# FUTURE ORIENTED DECISION-MAKING IN CHILDHOOD

By

Nancy M. Garon

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## DEDICATION

This thesis is dedicated to my wonderful family. Jon, Brittany, Brett and Megan, thank you for your support throughout this process. You have all helped me in your individual, special ways.

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## ABSTRACT

The main goal of the thesis was to explore the development of complex decision-making in children using a modified version of the Iowa Gambling task. This task assesses the individual's ability to make advantageous decisions over time, given conflictual rewards and losses (Bechara et al., 1994). The primary goal of the first experiment was to create a modified version of the Iowa task in relation to three age groups: 3-, 4-, and 6-year-olds. The results of this experiment indicated that there were age and sex differences in making decisions, with females outperforming males. The primary goal of the second experiment was to explore further decision-making in the pre-school period. A related goal was to explore the association of complex decision-making with performance on a simpler decision-making task. Finally, association of decision-making with temperament characteristics was also explored. This experiment confirmed a developmental effect in decision-making ability, indicating that decision making improves over the pre-school period. The findings also showed that performance on this task was linked to temperament characteristics. The correlation of the gambling task and simpler decision-making task approached significance for the younger children. The primary goal of the third experiment was to investigate the effect of altering the reinforcement contingencies on the Iowa Gambling task. The results indicated that altering reinforcement contingencies had no effect on age differences, but had differential effects on males and females. Finally, the goal of the fourth experiment was to explore complex decision making in children with Attention Deficit Hyperactivity Disorder (ADHD). Analysis of this experiment indicated a significant difference between this clinical group and an age and sex matched control group, with the control group choosing significantly more from the advantageous decks. The results of these four studies converge to indicate a pattern of improvement in decision-making during childhood.

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# Chapter 1

## Background on Future Oriented Decision-Making

Decisions that we make in the present are often coloured by past experiences and anticipation of the future. Consider a child who has been repeatedly punished for taking cookies from the cookie jar before supper. In deciding whether to take a cookie again, this child may feel torn between a desire for immediate gratification and the fear of later retribution by Mom. Of course, an adaptive response to this dilemma would be to avoid the cookie jar. In making this difficult decision, the child may retrieve various aspects of past similar incidents such as how delicious cookies are and the look of scorn on Mom's face. One factor that may help the child resist the cookies is the negative feelings associated with taking cookies. Another factor that may help is the child's ability to redirect attention away from the consummatory properties of the cookies (Metcalfe & Mischel, 1999). This example illustrates that making future oriented decisions depends on the ability to retrieve past information and certain cognitive skills.

To date, there have been two main approaches to future oriented decision-making. One approach originates from the developmental literature and the other approach originates from the neuropsychological literature. In the developmental literature, children's future-oriented decisions have been traditionally explored through the delay of gratification task (Mischel, Shoda, & Rodriguez, 1989). In this task, children are asked to make a choice between a small immediate reward or a larger delayed reward. Research indicates that this ability shows considerable development during the preschool period (Lemmon, 2003; Lemmon & Moore, 2001; Mischel et al., 1989).

The delay of gratification task explores the ability to make decisions between two options that have clear consequences. Considerably less work has been done in the developmental literature on other forms of decision making. For instance, the choices we make in social situations are often not as clear-cut as the choices presented in the delay of gratification task. While children are actually told explicitly which reward is larger in this task, many real life decisions involve more complex choices, where options are not as obvious. For instance, in the example of the child and the cookie jar, the child is not told explicitly by Mom which choice is better. Instead, the child must make this decision by weighing the rewards and losses involved in this situation. Further, in order to make that decision, the child must retrieve information from various similar situations. This process may include a consideration of how many times punishment occurred in the past versus how rewarding the cookies are. This form of decision-making involves weighing costs and rewards over time.

In order to look at this type of decision-making in brain damaged patients, Bechara and his colleagues developed the Iowa Gambling task (Damasio, 1994; Bechara, Damasio, Damasio, & Anderson, 1994). In this task, individuals are presented with four decks. Two of the decks are better in the long-term, leading to a larger net profit after 10 choices. Since individuals are not told which decks are better, they have to discover this for themselves. The game thus contains both learning and motivational aspects.

The delay of gratification paradigm and the Iowa Gambling task represent two different approaches to the problem of future oriented decision-making. It can be argued that the two tasks explore different, overlapping aspects of future-oriented decision making. While the delay of gratification paradigm involves making only a few well-

defined conscious choices, the Iowa Gambling task involves making several choices with consequences that are not initially well-defined. Individuals actually have to figure out what deck is better to choose from. It is only once individuals know which decks are better overall, that they can make a decision as to whether they want to choose a deck that provides better immediate rewards or a deck that is better over time. Similarly, in the delay of gratification paradigm, children have to make a choice between a small immediate reward and a larger future reward. In this way, the last phase of the Iowa Gambling task is similar to the delay of gratification paradigm. The Iowa Gambling task, therefore, can be seen as assessing a more complex form of decision-making, one that involves several abilities.

The goal of this thesis is to explore the development of this more complex form of decision-making in children. It is argued that exploring the development of this task in children can provide us with new insight into how children make decisions in everyday social situations. This chapter will provide an overview of the research on the two main approaches to future oriented decision-making. Next, the abilities hypothesized to underlie these two tasks are explored. This is followed by a review of the development of the abilities hypothesized to underlie the Iowa Gambling task. The development of temperament and its possible implications for the development of decision-making is also reviewed. Finally, the brain networks thought to underlie decision-making and its development are briefly reviewed.

