, Giedd, Marsh, Hamburger, & Schubert et al., 1997).

Furthermore, Montgomery and Koeltzow suggested that activation of the DL-PFC during a conflict task may represent the processing of an inhibitory function. This function serves to inhibit the neuronal pathways related to latent representations, and/or select the active representations needed to complete the task successfully (Montgomery & Koeltzow). Past research has found that children with heightened activation of the DL-PFC have increased response latencies when compared to adults (Durston, Thomas, Yang, Ulug, Zimmeran, & Casey et al., 2002). It was hypothesized that the over-activation of the ACC might be problematic to the functioning of the DL-PFC (Montgomery & Koeltzow, 2010). In short, Montgomery and Koeltzow indicated that when the over activation occurs, it becomes difficult for the DL-PFC to function appropriately because there are too many alternative neuronal circuits being sent over that must be dealt with. All of this activity creates too much noise, which competes with the signal that allows the DL-PFC to make appropriate decisions. Without this signal, the DL-PFC may not be able to inhibit a prepotent response, and/or select the active representations needed to respond accurately.

Ko, Ptito, Monchi, and Soo Cho et al. (2009) conducted a study that examined the relationship between the ACC and dopamine transmission. Participants in this study completed a variant of the Wisconsin Card Sorting task (WCST), and PET was used to examine the neurotransmission of dopamine. Results indicated that performing the WCST task increased the release of dopamine into the ACC (Ko et al., 2009). As mentioned earlier, the ACC is thought to be associated with conflict monitoring during cognitive control tasks (Ko et al., 2009). Therefore, Ko et al. suggested that dopamine transmission into the ACC is essential to successful conflict monitoring. However, this research was conducted on adults and not children. Montgomery and Koeltzow specify that there is very limited research with brain imaging studies on children. Specifically, little to no research relating to the neural components of the ACC has been conducted (Montgomery & Koeltzow, 2010). It was suggested that if there is too much competing noise within the DL-PFC from all of the neural circuitry activity, it may cause the signal to gate information to become very weak. Therefore, it is possible that the dopamine transmission may not be able to be used effectively for inhibiting a prepotent response and/or selecting new task-relevant information.

Because of this, it is possible that dopamine transmission within the ACC may have little to no effect at all on a child's cognitive control processing. Thus, even with the increased transmission of dopamine from the presence of reinforcement, children's performance may not show much improvement. On the contrary, adults should perform better with increased dopamine transmission. With a fully developed PFC increased dopamine transmission can be used efficiently to promote better cognitive performance (Braver et al., 2001).

AX-CPT and Motivational Incentive

Braver and Cohen (2000) have found that adding a predictive reward to a cognitive control task, such as the AX-CPT, may improve performance. According to Braver and Cohen, the DA system helps improve the gating of relevant context information into active memory in adults. It was also found that dopaminergic activity can be controlled by reinforcement learning. Braver and Cohen defined reinforcement learning as the pairing of a stimulus with a reward. When this type of pairing occurs, there is an increase in dopaminergic activity in the DL-PFC. As a result, the gating signals controlled by the DA system may be enhanced, thereby improving cognitive control (in adults). The type of reward used in reinforcement learning is considered to be extrinsically based. Extrinsic motivation refers to external rewards that include tangible reinforcement such as sanctions, praise, positive feedback, and grades (Ryan & Deci, 2000). The other type of motivation is intrinsic motivation. Intrinsically based motivation can be thought of as a motive that keeps an individual driven to complete a task through the task's own distinctive qualities (Ryan & Deci, 2000). In other words, the individual wants to continue in the task because of the enjoyment they are experiencing as a result of the qualities that the task possesses. Some researchers have proposed that extrinsic and intrinsic motivation are interrelated, in that extrinsic motivation may actually improve intrinsic motivation by contingently rewarding an individual for correct responses throughout a task (Cameron & Pierce, 1994).

Locke and Braver (2008) conducted a study that investigated the role of motivational incentive on a cognitive control task. In that study, a reward, penalty, and control condition were included in the AX-CPT in order to examine how motivational incentives impact performance on a cognitive control task. In the reward condition, participants were given a monetary incentive, and in the penalty condition participants were told that they were losing money after committing certain types of errors. Incorporating both rewards and penalties allowed Locke and Braver to examine how cognitive control processing strategies may be altered when given a positive or negative incentive (Locke & Braver, 2008). Neuroimaging data was collected simultaneously with behavioral data to determine the specific regions of the brain that displayed sustained activity during the administration of the task during the three different conditions. Locke and Braver found that there was activity in the right lateralized dorsal, ventral, posterior PFC and motor regions, and also in the right parietal cortex, anterior cingulate cortex, and the presupplementary motor area. Additionally, past research has found that when a motivational influence was added to a cognitive control task, brain imaging studies reflected increased sustained activity in the areas associated with cognitive control (Pochon, Levy, Fossati, Lehéricy, Poline, & Pillon et al., 2002; Taylor et al., 2004). As for the behavioral data, Locke and Braver found that RTs were faster in the reinforcement condition across all trial types when compared to the penalty and control group. Locke and Braver also found a significant increase in AY errors in the reward condition, relative to the control and penalty condition, while BX errors remained the same. This suggests that the reward condition is linked to proactive control. When an individual uses a proactive control strategy, they are able to pay attention to the cue information and maintain it in order to prepare response. For example, a participant engaging in proactive control in the AX-CPT would prepare themselves for an X probe when they saw the target (A) cue appear on the screen. Therefore, they will make more AY errors. Related to these findings, and consistent with previous research (Ponchon et al., 2002), neuroimaging studies have found that there is an increase in sustained activity in the right lateral area of the PFC (RLPFC) when a reward is given. Locke and Braver suggested that components of this brain region may play a critical role in maintaining active and latent representations, depending on the motivational state of the individual. That is, if the motivational state of the individual is positive, the individual would be more likely to be able to successfully maintain active and latent representations. Another specific region of the brain that was found to have increased continuous activity was the inferior frontal junction (IFJ). Activity has been seen within the IFJ during many cognitive tasks including task switching, WM, and response inhibition tasks. Additionally, Locke and Braver (2008) proposed that the right ventrolateral frontal cortex (RVLPFC) may be connected to cognitive inhibition. A subregion of the RVLPFC may have played a role in the participant's performance during the AX-CPT. Specifically, they needed to inhibit a prepotent tendency to make a target response during non-target trials since 70% of the trials were target trials. Increased activity may have enabled a higher level of inhibition for the participants.

Purpose and Hypotheses

Although past research supports the idea that motivation increases dopaminergic activity, and that increased dopaminergic activity within the PFC is essential in the performance of cognitive control (e.g., Hämmerer & Eppinger, 2012), there is very little research connecting these two ideas. Additionally, reinforcement has been investigated in terms of how it affects children as a population and how it affects adults as a population (e.g., Braver & Cohen, 2001; Hämmerer & Eppinger). However, limited research has brought the two populations together in a study in order to compare the differences in cognitive control between the two groups when given reinforcement. Additionally, very little research has been conducted regarding how reinforcement may affect children and adults differently when completing a comparable cognitive control task. As mentioned earlier, there are vast differences in the maturity level of the PFC of children and adults, and decreased difficulties in cognitive control as a product of this. Therefore, the current study incorporates a measure of cognitive control that can be administered to both adults and children. In this way, a more accurate model of cognitive control may be used for both populations when making comparisons relating to reinforcement effects.

Using the AX-CPT with adults and children, the current study was designed to examine the role of reinforcement in a cognitive control task. The AX-CPT allows cognitive control to be examined from a broad perspective, in that it taps multiple constructs of cognitive control: inhibition, attention, and WM (Braver et al., 2001). Additionally, past research has incorporated the AX-CPT in studies that look to determine the location of various brain regions that are activated during the administration of the cognitive control task (Miyake et al., 2000). Moreover, the AX-CPT has been used to assist researchers in understanding how cognitive control may be influenced by dopaminergic activity in adults (Cohen et al., 2002). To review, Braver et al. (2001) noted that the DA system regulates incoming context information so that only task relevant information is maintained in working memory. Braver et al. (2001) proposed that when enough DA is projected into the DL-PFC, successful active maintenance of task relevant information within WM is likely to occur. Relating this idea to the AX-CPT, Braver et al. have indicated that this task requires the ability to represent context information and maintain context information over a short period of time. However, to date, previous research has only employed the AX-CPT with adults, and not with children, when examining the effects of reinforcement and motivational incentive on cognitive control. Thus, the purpose of the current study was to investigate how the age of an individual may impact the effects that reinforcement may have on cognitive control abilities.

Montgomery and Koeltzow (2010) proposed that children engaging in a cognitive control task have a highly activated ACC. Montgomery and Koeltzow suggested that this may be because children's behavioral inhibition systems have not reached full maturity. As a result, more effort must be put forth by the inhibitory system in order to constrain a prepotent response. Therefore, the level of neural activity seen within the ACC becomes much higher. Montgomery and Koeltzow further suggested that an overload of activity in the ACC may equate to too much noise when all of the neural circuitry is sent to the DL-PFC. Too much noise may make it difficult for the DL-PFC to identify the signal that is needed to gate relevant and irrelevant information necessary for a cognitive control task. In a study by Ko et al., (2009), it was found that dopaminergic activity within the ACC is crucial for effective conflict monitoring. However, this study was conducted only on adults. Montgomery and Koeltzow stated that very limited research has been conducted on the neural components associated with the ACC. If the signal in the DL-PFC is being compromised by the high activity of neural circuitry, it is possible that increased dopaminergic activity may not be able to be utilized efficiently for the processing of cognitive control. Therefore, even with the increased transmission of dopamine from the presence of reinforcement, children's performance may not show much improvement. Conversely, adults should yield better performance within the reinforcement condition. Adults with a fully developed PFC can efficiently use increased dopamine transmission in order to promote better cognitive performance (Braver et al., 2001). For that reason, it is predicted that children within the reinforcement condition will have very little difference in cognitive control abilities in the AX-CPT when compared to the child non-reinforcement group. Between the child groups (non-reinforcement and reinforcement), it was predicted that there would be no significant differences in errors or reaction times with each of the trials types (AX, AY, BX, BY). More specifically, for the AX trial, there would be no significant differences in errors or RT from reinforcement to the non-reinforcement group. For the AY trial, there would be no significant differences in errors or RT from the reinforcement group to the non-reinforcement group. For the BX trial, there would be no significant differences in errors or RT from the reinforcement group to the non-reinforcement group. Lastly, for BY trials, there would be no significant differences in errors or RT from the non-reinforcement group to the reinforcement group.

For the adult age group, predictions were based on the results from a study by Locke and Braver (2008). In the AY trial, it was predicted that adults in the reinforcement group would produce more errors with faster reaction times, and fewer errors with slower reaction times in the non-reinforcement group. For all other trials, it was predicted that there would be no other significant differences between reinforcement conditions in terms of error rates for each of the other trial types (AX, BX, BY). However, it was predicted that there would be significant differences in reaction times for the AX, BX, and BY trials, in that the reaction times for the adults in the reinforcement group would be faster than the non-reinforcement group.

When comparing the overall differences between adults and children, predictions were based on a study by Lorsbach and Reimer (2008), which investigated developmental differences on the AX-CPT between adults and children. It was predicted that children in both the reinforcement group and non-reinforcement group would produce significantly more errors with longer reaction times in all trial types (AX, AY, BX, BY) when compared to the adults. More specific to the trial types, it was predicted that adults in the reinforcement group would have significantly more AY errors than BX errors when compared to the children in the reinforcement group. In addition, it was predicted that there would be no significant differences from AY errors to BX errors when comparing the child reinforcement and non-reinforcement conditions. However, it was predicted that both the child reinforcement condition and non-reinforcement condition would produce significantly more BX errors relative to the BY errors when compared to the adult groups.

CHAPTER THREE

METHODS

Participants

Children participants consisted of 21 boys and 28 girls between the ages of 8 and 9 years old (all 3rd graders) who were attending one of two elementary schools within the Riverside Unified School District. The children for the study were chosen by using a random sampling method. All parents of children participating in the study provided informed consent and child assent was affirmed by all children participating in the study as well. Parents and children were informed that the child may discontinue their participation in the study at any time. Adult participants were 45 female and 6 male undergraduate adults between the ages of 18 and 55 years of age who were attending California State University, San Bernardino. Informed consent was obtained for all adults prior to participation, and they were informed that they could withdraw from participation at any time during the course of the study.

Measure

A variant of the AX-CPT, and the descriptions that were used for the task were heavily based on a study completed by Lorsbach and Reimer (2010). Letters were presented sequentially and continuously on a Dell lap top computer for the children, while the adults used an HP computer monitor. E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) was used to display the sequence of events within each trial and to record the accuracy and reaction time. Lorsbach and Reimer's (2008) study stated:

> Red letters were presented on a black background in the center of the monitor using 24-point uppercase Helvetica font. Each trial began with a cue (500 ms), followed by a blank screen (5,500 ms) representing the cue-probe delay, and ended with a letter probe (500 ms). A 2,000 ms-interval was used between trials and was filled with a blank computer screen.(p.193)

Target cue-probe sequences are "AX" trials, where the letter "A" appears and followed immediately after with the letter "X". Non target trials are any sequence with any letter except for "A" as the cue and is then followed immediately after with any letter except for "X" for the probe. Lorsbach and Reimer's (2010) study also stated:

Because of the similarity to target probe letter X, the letters K and Y were not used as non-target probes, they are not used as non-target probes. There were three types of non-target trials: BX (a cue other than the letter A followed by an X probe), AY (an A cue followed by any letter other than X), and BY (a cue that is any letter other than A followed by a probe that is any letter other than X). The letter sequences were presented randomly, with target trials appearing 70% of the time and non-targets trials (AY, BX, and BY) appearing 30% of the time. Each of the non-target trial types occurred with equal frequency (10% each). Participants were instructed to respond to each letter by pressing one of two keys labeled ''YES'' (target) and ''NO'' (non-target) on the keyboard as quickly, but as accurately, as possible. Given that children were tested, the labels ''YES'' and ''NO'' were used rather than ''target'' and ''non-target. Responses were made using two fingers of the same hand. Right-handed participants were instructed to respond with their right hand using their index finger for target trials (J key) and their middle finger for non-target trials (L key). Left-handed participants responded with their left hand using their index finger for target trials (J key) and their middle finger for non-target trials (G key). The probe was presented for 500 ms and participants were given an additional 2,000 ms in which to respond. Responses that exceeded the 2,500 ms time limit were accompanied by a message appearing on the monitor reminding the participant to respond quickly and were excluded from the analyses.(p. 193-194)

Procedure

Each child and adult was tested within a single session, which was comprised of 150 trials divided into 10 blocks of 15 trials each. After each block a percentage appeared on the screen, signifying the percentage correct responses for that block. The first two blocks within the session were practice trials, while the remaining eight blocks experimental trials. The practice trials were presented in the same fashion as the experimental trials, but they were not included within the analyses. Participants were given a short break, as desired, between trial blocks.