**Delay of Gratification and Future Oriented Decision Making**

Beginning in the pre-school period, children are able to make conscious decisions that are advantageous in the future. Probably one of the most well researched paradigm during the pre-school and childhood period is the delay of gratification task. There are two main types of tasks used in the delay of gratification paradigm (Mischel, 1974). In the first type of task, children have to make a choice and decide whether they want a small reward now or to wait a specified period ranging from hours to days and get a larger reward. For the sake of clarity, this type of task will be referred to as the choice paradigm throughout this thesis. The second type of task involves the actual delay period and processes involved in lengthening waiting time. This type of task will be referred to as the delay paradigm. While the choice paradigm has been applied to the pre-school period, the bulk of the earlier research on pre-schoolers has focused on the delay paradigm. Research on this paradigm will therefore be discussed first.

During the delay paradigm, children are shown a reward such as a marshmallow and told that they can have one marshmallow now or wait until later and receive two marshmallows. Children are typically told that they can ring a bell anytime before the delay period is up to receive the smaller reward. The dependent variable of interest, then, is the length of time the child is able to wait before ringing the bell. The research of Mischel and his colleagues indicates that the ability to wait for a larger future reward begins to emerge during the pre-school period. Even the youngest children show some ability to wait (Mischel & Ebbesen, 1970; Mischel, Ebbeson, Zeiss, 1972; Mischel & Moore, 1973; Mischel & Baker, 1975). Further, research indicates that the amount of waiting increases during the pre-school period (Toner, Holstein & Hetherington, 1977).

Mischel et al. (1989) argued that various factors affect children's ability to delay rewards during the pre-school period. In trying to elucidate what made delays longer, Mischel and Ebbesen (1970) hypothesised that attention may be an important factor. They noticed that children who were able to distract themselves waited longer. They, therefore, manipulated the presence of both immediate and delayed rewards during the waiting period. They found that waiting time increased when rewards were not present. This was consistent with a distraction hypothesis. Attending to rewards appeared to make waiting more difficult. Subsequent research indicated that even having children imagine the rewards made waiting more difficult (Mischel et al., 1972).

Interestingly, presenting images of the rewards increased the amount time children were able to wait for delayed rewards (Mischel & Moore, 1973). While these results were in contrast to rewards being imagined or physically present, Mischel (1974) hypothesised that it may be that these findings are due to the differences between "hot" and "cool" aspects of cognitions. Having a reward physically present or being left to imagine the reward might lead young children to focus on the consummatory aspects of the reward such as how tasty the candy is (Mischel, 1974). When they tested this hypothesis, Mischel and Baker (1975) found that as predicted, cool ideation increased delay while hot ideation decreased the delay period. They found that having children think about "hot" aspects of the reward such as its taste decreased waiting time. In contrast, having children focus on "cool" aspects of the reward such as its shape increased waiting time. Investigating this relationship in older children at risk, Rodriguez, Mischel and Shoda (1989) found that age, verbal intelligence, attention to reward, and knowledge of delay rules all contributed to delay time.

This line of research suggested that being able to control attention enabled children to more effectively reach their goal of a larger reward. Interestingly, the ability to voluntarily direct attention has been linked to social adjustment and the development of conscience (Eisenberg, Valiente et al., 2003; Grim & Kohlberg, 1968; Kochanska, Murray & Coy, 1997; Kochanska, Murray & Harlan, 2000). Further, many parents use distraction as a way of reducing distress during infancy (Rothbart & Posner, 2001). This indicates that manipulating attention can be used to regulate pain/distress even during infancy. Harman, Rothbart, and Posner (1997) investigated the use of distraction in regulating the distress of 3- and 6-month-old infants. They found evidence that regulation of distress was more closely tied to the anterior attention system. The anterior attention system has been hypothesized to regulate voluntary aspects of attention in contrast to the posterior attention system, which has been associated with more automatic aspects of attention (Posner & Rothbart, 1998). The authors suggested that the anterior attention system is involved in pain perception so this area may function as a gatekeeper. This study suggests a possible mechanism by which attention may affect waiting time in delay of gratification. Directing attention away from reward may lead to lessening of "pain" and discomfort of waiting.

In a recent study, Sethi, Mischel, Aber, Shoda, and Rodriguez (2000) found evidence that even early differences in attention regulation are related to the ability to delay gratification. They found a link between toddler's use of attention strategies during separation from mother and later delay of gratification at 5 years of age. Specifically, toddlers who used distraction during a brief separation from mother were found to delay immediate gratification significantly longer at 5. This again supported the hypothesis that

being able to direct attention away from hot ideation helps children to wait longer. This fits with Metcalfe and Mischel's proposal that an effortful, cognitive system allows children to wait longer (Metcalfe & Mischel, 1999).

Interestingly, future oriented decision-making has important implications for social adjustment. Mischel, Shoda and Peake (1988) found that length of waiting during the preschool period predicted later social adjustment. It may be that the ability to control attention is the factor mediating the correlation between delay of gratification and social adjustment. Supporting this idea, Mischel et al. (1988) found that individual differences in waiting time was linked to later personality factors in adolescence. Specifically, they found that individual differences in waiting time were significantly correlated with Ego-resilience, a personality factor in the California Child Q-set. Ego-resiliency refers to self-regulatory skills and is made up of several questions relating to the control of attention (Funder, Block & Block, 1983). Moreover, this personality factor has been linked to the ability to voluntarily control attention and the temperament trait of Effortful Control (Mischel et al., 1988; Kochanska et al., 2000). Later research confirmed these findings, suggesting that attention and cognitive control were correlated to delay periods (Shoda, Mischel & Peak, 1990). Metcalfe and Mischel (1999), in fact, suggested that it was "willpower" (p. 3) that predicted both the ability to delay and social adjustment.