A private room away from distractions was used for this task. The children were taken into the room one by one during a school day, but only during academics. Adults were brought into the lab room in the basement of the Social Behavioral building on the CSUSB campus and tested individually in a setting similar to the one to which the children used.

The children and adults were randomly assigned to a control group or an experimental group. The control group was administered the AX-CPT, but was not given reinforcement (small toys/candy for children, or money for adults) throughout the entire assessment. Prior to beginning the study, the children and adults were informed that they could stop playing the "game" whenever they wanted to. The task and nature of the study was explained to the child and the adult like a game; each individual was then administered a pretest, which consisted of a full two 15 trial blocks. Before beginning the pretest, the researcher explained exactly how the participant needed to respond for target trials (AX) and non-target trials that were be presented to them, and then they were asked to demonstrate these responses by pressing the corresponding keys for target trials and non-target trials. After responding correctly, they began the pretest. The practice trials in the pretest were presented in the same fashion as the experimental trials, but they were not included within the analyses. Participants were given a short break between trial blocks.

During the test phase for the experimental group, the children and adults were reminded of the same instructions as the pretest phase, but they were also presented with the reinforcement they were going to be receiving at the end of the game. The children were asked to pick out 10 pieces of candy and/or toys of their choice from a large selection of both. Then, they were told that they needed to try doing their best so that they could get 85% or higher on each block. The researcher let them know that if they did not get 85% or higher at the end of the block, then they would lose one of their pieces of candy or a toy. However, the researcher also let them know that they would not lose any toys or candy during the pretest blocks, so they would ultimately get two pieces of candy/toys at the end of the game. The adults followed the same rules as the children, but they started out with $10.00 instead of 10 candies and/or toys. Additionally, the adults would have to achieve at least 95% accuracy on each block in order maintain their reward. At the end of the 10 blocks, if the children or adults did not have all of their candies/toys or dollars, they still received the full reward at the end of the experiment. Accuracy percentages used for this study were based on average error rates across trial types of previous studies that used the AX-CPT with children and adults (Braver et al., 2001; Paxton et al., 2008; Lorsbach & Reimer, 2010).

The children and adults that were randomly assigned to the control group which followed all the same guidelines as the experimental group, but they were not told that they would receive a piece of candy/toy or money at any point during the experiment. However, at the very end of the assessment, they were allowed to choose a 10 pieces of candy and/or toys from the selection provided, and the adults were still given the full monetary compensation ($10.00). In addition, the children and adults were debriefed immediately following the completion of the experiment. All personal and demographic information pertaining to each child and adult were kept secure and confidential. The data that was collected from the E-Prime software was entered into a database. It was reviewed and analyzed using Microsoft Excel and SPSS on a later date.

CHAPTER FOUR

RESULTS AND FINDINGS

Introduction to Results

Target (AX) and non-target (AY, BX, BY) responses were analyzed separately because each have different response requirements (pressing different buttons based on the trial type) and different frequencies of occurrence, where target trials occurred 70% of the time and non-target occurred 30% of the time. The speed of correct responses and accuracy of performance on target and non target trials were calculated based on the mean reaction times (RTs) and error rates (ERs). Since the BY trial type represents a control condition, there should be no differences from adults to children for RTs or ERs. However, to the extent that there are differences in the RTs and/or ERs between adults and children, the BY trial RTs and/or ERs were subtracted from AY and BX trials. Age differences in BY RTs and/or ERs may have to do with developmental differences in speed of processing. An alpha level of .05 was used for all statistical tests.

Target (AX) Trials

The first set of analyses examined the ERs and RTs of the third graders and the adults on target (AX) trials. Target ERs and RTs were examined separately using a 2 (Age: adults vs. children) x 2 (Condition: reinforcement vs. non-reinforcement) factorial analysis of variance (ANOVA). For ERs, results indicated that there was a main effect of age, $F(1,95) = 5.90$, $MSE = .000$, $p < .05$, where children (M = 1.5%) made significantly more errors than adults, (M = 0.4%). Additionally, there was a main effect of condition $F(1, 95) = 3.93$, $MSE = .000$, $p < .05$, where children and adults committed fewer errors in the reinforcement condition (M = 0.5%) than in the non-reinforcement condition (M = 1.4%). There was no significant interaction between age and condition for the accuracy of performance $F(1, 95) = 1.18$, $MSE = .000$, $p > .05$.

For RTs, it was found that there was no main effect of condition $F(1, 95) = 1.71$, $MSE = 15421.766$, $p > .05$. However, there was a main effect of age, $F(1, 95) = 16.52$, $MSE = 15421.766$, $p < .001$, where children (M = 607 ms) responded significantly slower on target trials than adults (M = 505 ms). Additionally, there was a significant interaction between age and the condition for the RTs on target trials, $F(1,95) = 4.074$, $MSE = 15421.766$, $p < .05$ (See Figure 1). Simple main effects test indicated that adults were significantly slower (M = 547 ms) in the reinforcement condition, than in the non-reinforcement condition (M = 464 ms), $t(47) = 3.003$, $p < .05$. There were no significant differences for children in RTs from the reinforcement to non-reinforcement, $t(48) = -.424$, $p > .05$. The slower RTs for the reinforcement condition may suggest that the adults were slowing down to ensure their accuracy on the target trials to increase their chances of keeping their reward.

Differences Between Non-target Trial Types

Non-target ERs were submitted to a 2 (age group: children vs. adults) x 2 (non-target trial type: AY, BX) x 2 (condition: reinforcement vs. non-reinforcement) mixed-ANOVA, with non-target trial type as the within-subject factor. For the AX-CPT, the BY trial type represents a control condition, in that there are no significant differences from adults (M = .094%) to children (M = 2.5%) for the ERs, $t(97) = -1.61$, $p > .05$. Therefore, BY trials were not included within the analyses for the ERs of the non-target trials. Results indicated that there was a main effect of trial type, $F(1, 97) = 4.543$, $MSE = .021$, $p < .05$. This indicates that adults and children made fewer errors on the BX trials ($M = 4.9\%$), than on the AY trials ($M = 9.4\%$). Additionally, there was a main effect of age for the ERs, $F(1, 95) = 12.05$, $MSE = .042$, $p < .05$, where children made significantly more errors ($M = 12.2\%$) than adults ($M = 2.1\%$) on both the AY and BX trial types. These effects were modified by a significant interaction Age X Trial Type interaction, $F(1, 95) = 4.835$, $MSE = .021$, $p < .05$ (See Figure 2). Simple main effects tests indicated that children made significantly more errors ($M = 16.8\%$) on AY trials than BX trials ($M = 7.7\%$), $t(48) = -2.250$, $p < .05$. However, adults did not have any significant differences from AY trials ($M = 2\%$) to BX trials ($M = 2.2\%$), $t(49) = .123$, $p > .05$.

For RTs, results revealed that there were significant differences between adults ($M = 466$ ms) and children ($M = 592$ ms) for the BY trial type, $t(97) = 4.401$, $p < .05$. However, the non-target trials were first analyzed without subtracting the BY trials out from the non-target analyses. It was found that there was a main effect of trial type, such that RTs for AY ($M = 702$ ms) trials were slower than BX trials ($M = 516$ ms), $F(1,95) = 301.64$, $MSE = 5663.392$,

$p < .05$. In addition, there was a significant interaction between trial type and age $F(1,95) = 21.582$, $MSE = 5663.39$, $p < .05$ (See Figure 3). Simple main effects tests indicated that adults were significantly faster on AY trials ($M = 608$ ms) when compared to children ($M = 796$ ms), $t(97) = 9.531$, $p < .05$. Similarly, for BX trials, adults ($M = 472$ ms) were found to be significantly faster than children ($M = 560$ ms), $t(97) = 2.889$, $p < .05$.

Non-target Trial Type Reaction Times with BY Reaction Times Removed

Because there were significant differences in RTs from adults to children for the BY trial type, a separate analysis was conducted, where BY RTs were subtracted from the AY and BX trial types. This was done based upon the assumption that differences in RTs may be related to developmental differences that affect the speed of processing from adults to children. After subtracting the BY RTs from AY and BX trial types, it was found that there was a main effect of trial type, $F(1,95) = 301.646$, $MSE = 5663.302$, $p < .05$. Based on the difference scores, AY trials ($M = 173$ ms) were significantly slower than BX trials ($M = -12$ ms). There was also a significant interaction between trial type and grade level, $F(1,97) = 21.582$, $MSE = 5663.392$, $p < .05$. Simple main effects revealed that children were significantly slower on AY trials (M = 204 ms) when compared to adults (M = 142 ms), $t(97) = 3.329$, $p < .05$. Additionally, it was found that children had significantly slower RTs (M = -31 ms) on BX trials when compared to adults (M = 6 ms), $t(97) = -2.518$, $p < .05$.

AY Trial Type

Because of the predictions that were made, AY and BX trials were also analyzed separately. For AY trials, target ERs and RTs were examined separately by a 2(age: adults vs. children) x 2(condition: reinforcement vs. non-reinforcement) factorial ANOVA. For ERs, there was a main effect of age, $F(1,95) = 13.502$, $MSE = 0.04$, $p < .05$, where children (M = 16.7%) made significantly more errors than adults (M = 2%). However, there was no main effect of condition, $F(1,95) = 13.502$, $MSE = .04$, $p > .05$, and no significant interaction, $F(1, 95) = 1.203$, $MSE = .04$, $p < .276$. Although no significant interaction was found, simple main effects indicated that the differences in ERs for adults approached significance, where adults made less errors within the reinforcement condition (*M* = 0.64%), when compared to the non-reinforcement (*M* = 4.4%) condition, $t(48) = 1.738$, $p < .089$. These results are not consistent with past research, which suggests that reinforcement should help improve cognitive control, thereby resulting in more AY errors within the reinforcement condition when compared to the non-reinforcement condition. Additionally, simple main effects indicated that there was no significant differences from reinforcement (*M* = 20.7%) to non-reinforcement (*M* = 13.7%) conditions for the children for the AY ERs, $t(47) = -.759$, $p > .05$.

For AY RTs, there was a main effect of age $F(1,95) = 97.2$, *MSE* = 8983.93, $p < .05$, where children had significantly slower RTs on AY trials (*M* = 796 ms) than adults (*M* = 608 ms). There was also a main effect of condition, where there were slower RTs in the reinforcement condition (*M* = 724 ms) when compared to the non-reinforcement condition (*M* = 681 ms). Additionally, results indicated that the interaction between age and condition approached significance, $F(1,95) = 3.604$, *MSE* = 8983.93, $p = .061$ (See Figure 4). Simple main effects tests indicated that children exhibited very little differences in RTs from reinforcement (*M* = 800 ms) to non-reinforcement condition

(M = 793 ms), $t(47)=.247$, $p < .05$, while adults demonstrated significantly slower RTs from reinforcement (M = 648 ms) to non-reinforcement(M = 569 ms) condition, $t(48)=3.372$, $p < .05$.

BX Trial Type

The subsequent analysis aimed to investigate how reinforcement affected the BX trials for children and adults. A 2(age: adults and children) x 2(condition: reinforcement and non-reinforcement) factorial ANOVA was used, and RTs and ERs were submitted separately. For RTs, it was found that there was a main effect of age $F(1,95)$ = 8.747, MSE = 22138.993, $p < .05$, where children (M = 561 ms) were significantly slower than adults (M = 472 ms). In addition, a significant interaction between age and condition was found, $F(1,95)$ = 9.343, MSE = 22138.993, $p < .05$ (See Figure 5). Simple main effects indicated that adults had significantly slower RTs within the reinforcement condition (M = 523 ms), when compared to the non-reinforcement group (M = 421 ms), $t(48)=2.708$, $p < .05$. In contrast, children did not have significant differences in RTs from reinforcement (M = 549 ms) to the non-reinforcement (*M* = 572 ms) condition, $t(47) = -.483$, $p > .05$.

For BX ERs, there was a main effect of age that was approaching significance, $F(1,95) = 3.206$, $MSE = .024$, $p = .077$, where children (*M* = 7.7%) made more errors on BX trials than adults (*M* = 2.2%). There was no main effect of condition, $F(1,95) = 0.702$, $MSE = 0.024$, $p > .05$ and no significant interaction between age and condition, $F(1, 95) = .014$, $MSE = 0.024$, $p > .05$. Additionally, simple main effects revealed there were no significant differences between conditions for adults or children for the BX ERs.

CHAPTER FIVE

DISCUSSION

Overall Hypotheses and Purpose

The purpose of the current study was to investigate how reinforcement may affect adults and children differently on a cognitive control task. Overall, it was predicted that children within the reinforcement condition would have very little differences in cognitive control abilities in the AX-CPT when compared to the child non-reinforcement group. In contrast, adults would show enhanced accuracy and faster RTs for some of the trial types within the reinforcement condition. As mentioned previously, Montgomery and Koeltzow (2010) proposed that children engaging in a cognitive control task have a highly activated ACC because of an immature behavioral inhibition system. As a result, more effort must be put forth by the inhibitory system in order to constrain a prepotent response. Therefore, the level of neural activity produced within the ACC increases because it has to work much harder to compensate for its deficits. It was further suggested that an overload of activity in the ACC may equate to too much noise when all of the neural circuitry is distributed to the DL-PFC. Too much noise may make it difficult for the DL-PFC to identify the signal that is needed to gate relevant and irrelevant information necessary for cognitive control. If the signal in the DL-PFC is being compromised by the high activity of neural circuitry, it is possible that increased dopaminergic activity may not be able to be utilized efficiently for the use of cognitive control. Therefore, even with the increased transmission of dopamine that results from the presence of reinforcement (Braver & Cohen, 2000), children's performance may not show much improvement. Conversely, adults should yield better performance within the reinforcement condition. Adults with a fully developed PFC can efficiently use increased dopamine transmission in order to promote better cognitive performance (Braver et al., 2001).

Children Hypotheses and Findings

Predictions For All Trial Types

Between the child groups (non-reinforcement and reinforcement), it was predicted that there would be no significant differences in ERs or RTs for each of the trials types (AX, AY, BX, BY). These hypotheses were partially supported.

AX Trial Type

It was predicted that there would be no significant differences from reinforcement to non-reinforcement for the children age group for target (AX) trials. The predictions were not supported by the ERs results for the AX trial type. Children were found to have significant differences between the reinforcement and non-reinforcement conditions, where children in the reinforcement condition produced fewer errors than children in the non-reinforcement condition on the target trials. Since the target (AX) trials are not typically used to measure the cognitive control abilities, the children's improved performance within the reinforcement condition for these trial types may suggest that children were able to use a type of higher order thinking, which permitted them to create a strategy that allowed them to build an association between the AX trials and reinforcement. Therefore, they were able to respond to these types of trials more accurately. Although the hypotheses for the ERs were not confirmed by the results, these predictions were supported by the results for the RTs for the AX trial type. Children were not found to have any differences in RTs from the reinforcement condition to the non-reinforcement condition. This suggests that the reinforcement (toys and candy) may have helped the children complete the task more accurately, but it did not help them improve the speed of their responses. This could have occurred because the participants were not required to make their responses as quickly as possible, rather they were just asked by the researcher to respond as quickly as they could at the beginning of the task. Additionally, maintaining their reward was not dependent on RTs, only ERs.