While the delay paradigm has been investigated quite heavily during the pre-school period, the choice paradigm has primarily been investigated in older children and adults until recently. The choice paradigm looks at the ability to make the choice. Here, the dependent variable is the number times the child chooses to delay. In this way, it looks at the individual's overall desire to wait for a larger reward. As with the delay

paradigm, the choice paradigm has been linked to social adjustment, academic achievement and attention control (Funder & Block, 1989; Mischel, 1961a; Mischel, 1961b; Mischel & Gilligan, 1964; Mischel et al., 1989).

While age effects have been found for older children on the choice paradigm, age effects during the pre-school period have not been as consistent (Farnham-Diggory, 1966· Mischel & Metzner, 1962 Montgomery, 1976; Schwarz, Schrager, & Lyons, 1983; Walsh, 1967). This may be due to the fact that this paradigm is more difficult to apply to this age group. For instance, the typical task involves waiting for times that range from hours to days. Children of this age may not be able to fully comprehend this time frame. Studies using this task on younger children have typically found no age differences (Montgomery, 1976; Schwarz et al., 1983; Walsh, 1967). Schwaz et al. (1983) conducted a study to look at this paradigm in pre-schoolers. They found that while children this young understood the choices, there were no age differences.

Interestingly, children's actual choices and their idea of what is the best choice do not necessarily agree. Nisan and Koriat (1977) found that while children thought it was smarter to wait for the delayed, larger reward, they still often chose the immediate reward for themselves. When they asked children what a smart child would choose, they attributed significantly more delay to the smart child than what they actually chose for themselves. This indicates a dissociation between what children think and what they actually do during this age period.

The failure to find age differences may reflect either few developmental changes in this period or lack of power to find developmental differences. It may be that small sample sizes or long time periods used restricted experimenters' ability to find age

differences. There is support for the latter idea in more recent studies done on the choice paradigm in pre-schoolers. Thompson, Barresi, and Moore (1997) found a significant age difference on a new variation of the choice paradigm that they called "future oriented prudence". They tested 3- to 5-year-olds on a task using stickers as a reward. In this task, children were asked three times to choose whether they wanted one sticker now or to wait until the end of the game to receive two stickers. This time period was smaller than the hours or days used in other procedures and may have been more sensitive to differences in the pre-school period. Thompson et al. also added a new choice hypothesised to measure what they referred to as "future oriented altruism". This task had children delaying gratification now for a larger reward that they would share with an experimenter later. They found that younger children demonstrated significantly less future oriented prudence and altruism than older children demonstrated did. Further, they also found that future oriented prudence and altruism tasks were significantly correlated. This indicates that being able to consider future scenarios for self and other are closely linked. Another interesting finding from this line of research is the link between this task and episodic memory, suggesting that being able to retrieve the past is linked to consideration of the future (Lemmon & Moore, 2001).

Even using this version of the task, however, age differences have not been consistently found during the pre-school period. In a longitudinal study, Moore and MacGillivray (in press) failed to find significant developmental effects from 3.5 to 4.5 years of age. Moore, Barresi, Thompson (1998) found only a marginal age difference of future oriented prudence. Lemmon and Moore (2001) found that age correlated significantly with performance on this task during the pre-school period. Lemmon (2003)

argued that age differences may be partially dependent on the age range used, with larger age ranges yielding more significant age effects. For instance, she did not find an age effect on her first experiment using children ranging in age from 3 ½ years to 4 years old, but she did find a relation with age in her later experiments when an age range of early 3's to older 4's was used.

Further, the more recent work done by Lemmon (2003) suggests that the ability to think consciously about the future is not as well developed in young children as had originally been assumed. Lemmon's research indicates that while young children may be able to make decisions to profit them in the future, they may be using cues about the present to make their decisions (Lemmon, 2003). In fact, the recent research on this particular version of the delay of gratification paradigm suggests that children's ability to make conscious decisions that will profit them in the future is not fully developed until approximately 4.5 years of age (Thompson et al., 1997; Moore et al., 1998; Lemmon & Moore, 2001).

Finally, it should be noted that a recent meta-analysis by Silverman (2003) reported a sex difference for delay of gratification. Specifically, females chose to delay rewards more than males, particularly for studies in which multiple choices were made. One factor that may be responsible for this sex difference is the female advantage in attention control. Several studies have found that females appear to show superiority in the ability to voluntarily direct attention and behavior (Eisenberg, Valiente et al., 2003; Kochanska, Jacques, Koenis & Vanderceest, 1996; Kochanska et al., 1997).

## The Iowa Gambling Task

Bechara et al. (1994) first constructed the Iowa Gambling task to study a group of patients with lesions to the ventromedial (VM) region of the prefrontal cortex (PFC). [1] The VM patients demonstrated a variety of social problems and yet were performing normally on tests of PFC functioning (Barrash, Tranel & Anderson, 2000; Bechara et al., 1994). These patients, for instance, demonstrate general dampening of emotional expression, poorly modulated emotional reactions, and poor decision making (Barrash et al., 2000). Further, Adolphs, Tranel, Bechara, Damasio and Damasio (1996) found evidence that their deficits in decision making were primarily for social situations.