AY Trial Type

The hypotheses relating to the AY trial type for the children were also supported. Specifically, there were no significant differences between the reinforcement and non-reinforcement conditions for the ERs or RTs. These results suggest that reinforcement may have little to no effect on enhancing attentional skills within the AX-CPT.

BX Trial Type

Similar to the AY trial type, the hypotheses for the BX trial type were also confirmed. There were no significant differences in ERs or RTs between the reinforcement and non-reinforcement conditions. This finding may suggest that reinforcement produces an excess amount of dopaminergic activity. With this increased dopaminergic activity, there may have been an overload of neural circuitry in the ACC, thereby resulting in too much noise when all the neural circuitry is transmitted to the DL-PFC (Montgomery & Koeltzow, 2010). Therefore, this may have made it difficult for the DL-PFC to detect the signal that is needed to gate relevant and irrelevant information that is necessary for the cognitive control task (Montgomery & Koeltzow, 2010). Consequently, the increased dopaminergic activity due to the presence of the reinforcement may not have benefited the children's ability to complete the cognitive control task more accurately. Therefore, this is one explanation as to why there was very little change in performance from the reinforcement condition to non-reinforcement condition.

Adult Hypotheses and Findings

Predictions For All Trial Types

For the adult age group, predictions were based on results of a study by Locke and Braver (2008). In this study, a reward, penalty, and control condition were included in the AX-CPT in order to examine how motivational incentives impact performance on a cognitive control task for adults. In the AY trial, it was predicted that adults in the reinforcement group would produce more errors with faster RTs, and fewer errors with slower RTs in the non-reinforcement group. For all other trials, it was predicted that there would be no other significant differences between reinforcement conditions in terms of ERs for each of the other trial types (AX, BX, BY). However, it was predicted that there would be significant differences in RTs for the AX, BX, and BY trials, in that the RTs for the adults in the reinforcement group would be faster than the non-reinforcement group. These hypotheses were partially supported by the results.

AX Trial Type

Results indicated that reinforcement helped reduce the ERs on the AX trial type. This suggests that the reinforcement (money) helped the adults represent the goal information of the valid (A) cue to make correct responses on target (AX) trials. Additionally, it was predicted that the RTs for the AX trials would be faster in the reinforcement condition. However, it was found that the adults were slower in the reinforcement condition on target trials. Although these results are not conclusive, this may suggest that adults slowed down the speed of their response to help improve their accuracy on the target trials in an effort to maintain their monetary reward.

AY Trial Type

With the AY trial type for the adults, hypotheses were not confirmed by the present results. Results indicated that adults had significantly lower ERs on AY trials within the reinforcement condition, with slower RTs, when compared to the non-reinforcement condition. Although past research has confirmed that adults typically make more errors on AY trials within a reinforcement condition, with faster RTs (Locke and Braver 2008), there are several explanations for lower ERs and slower RTs found in the present results. One explanation could be that the adults were able to do better with AY trials because they took their time to respond to help improve their accuracy. Therefore, there was a cost on reaction time in order to enhance their accuracy. In a study by Lock and Braver (2008), researchers incorporated a reward for RTs that were faster than the participant's average during the baseline/pretest trials. Having a reward for faster responses may have helped produce a more accurate depiction of how reinforcement affects both accuracy and RTs on a cognitive control task.

BX Trial Type

The hypotheses for the BX trials types for adults were partially confirmed. Consistent with the predictions, results indicated that there were no significant differences in ERs. These results suggest that reinforcement does not help improve inhibitory control for adults. Similar to AX and AY trials types, BX RTs were significantly slower within in the reinforcement condition as well. Again, this suggests that with the presence of reinforcement, adults slowed their responses to help increase their accuracy on the task.

Adult and Children Comparison Hypotheses and Findings

Because there are clear developmental differences between adults and children, it was predicted that, overall, children would have more errors with longer RTs in all trial types (AX, AY, BX, BY) when compared to the adults. These hypotheses were confirmed by the results. Overall, when adults were compared to children, they were found to have less AX errors with faster reaction times, less BY errors with faster reaction times, less AY errors with faster reaction times, and less BX errors with faster reaction times. These results simply confirm that there are developmental differences from adults to children, which affect how accurately and quickly the children and adults complete the AX-CPT.

More specific to the trial types, it was predicted that adults in the reinforcement group would have significantly greater differences between AY ERs and BX errors when compared to the children in the reinforcement group. These predictions were not confirmed by the results. For the children age group, it was found that there were significant differences from AY to BX trial types, where children had significantly more AY errors than BX errors. These results are consistent with the literature relating to adult's cognitive control. In past research, it has been found that adults tend to have greater differences between AY and BX ERs, when compared to children. This is because adults typically display proactive control during the AX-CPT. An individual utilizing proactive control on the AX-CPT would be able to actively maintain the context information of the target cue (A) in mind, while waiting for the target probe (X) to appear on the screen. Consequently, individuals using proactive control will do relatively well on BX trials, since they do well with maintaining the context information of the cue (A), which helps immediately determine that the BX trial is a non-target response. On the other hand, they end up making more AY errors throughout the task, since 70% of the trials are (AX) target responses, and the cue (A) helps predict a target response. In contrast, younger children generally demonstrate reactive control. In other words, children should have greater difficulty maintaining the context information of the cue (A), and instead, are more inclined to make a target response when they see the target probe (X). Therefore, they make more BX errors and fewer AY errors, relative to adults (Locke & Braver, 2008). However, there was no three-way interaction between age group, trial type, and condition. Therefore, when comparing the reinforcement conditions from the AY and BX trial types individually, there were no significant differences from the reinforcement to non-reinforcement conditions for the children. As a result, the presence of the reinforcement was not indicative of the unusual results for the children age group. That is, children's ability to use proactive control on the AX-CPT was not affected by the reinforcement.

The results for the adult age group revealed that there were no significant differences from AY to BX trial types. However, they did have significant differences from the reinforcement condition to the non-reinforcement condition when examining the AY and BX trial types separately, where the adults did better within the reinforcement condition for both of the trial types. Taken together, this may suggest that adults are able to complete the task so effortlessly that they may not be displaying the difficulties and errors that are typically associated with individuals who have good cognitive control (i.e., more AY errors when compared to BX errors). Therefore, they are doing well on all trials, with no significant differences between the trial types. Additionally, when comparing the reinforcement conditions, the results revealed that adults had fewer errors within the reinforcement condition for all trial types, which further supports the previous suggestion relating to how the adults are completing the AX-CPT with very little difficulty. Past studies have provided evidence that suggests reinforcement helps improve cognitive control, where adults produce more AY errors within the reinforcement condition when compared to the non-reinforcement condition (Locke & Braver, 2008).

More simply, adults cognitive control abilities may not have been truly challenged when completing the task during the current study. As a result, the effects of reinforcement did not impact their cognitive control, rather it only played a role in their overall ability to complete the task more accurately on all trials so that they could get their entire reward at the end of the task.

The unexpected findings for the children and adults may be explained by a number of factors. One explanation could be due to personality factors and how sensitive children and adults are to different types of reinforcement. Differences in reward sensitivity and personality factors could have been examined by administering measures that would help determine the participants level of reward sensitivity and/or personality factors that may effect their motivation for the task (Locke & Braver, 2008). Another factor may be that there was no cue-probe delay. The current study used a short, 1-second delay, between the cue and the probe, requiring very little maintenance of the representation of context information in working memory. However, if a longer delay was used, Braver et al. (2001) indicated that difficulties and developmental differences associated with the working memory functions of context processing would become more evident. For the current study, a longer delay was not used due to time constraints and concerns for the level of difficulty it placed on the third grade children.

Limitations

Reward/Punishment for RTs

A few other limitations for the current study must also be addressed. First, it should be noted that no incentive was put forth for participants to make responses as quickly as possible. Before beginning the task, the participants were told that they need to make their responses as quickly as possible, but no reward or punishment was given throughout the task to ensure that they are making the responses as quickly as possible. If some type of motivational incentive were established (i.e., more money for faster RTs, or money taken away for slow RTs), then the participants would likely not slow down to improve their accuracy. Instead, it is possible that one would be able to see how reinforcement truly affects the overall performance of both ERs and RTs.

Reward Sensitivity

As mentioned previously, the children and adults unusual findings may have been due to personality factors or reward sensitivity. Measures such as the Behavioral Activation Scale (BAS) would help determine how interested participants would be in possible rewards. That is, participants who are vastly reward-sensitive, are inclined to find rewards more gratifying, and will put forth a great deal of effort to attain the reward. Other measures, such as the Generalized Reward and Punishment Expectancy Scale (GRAPES), could be used to help determine how optimistic or pessimistic the participant is, and whether or not they believe they have a good chance at achieving the reward. Both of these personality measures were used within the study by Locke and Braver (2008) to determine how personality variables are correlated with brain activity with the presence of a motivational incentive.

Sample Size

Another limitation relates to the size of the sample. Because of the relatively small sample size, there was very little statistical power. With a larger sample size, and greater statistical power, it is more likely that the t-tests and ANOVAS would more accurately detect the effect of the reinforcement on the different trial types for the adults and children.

Physiological Evidence

The last limitation is based on the inability to support our results with physiological evidence. This could be achieved by analyzing brain activity with an fMRI during the administration of the task. In this way, researchers could determine if there were any physiological differences based on brain activity within PFC. Having this additional evidence would help further explain how reinforcement affects adults and children differently.

Future Directions

Since the current study only incorporated extrinsic rewards, future studies should look to design a study that includes both extrinsic and intrinsic rewards. In this way, researchers can examine how an extrinsic, tangible reward may affect adults and children differently than intrinsic rewards (i.e., success on the task due to extra practice).

Other future directions could look to investigate how varying ages throughout childhood may be affected by reinforcement differently than adults. In doing this, it is possible that researchers would be able to determine the optimal ages to which teachers, parents, and/or educators could utilize reinforcement to help improve cognitive control.

Conclusion

Although not conclusive, the results for this study provided some evidence that reinforcement may not affect children in quite the same way as adults. With these results, future studies can expand upon the current research to help our understanding of how educators and parents can help improve children's cognitive control with the presence of a reward. Furthermore, by continuing research in this area of cognitive development, we may be able to find that children who are struggling on tasks that challenge their cognitive control abilities, may not be struggling because of a lack of motivation, but rather, a lack of cognitive development. In other words, the performance of cognitive control abilities may not be able to be governed by a motivational operative. Instead, maturation of the PFC may be the only factor that can help improve the children's performance. However, future studies incorporating the limitations that were discussed previously may give us a better understanding of how cognitive control may be affected by a motivational incentive.

APPENDIX A

INSTITUTIONAL REVIEW BOARD LETTER OF APPROVAL

CALIFORNIA STATE UNIVERSITY
SAN BERNARDINO

Academic Affairs
Office of Academic Research • Institutional Review Board

November 09, 2012

CSUSB INSTITUTIONAL REVIEW BOARD
Full Board Review
IRB# 12013
Status
APPROVED

Ms. Jackie Dziadosz and Prof. Jason Reimer
c/o: Prof. Jason Reimer
Department of Psychology
California State University, San Bernardino
5500 University Parkway
San Bernardino, California 92407

Dear Ms. Dziadosz and Prof. Reimer:

Your application to use human subjects, titled "The Role of Reinforcement on Cognitive Control in Adults and Children" has been reviewed and approved by the Institutional Review Board (IRB). The attached informed consent document has been stamped and signed by the IRB chairperson. All subsequent copies used must be this officially approved version. A change in your informed consent (no matter how minor the change) requires resubmission of your protocol as amended. **Your application is approved for one year from November 09, 2012 through November 08, 2013. One month prior to the approval end date you need to file for a renewal if you have not completed your research. See additional requirements (Items 1 – 4) of your approval below.**

Your responsibilities as the researcher/investigator reporting to the IRB Committee include the following 4 requirements as mandated by the Code of Federal Regulations 45 CFR 46 listed below. Please note that the protocol change form and renewal form are located on the IRB website under the forms menu. Failure to notify the IRB of the above may result in disciplinary action. You are required to keep copies of the informed consent forms and data for at least three years.

1) Submit a protocol change form if any changes (no matter how minor) are made in your research prospectus/protocol for review and approval of the IRB before implemented in your research.
2) If any unanticipated/adverse events are experienced by subjects during your research.
3) Too renew your protocol one month prior to the protocols end date.
4) When your project has ended by emailing the IRB Coordinator/Compliance Analyst.

The CSUSB IRB has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval notice does not replace any departmental or additional approvals which may be required.

If you have any questions regarding the IRB decision, please contact Michael Gillespie, IRB Compliance Coordinator. Mr. Michael Gillespie can be reached by phone at (909) 537-7588, by fax at (909) 537-7028, or by email at mgillesp@csusb.edu. Please include your application approval identification number (listed at the top) in all correspondence.

Best of luck with your research.

Sincerely, Sharon Ward, Ph.D.

Sharon Ward, Ph.D., Chair
Institutional Review Board

SW/mg

cc: Prof. Jason Reimer, Department of Psychology

909.537.7588 • fax: 909.537.7028 • http://irb.csusb.edu/
5500 UNIVERSITY PARKWAY, SAN BERNARDINO, CA 92407-2393

APPENDIX B

PARENTAL CONSENT FORM

CALIFORNIA STATE UNIVERSITY
SAN BERNARDINO

College of Social and Behavioral Sciences
Department of Psychology

To the parent or guardian of child's name in teacher's name classroom:

Your child is invited to participate in a study designed to investigate working memory. This study is being conducted by Jackie Dziadosz, a graduate student in the MA Child Development program; and Dr. Jason Reimer, Professor, California State University, San Bernardino. The university asks that we obtain your consent before your child's participation in this study. This form should bear the official Institution Review Board (IRB) stamp of approval. The stamp verifies that this study has full board approval by the Institutional Review Board of California State University, San Bernardino. The IRB is a committee that reviewed the study to determine the amount of risk to your child.

Your child will be asked to complete a computerized memory task that will be presented as a "memory game." The task requires about 20-25 minutes to complete. Instructions for the task will be read allowed by the researcher, and then your child will begin the memory task. Letters will be presented on a computer monitor, one-at-a-time. The object of the task is to identify certain letter sequences and do so as quickly but as accurately as possible. Your child will be able to take short breaks periodically throughout the task. The researcher will administer the task to your child task in a quiet, well-lit room during regular classroom time (excluding lunch, recess, and library time). The task is designed to measure how reinforcement affects performance. Candies and toys are going to be involved in this game, so if your child has any known food allergies, please make note of it at the bottom of this form. Furthermore, if you would prefer that your child be reinforced with toys and not candy please mark the appropriate box below. No identifying information will be collected with your child's responses, so his/her responses will remain completely anonymous. All responses will be reported in group form only. You may receive the group results of this study upon completion in May of 2013.