The Iowa Gambling task was an attempt to more closely simulate real life decision-making problems. In the standard Iowa Gambling task, individuals are presented with 4 decks. They are asked to make 100 choices and told that the goal of the game is to accumulate as much money as possible. They are not told which decks are better to choose from. Two of the decks are considered advantageous and two are considered disadvantageous. Further, two of the decks (1 advantageous & 1 disadvantageous) have more frequently occurring losses. Every card of the disadvantageous decks leads to a win of $100. However, some of the cards also have large losses. Over the course of 10 cards, individuals end up losing $250. In contrast, every card of the advantageous decks leads to a win of $50 with some cards leading to small losses. Over the course of 10 cards, these 2 decks lead to a win of $250. Hence, both decks contain consistent wins that are in conflict with the overall profit over the course of 10 cards. While normal individuals eventually learned to choose more frequently from the good decks, the VM patients did

[1] It should be noted that the VM region contains portions of the orbitofrontal cortex (OFC) and these two areas are often referred to interchangeably in the literature (Bechara et al., 1994).

not show this pattern, continuing to choose from the bad deck throughout the game (Bechara et al., 1994). This pattern of finding for the VM and OFC patients have been found repeatedly since this first study (Bechara, Damasio, Tranel & Damasio; Bechara, Tranel, Damasio & Damasio, 1996; Damasio, 2003).

Bechara, Tranel and Damasio (2000) suggested that the VM patients have a type of "myopia" for the future. Instead of focusing on future consequences, they focus on the more immediate benefits of the bad decks. However, with the standard version of the task, it is impossible to make firm conclusions about this. There is actually a confound between the type of reinforcement (loss versus win) and consistency of its occurrence. For instance, a win of $50 occurs for every card turn of the good decks. In contrast, a loss occurs once every 10 cards for one good deck and five times for every 10 cards in the other good deck. Given this confound, there are three possible interpretations for the performance of the VM patients in the standard version. It may be that they choose more from the bad deck because they are overly sensitive to rewards, insensitive to punishment, or insensitive to future consequences.

In order to clarify this issue, Bechara, Tranel et al. (2000) designed a new version of this task where the occurrence of losses and wins were reversed. The good decks now had consistently occurring large losses ($100), with some cards leading to high win. In contrast, the bad decks had consistently occurring smaller losses ($50), with some cards leading to small wins. Again, the good decks led to an overall net win after 10 cards while the bad decks led to an overall net loss. When Bechara, Tranel et al. (2000) gave this new variant to VM patients, they found a pattern of choices very similar to the original variant, with VM patients still choosing more from the bad decks than normal

participants did. This suggested that the VM patients were not hypersensitive to rewards or insensitive to loss. Instead, the results indicated that they were insensitive to future consequences.

To account for the deficits in decision making by these individuals, Damasio (1994; 2003) proposed the somatic marker hypothesis, which argued that the VM area network was involved in associating somatic (bodily) states with various situations. Noting their apparent difficulties with emotion perception and regulation, Damasio argued that the VM patients were deficient in the ability to use emotions to guide behavior. In normal individuals, once a situation has been associated with a particular somatic state, encountering this situation again will lead to a reactivation of this somatic state via the VM network. Damasio (1994) hypothesized that these somatic states will bias decision-making. He suggested that feelings were an important aspect of this system. By associating certain situations with negative or positive feelings, this helps to automatically constrain the options available, thereby making decisions easier. According to this theory, then, normal individuals performing the Iowa Gambling Task should develop affective associations to the decks that would bias their decisions. Instead of trying to consciously calculate all the losses and wins to decide which decks are better, participants can rely on their "gut" feeling that some decks need to be avoided. The advantage of such a system is its speed and automacy. One can make a quick decision without having to consciously consider all past information.

In testing this theory, Bechara et al. (1996) looked at the skin conductance responses (SCRs) to rewards and losses. When they measured SCRs to rewards and punishments, they found differences between the patients with VM lesions and the

control group. Both groups produced similar SCRs immediately after rewards and punishment. Hence, these patients were at least able to demonstrate a somatic response to reinforcement. However, as the task progressed, the control group began to generate increased SCRs before they even picked from the decks. Particularly, they developed higher anticipatory SCRs to the "bad" decks.

Another interesting finding from the VM patients was the apparent dissociation between awareness and behavior. After twenty card choices, Bechara et al. (1997) asked participants to tell them what they knew about the game. Thereafter, participants were asked the same question after every 10 cards. They found that control participants went through three stages of awareness during the game. During the baseline stage (before they experienced their first loss), participants displayed no anticipatory skin conductance response to the decks and no knowledge. After about 10 card choices, participants experienced their first loss. Interestingly, it was during this period that controls began experiencing SCRs before choosing from the decks. Bechara et al. (1997) called this period the "Pre-Hunch" period. Despite this physiological response, they reported no knowledge of which decks were better by card 20. During the "Hunch" period, all participants began to report that they knew the bad decks were riskier. It was during this period that they began choosing significantly more from the good decks. This usually occurred halfway through the game. Finally, by about card 80, 70% of the controls reached the conceptual period. During this period, controls knew not only what decks were better but why they were better. What is most intriguing is that full conceptual knowledge does not appear necessary in order to choose more from the good decks. Even the participants who did not reach this stage chose more from the good decks.