Your child's participation in this study is voluntary. He or she is free to withdraw at any time during this task. This study involves no risks beyond those routinely encountered in daily life, nor any direct benefits to your child as a participant other than enjoyment they may encounter from the game. In order to ensure the legitimacy of the study, we ask that you speak with your child about not speaking with other children about the game.

CALIFORNIA STATE UNIVERSITY, SAN BERNARDINO
INSTITUTIONAL REVIEW BOARD COMMITTEE
APPROVED 11/09/12 VOID AFTER 11/08/13
IRB# 12013 CHAIR Thomas D. Ward, Ph.D.

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CALIFORNIA STATE UNIVERSITY
SAN BERNARDINO

College of Social and Behavioral Sciences
Department of Psychology

By placing a check mark in the box below, I acknowledge that I have been informed of, and that I understand, the nature and purpose of this study, and I give my child permission to participate. I also acknowledge that I am the legal guardian of this child.

Place a check mark here Today's date

Parent signature ______________________

The candy that is going to be used for this study will consist of Starbursts, Skittles, and/or Hershey's chocolate. If you do not wish to allow your child to receive any of these candies, or if they have food allergies/restrictions for any of these food items, mark none of above in the box below. If all of the food items are okay to for your child to eat, you can mark each of them.

- [ ] Starbursts
- [ ] Skittles
- [ ] Hershey's chocolate
- [ ] Blowpop sucker
- [ ] None of the above

Please return on the bottom page with your child to teacher's name here no later than return date here.

CALIFORNIA STATE UNIVERSITY, SAN BERNARDINO
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APPROVED 11/09/12 VOID AFTER 11/08/13
IRB# 12013 [signature] Ward, Ph.D.

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APPENDIX C

CHILD ASSENT

CALIFORNIA STATE UNIVERSITY
SAN BERNARDINO

College of Social and Behavioral Sciences
Department of Psychology

We are doing a study that looks at kid's memory abilities. We are doing this study because we want to see how kid's memories may be different than adults. If you agree to be in our study, we are going to start playing a game that should take about 20-25 minutes. I'll read the rules for the game aloud, and then I'll explain how you can win at the end. The game you're going to play will be on the computer. The object of the game is to make as many correct responses as possible according to the rules that I will explain in further detail in a few minutes. I'll let you know when to start the game. You will get a break after 30 trials, and I will let you know when you have finished all of those trials.

If you decide you don't want to play the game anymore you can stop playing at any time, just let us know. You won't hurt my feelings. If you have any questions before starting the game, feel free to ask as many questions as you would like. Once we start the game, make the responses as best as you can. This game has nothing to do with school, and no one else will know how well you do on the game. Just try doing your best and remember to have fun!

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APPENDIX D

INFORMED CONSENT FOR ADULTS

CALIFORNIA STATE UNIVERSITY
SAN BERNARDINO

College of Social and Behavioral Sciences
Department of Psychology

You are invited to participate in a study designed to investigate working memory. This study is being conducted by Jackie Dziadosz, a graduate student in the MA Child Development program, and Dr. Jason Reimer, Professor of Psychology. The University asks that we obtain your consent before your participation in this study., This form should bear the official Institution Review Board stamp of approval. The stamp verifies that this study has full board approval from the Institutional Review Board of California State University, San Bernardino.

In this study you will be asked to complete a computer-based working memory task. In this task you will be presented with a series of letters on a computer screen. You will be asked to make responses to certain combinations of letters. All together this study should take no more than 30 minutes to complete. All identifying information will be stored separately from your responses to protect the anonymity of your responses. All data will be reported in group form only. All responses collected for this study will be stored on a password-protected computer that is locked in the Language and Memory Development lab at CSUSB. Only the researchers will be able to access the data. Data will be destroyed 5 years after publication in a scientific journal. You may receive the group results of this study by July 2013 by contacting Dr. Reimer at jreimer@csusb.edu.

Your participation in this study is entirely voluntary. You are free to withdraw your participation at any time during the study, or refuse to answer any specific question, without penalty or loss of payment to which you are otherwise entitled. This study involves no risks beyond those routinely encountered in daily life, nor any direct benefits to you as a participant. When you complete the task, you will receive a post-study information form describing the study in more detail. In addition, you will receive extra credit for your participation. We ask you not to discuss this study with other students in order to keep our results as accurate as possible. Results from this study will likely be included in student theses, presented at scientific conferences, and submitted to a scientific journal for publication.

If you have any questions or concerns about this study, please feel free to contact Jason Reimer at jreimer@csusb.edu. You may also contact the Univerity IRB Committee if you have any questions or concerns about this study.

By placing a check mark in the box below, I acknowledge that I have been informed of, and that I understand, the nature and purpose of this study, and I freely consent to participate. I also acknowledge that I am at least 18 years of age.

Place a check mark here Today's date

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IRB# 12013 CHAIR [signature], Ph.D.

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APPENDIX E

FIGURES

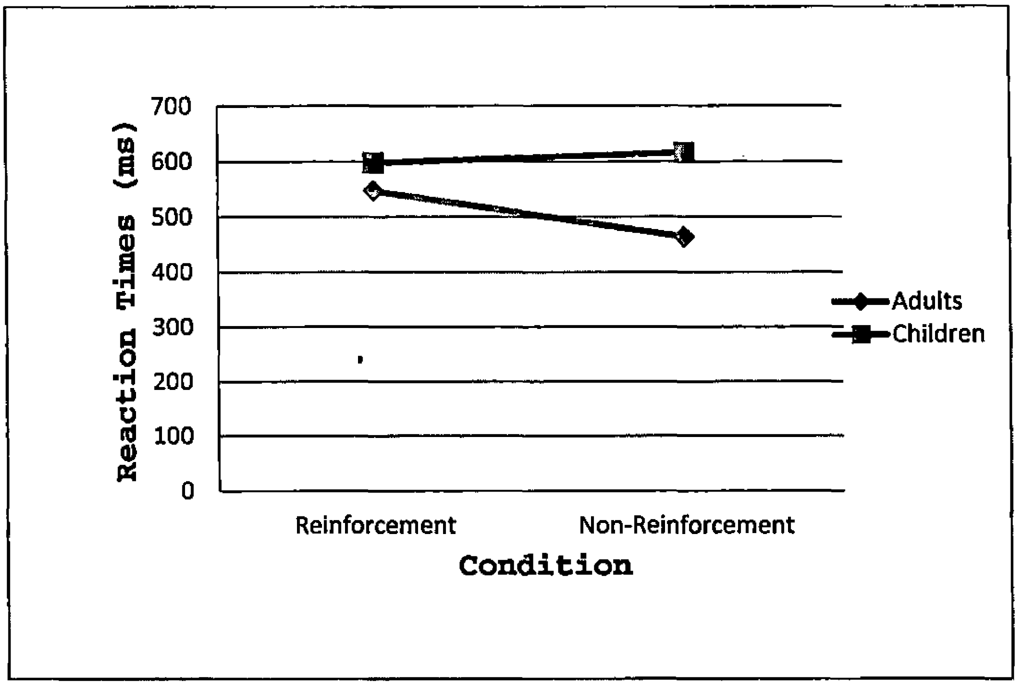

Figure 1. Reaction times of adults and 3rd graders from the reinforcement condition to the non reinforcement condition in ms for the AX trial type.

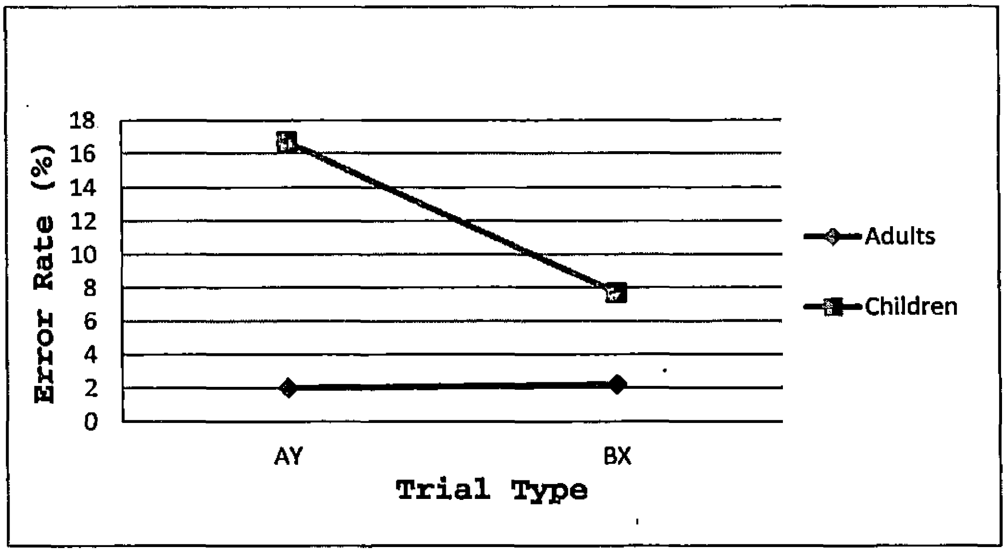

Figure 2. Error rates of third graders and adults for the non-target trial type (AY and BX).

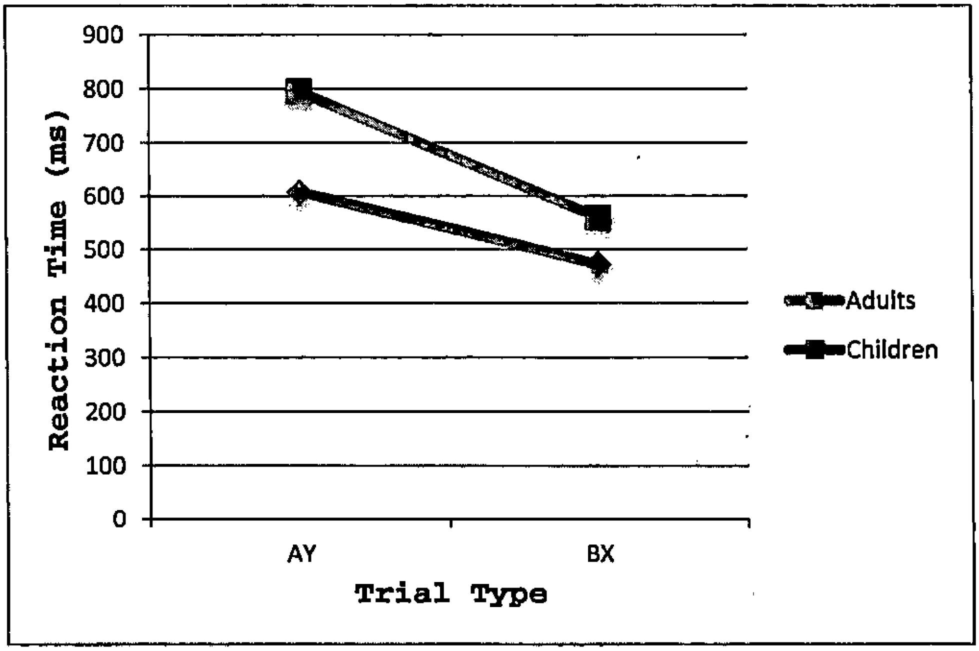

Figure 3. Reaction Times for adults and children from AY to BX.

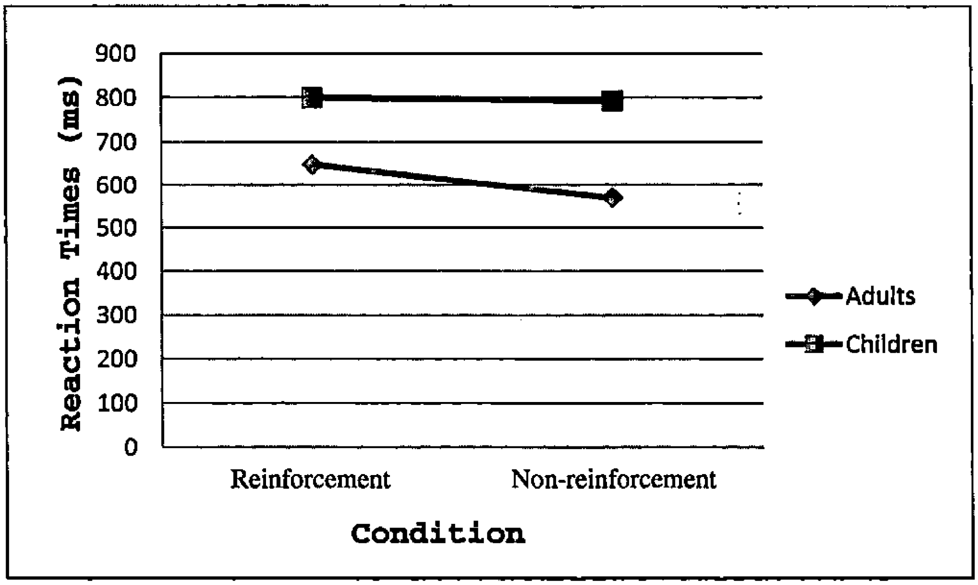

Figure 4. Reaction times of adults and children for the AY trial type from the reinforcement condition to non-reinforcement condition.

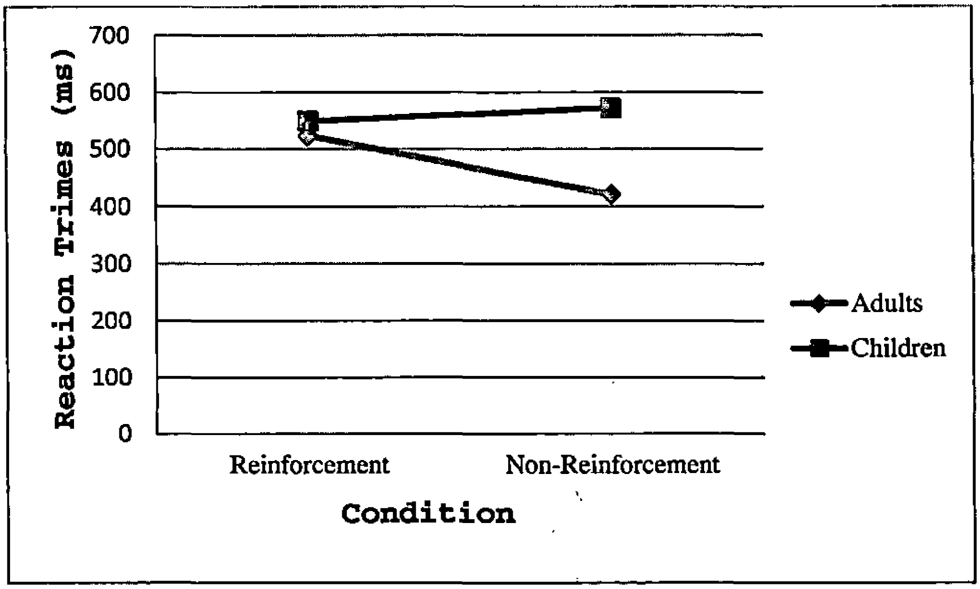

Figure 5. Reaction times for adults and children from reinforcement to non-reinforcement condition for BX trial type.

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