The VM patients showed a different pattern than the controls. They never reached a period where they had anticipatory SCRs. Yet, towards the end of the game, 50% of the patients could verbalise what was happening in the game. Despite this knowledge, these patients still continued choosing from the bad decks, indicating that conceptual knowledge may be less important than the "bodily" response to change behavior. Tranel, Bechara, and Damasio (2000) argued that there is a complex interaction between somatic states and awareness in biasing decision making. Bechara, Damasio and Damasio (2001) further found evidence for two stages of decision making; a pre-conscious and conscious phase of decision-making that involved different biological processes.

*Other Clinical Populations*

The Iowa Gambling task has generated much research, inspiring work on other populations that have various clinical disorders. Psychiatric populations such as those with depression, mania, and obsessive compulsive disorder have been found to show impairment in decision-making (Cavedini, Riboldi & D'Annucci et al., 2002; Elliot, Shakian, Michael, Paykel & Dolan, 1998; Murphy et al., 2001; Rubinsztein et al., 2001). Individuals with Huntington's have been found to show impairment on the Iowa Gambling task (Stout, Rodawalt & Siermers, 2001). Research has provided some evidence of impairment in psychopathic and antisocial individuals as well (Best, Williams, & Coccaro, 2002; Blair et al., 2001; Mitchell, Colledge, Leonard, & Blair, 2002). One population that has received extensive study is the substance abuse population. Research has consistently indicated that these individuals are impaired in making decisions (Bechara & Damasio, 2002; Bechara, Dolan, et al., 2001; Bechara, Dolan & Hindes, 2002; Cavedini, Riboldi, Keller, D'Annucci & Bellodi, 2002;

Monterosso, Ehrman, Napier, O'Brien & Childress, 2001; Petry, 2001; Petry, Bickel, & Arnett, 1998).

Given the multitude of individuals found to have deficits on the Iowa Gambling task and related decision-making tasks, it could be concluded that this task lacks discriminative power. Research does indicate that a variety of brain areas contribute to decision-making (Krawczyk, 2002). However, one common dysfunction in the populations that have been found to have difficulty with the Iowa task occurs in the fronto-striatal networks. For instance, substance abusers show altered activation in this network (Bolla et al., in press; Paulus, Hazak, Frank, Brown & Schuckit, 2003).

Interestingly, the specific location of the dysfunction may affect the pattern of errors on the Iowa Gambling task. For instance, Stout, Busemeyer, Lin, Grant & Bornson (submitted) used cognitive modelling to compare the performance of patients with Huntington's, and substance abusers. While the specific components of this model are beyond the scope of this review (see Busemeyer & Stout, 2002 for overview), they found that Huntington's patients appeared to show deficits in reinforcement learning over time while substance abusers seemed to show excessive attention to immediate reinforcers over delayed losses. Similarly, Busemeyer, Stout and Finn (in press) found that VM patients showed patterns of impairment similar to the substance abuse patients.

*Iowa Gambling Task and Children*

Work on the Iowa Gambling task in children is just beginning and very sparse. However, this work suggests that performance on the Iowa Gambling task improves during childhood and adolescence. Blair et al. (2001) gave the Iowa Gambling task to a group of boys with psychopathic tendencies and normal controls. The children ranged in

age from 9 to 17 years of age. The results indicated a significant difference between control and psychopathic boys. More importantly, controls were found to behave similarly to normal adults, choosing more from the good deck as the task progressed. Further, while performance was not related to IQ, it was significantly correlated with age. Similarly, Overman (in press) has found some evidence that the ability to perform the Iowa Gambling task develops during adolescence for both males and females. Interestingly, Overman found a male advantage on this task for most age ranges that he looked at. This fits with the male superiority found in the reversal tasks and fits with his hypothesis that gender differences in OFC (VM) functioning continues into adulthood (Overman & Bachevalier, 2001).

Research also suggests the ability to perform the Iowa Gambling task may develop at around 4 years of age. Kerr and Zelazo (in press) found some evidence of a developmental difference between 3- and 4-year-olds. In this study, 3-year-old children were found to develop a preference for the disadvantageous deck while 4-year-olds were found to show a preference for the advantageous deck. They also found some evidence supporting a male advantage on this task for 3-year-olds. However, the differences did not reach statistical significance. The findings from this study are consistent with the development of various abilities such as reversal learning and future-oriented thinking that develop during the preschool period.

## Individual Differences in Performance on the Gambling Task

The performance of different abnormal populations indicates that certain personality traits may be associated with decision making in the normal population. Bechara, Damasio & Damasio (2000) noted that approximately 20% of the normal population choose significantly more from the bad decks relative to the good decks. They argued that these individuals differ from patients with VM lesions. These individuals have anticipatory SCRs, although these are slightly lower for the bad decks in relation to good decks. Bechara, Damasio et al. (2000) described these individuals as risk takers because they seem to override their somatic marker biases to choose more from the bad decks. These risk-taking individuals indicate that different personality traits will affect performance on the gambling task.

*Personality Factors Associated with Performance in Normal Adults*

Research is now accumulating that supports the idea that there are individual differences in performance on the Iowa Gambling task. Peters & Slovic (2000) created a variation of the Iowa Gambling task that separated the effects of losses and wins. Basing their hypothesis on Jeffrey Gray's work (Gray & McNaughton, 2000; Pickering & Gray, 1999), they administered a questionnaire that assessed the Behavioural Inhibition System (BIS) and the Behavioural Activation System (BAS). Individuals with high scores on the BIS tend to be more inhibited and more attentive to losses. This system has also been closely associated with anxiety (Gray, 1987). Individuals with high scores on the BAS tend to be more outgoing and highly motivated by rewards. As expected, Peters and Slovic (2000) found scores on the BAS scale to be associated with choices on the high reward decks and scores on the BIS scale to be associated with avoidance of high loss

decks. Another interesting finding was the separate contribution of the two aspects of personality and awareness of decks. They found that in the first 20 choices, BIS scores contributed significant unique variance to the prediction of choices from the high loss decks while conscious knowledge of high loss decks provided unique variance from the 20th card onward. This may reflect an interaction between the BIS and consciousness. For instance, once information from the BIS becomes conscious, the BIS may cease to have as important an impact on choice. BAS scores and awareness of high reward decks, on the other hand, explained separate proportions of the variance of high reward deck choices throughout the game. Similarly, Van Honk, Hermans, Putman, Montagne, & Schutter (2002) found individual differences on performance on the Iowa Gambling task based on differences on BIS and BAS scales.

*Temperament and Future Oriented Decision-Making in Children*

Research on normal adults suggests that individual difference in personality factors will lead to differences in performance on the gambling task. Similarly, in the developmental literature, individual differences in personality traits such as the ability to control attention have been associated with delay of gratification. More interestingly, preliminary research indicates that performance on the last 20 card choices on a child version of the Iowa Gambling task is also associated with attention control in children 3 to 5 years of age (Hongwanishkul, Hapaney & Lee, 2003). This suggests that temperament traits, particularly attention control, are also associated with performance on the gambling task at a very early age.

Temperament traits have been divided into automatic, reactive and more effortful systems. Research indicates that individual differences in temperament exist even in early

infancy (Fox, Henderson, & Marshall, 2001; Rothbart & Bates, 1998; Rothbart, Chew, & Gartstein, 2001; Rothbart, Derryberry, & Hershey, 2000). Rothbart, Derryberry et al. (2000) found that temperament traits begin to show stability at different ages. Research on temperament indicates that traits develop at different times, with later developing traits building on and influencing earlier traits (Rothbart, Ahadi & Evans, 2000; Rothbart & Bates, 1998; Rothbart et al., 2001; Rothbart, Derryberry et al. 2000). At 4 to 8 months, the approach system develops and it is at this age that individual differences in reaching can be measured, free from the effect of other systems. Behavioural inhibition and fear develop later in the first year between 9 and 12 months. Rothbart et al. (2001) argued that development of the behavioural inhibition system modulates the approach system. For instance, a child who before demonstrated a strong approach response may become more inhibited with the development of fear. Finally, Rothbart, Derryberry et al. (2000) argued that the Effortful Control system does not appear until later on during infancy. This system shows a more protracted maturation, with some important developments between 2 to 4 years of age (Rothbart & Posner, 2001). As a new temperament system is added, it affects the functioning of the other systems. The Effortful Control system, in particular, has been hypothesised to modulate the other more reactive temperament systems (Eisenberg, Valiente et al., 2003; Rothbart, Ahadi et al., 2000).

Interestingly, Rothbart, Ahadi et al. (2000) linked various aspects of temperament to different psychobiological models. This framework provides a bridge between work done in the child literature on temperament with work in the adult literature on personality factors. Rothbart, Ahadi et al. (2000) related the Behavior Activation System (BAS) to the Approach/Positive Affect (Extraversion) factor. The Behavior Inhibition

System (BIS) was linked to the Fear and Inhibition scales. Finally, the later developing aspect of temperament, Effortful Control, has been linked to the development of the anterior attention network and voluntary control of attention (Davis, Bruce & Gunnar, 2002; Posner & Rothbart, 1998; Rothbart, Ahadi & Evans, 2000; Fox et al., 2001).

Rothbart, Ahadi and Evans (2000) argued that two main types of temperament traits appear to be especially relevant to social development. They suggested that behavior can be regulated through a reactive emotional system such as the approach system and fear or through a voluntary system such as Effortful Control. In support of this theory, recent neurobiological models of emotion regulation have similarly suggested an automatic and effortful system (Phillips, Drevets, Rauch, & Lane, 2003 for review). Rothbart's theory has stimulated much work in the area of temperament, social development, and parenting. Research has been supportive of her theory, indicating that both automatic and voluntary, effortful systems are important in the development of conscience, sympathy, and general social adjustment (Eisenberg et al., 1988; Eisenberg et al., 1989; Eisenberg, Zhou et al., 2003; Eisenberg, Valiente et al., 2003; Eisenberg, 2000; Kochanska, 1991; Kochanska, Coy, & Murray, 2001; Kochanska, DeVet, Goldman, Murray, & Putnam, 1994; Kochanska, Gross, Lin, & Nichols, 2002).

**Abilities Involved In Future Oriented Decision-Making**

The delay of gratification task and Iowa Gambling task are two main approaches that have been used to explore future oriented decision-making in the literature. There are several parallels between delay of gratification and the Iowa Gambling task. First, both tasks look at the ability to choose the best option for the future. Secondly, both tasks have been linked to episodic memory and the ability to bind the self over time (Lemmon

& Moore, 2001; Levine, Freedman, Dawson, Black & Stuss, 1999). Thirdly, the ability to perform these tasks appears to develop at approximately the same time (Kerr & Zelazo, in press; Moore & Lemmon, 2001). Fourthly, both tasks have been linked to the ability to voluntarily direct attention in childhood (Hongwanishkul et al., 2003; Mischel et al., 1989). Finally, one study found a significant correlation between an adult version of the delay of gratification task and the gambling task, suggesting that they assess overlapping abilities (Monterosso et al., 2001).

Nonetheless, despite their similarity, the two tasks have important differences. Probably the most significant difference is the type of information that is provided about the choices. The delay of gratification tasks has the child make one or more clearly defined choices. The child is actually told which reward is better in the future. On the other hand, individuals in the Iowa Gambling task are not told which decks are better. They have to discover this for themselves by making repeated choices from the decks. Basically, to perform well, individuals initially need to be guided by the rewards and losses of each deck. Many authors have suggested that the Iowa Gambling task initially involves a type of implicit learning like conditioning (Damasio, 1994; Rolls, 1999). In support of this position, research indicates that individuals with damage to the amygdala, who cannot acquire a conditioned response, are unable to perform well on this task (Bechara, Damasio, Damasio & Lee, 1999). This suggests that a minimum requirement to perform this task is the ability to associate reward and stimulus.

It is not the only ability required, however. Patients with VM lesions can acquire a conditioned response and yet are unable to learn to choose more from the good decks in the gambling task (Bechara et al., 1999). Clearly the Iowa Gambling task requires a more

complex type of learning than simple conditioning. Research on the gambling task indicates that this may involve the ability to quickly reverse associations once conditioning has occurred. Initially, the bad decks appear to be better. Bechara et al. (1994) reported that normal individuals initially preferred the bad decks, switching to the good decks after encountering losses from the bad decks. Therefore, the ability to reverse associations is another important ability needed to perform well on the Iowa Gambling task. In fact, studies have shown that individuals with damage to the OFC (VM) are deficient in tasks requiring the reversal of conditioned associations (Fellows & Farah, 2003; Rolls, Hornak, Wade & McGrath, 1994). Animal research also suggests that the ability to reverse associations is mediated by the OFC (Dias, Robbins & Roberts, 1996; Rolls, 1999). Further, a related ability that has also been found to be mediated by the OFC is ability to make a decision about a situation, despite being given inconsistent reward and loss information (Elliot, Dolan & Frith, 2000). In the Iowa Gambling task, individuals have to learn which decks are better despite conflicting reward and loss information from the decks. This may therefore be a third ability required for the gambling task.

Finally, it is only when the individual develops a sense or a "hunch" of which decks are better that the game becomes more similar to the delay of gratification task. In normal individuals, this occurs mid-way through the game (Bechara et al., 1997). Once participants become conscious of which decks are better in the long run, they can decide to choose a deck that provides better immediate rewards or a deck that is better overall.

Metcalfe and Mischel (1999) proposed a theory to explain the development of the ability to delay gratification. This theory may also provide a useful approach in

understanding the Iowa Gambling task. Their theory proposes that there are two main systems involved in being able to wait for a larger reward. They proposed that a more automatic, affective system motivates children to want a reward while an emotionally neutral, cognitive system enables children to wait longer. Further, they linked the first system with implicit learning and conditioning. In contrast, they linked the cognitive system with the explicit memory system, particularly episodic memory and working memory. Finally, another interesting aspect to their theory is that they labelled the automatic system "hot" and the cognitive system "cool", which fits with the division of executive function into hot and cool processes that have been proposed in the literature (see Zelazo & Müller, 2002 for review).

Metcalfe and Mischel (1999) suggested that the interaction of these two systems is key to self-control and goal-directed behavior. They argued that the dominance of the cool system over the hot system improves over the course of development. It should become easier as children get older to use the cool system to control impulses. In fact, Metcalfe and Mischel suggested that the cognitive system becomes so dominant in adulthood that it may be necessary to activate the hot system to sustain motivation in situations involving delayed reinforcers. On the other hand, since the hot system is the default system during childhood, the development of the cool system may be what results in longer periods of delay for children (Metcalfe & Mischel, 1999). It may be then, that individual differences in performance on the delay of gratification task is mediated by different systems throughout development. Performance on the delay of gratification in childhood should be more strongly correlated with measures of the cognitive system while it may be more strongly correlated with measures of the hot system in adulthood.

These two systems also appear to closely parallel Rothbart's automatic and effortful control systems (Rothbart & Posner, 2001). Not surprisingly, Metcalfe and Mischel tied differences in temperament to differences in dominance of the two systems. This line of reasoning would also suggest that the development of temperament may lead to differences in how children cope with delay of gratification and possibly other types of future oriented decision making tasks. This may be the reason that the ability to delay gratification in childhood is so closely associated with measures of the cognitive system.

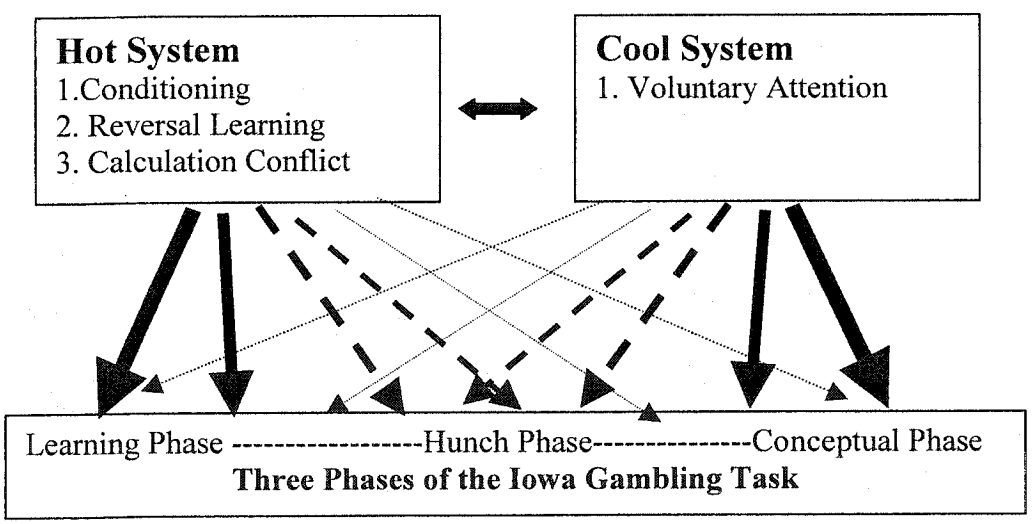
Given the similarities between delay of gratification and the Iowa Gambling task, it may be useful to expand this theory to the gambling task. Based on findings from the gambling task, it can be argued that performing well on this task requires the hot and cool systems. More specifically, there appears to be at least four inter-related abilities involved in performing this task. The first three abilities are more strongly associated with the "hot" systems proposed by Metcalf and Mischel while the last ability can be more strongly associated with the "cool" system.

First, the gambling task requires the ability to associate a stimulus with affective states as occurs in simple conditioning. Second, the gambling task requires the ability to inhibit and reverse previous learning on reward/stimuli contingency. Third, the gambling task presumably requires the ability for calculations of reward and punishment values over repeated instances, particularly when these are conflicting. Finally, the gambling task requires the ability to use conscious knowledge of the game and attention to regulate more automatic processes and direct deck choice towards the good deck. As each of these abilities is acquired during development, they are hypothesized to interact with one another. The hot system would be more relevant to the initial phase of the gambling task

when learning of contingencies is beginning. The cool system, which involves conscious aspects of decision making, would be more closely associated with the last phase of the gambling task.

Diagram 1 illustrates the hypothesized abilities involved in the hot and cool system and their influence on the gambling task. The heavy arrows indicate greater influence while the thinner arrows indicate less influence. Hence, while both systems would theoretically continue to affect decision-making through the game, the hot system would have its largest impact in the early part of the game while the cool system would have its largest impact in later phases. Another interesting point to note is that the cool system would not be expected to have a significant impact until children reached at least the hunch stage and had some idea which decks were better. Developmental literature on tasks related to these four abilities proposed in this framework is reviewed next.

Diagram 1. *The four abilities hypothesized to be involved in the gambling task.*



*Development of Abilities Related to the Iowa Gambling Task*

Metcalfe and Mischel (1999) suggested that the hot system develops first while the cool system develops later. There is some support for this suggestion in the literature. Certainly, research in the field of temperament, which is closely associated with these two systems, suggests that more automatic emotion regulation systems develop before the effortful system.

Other research on implicit learning and cognitive abilities also suggest that at least some abilities related to implicit learning develop before abilities associated with the cool system. For instance, simple conditioning, is present very early in life (Nelson, 1997; Rovee-Collier & Haynes, 2000). Simple eyeblink conditioning has been demonstrated in 4- and 5-month-old infants (Ivkovick, Collins, Eckerman, Krasnegor, & Stanton, 1999). Dating back to 1920, Watson & Rayner demonstrated that an emotional reaction can be conditioned during infancy (Watson & Rayner, 1920/2000). Rovee-Collier and her colleagues have also shown that young infants are also capable of operant conditioning (Rovee-Collier, Enright, Lucas, Fagen, & Gekoski, 1981; Rovee-Collier, Griesler & Earley, 1985; Hayne, 1990; Rossi-George & Rovee-Collier, 1999). Research on animals and humans with brain lesions suggest that conditioning learning and other implicit type learning are primarily mediated by subcortical brain areas such as the brain stem, cerebellum, amygdala, and the striatum (Nelson, 1997; LeDoux, 1996; Overman & Bachevalier, 2001; Schultz, Tremblay & Hollerman, 2000). Research on conditioning in normally developing pre-schoolers is remarkably sparse. However, it does indicate that various responses can be conditioned in pre-school children (Antonitis, 1978; Davidson & Osborne, 1974; Johnson, McPhee, & Birch, 1991; Montare, 1988). By this age, with

developing verbal abilities, children are capable of being influenced by verbal reinforcers (Cook, 1985).

The second and third abilities are closely related and thought to be mediated by the OFC (Elliot, Dolan & Frith, 2000). Both require rapid, flexible learning of associations (Rolls, 1999). There is evidence of functional maturation of the OFC during the preschool period (Overman, Bachevalier, Schuhman & Ryan; Overman, Bachevalier, Schuhman & McDonough-Ryan, 1997). Research indicates that the ability to "reverse" associations between stimuli and reinforcers develops considerably during the pre-school period. Overman et al. (1996) found that performance on an object reversal task, which has been linked to orbitofrontal functioning in primates, improves during the pre-school period. This task assesses the ability to flexibly change behaviour that has previously been reinforced. In this task, the child must choose between two objects. In the beginning, one object is consistently reinforced. Once the child has reached criterion, the reinforcement is switched to the other object. Overman et al. found significant age differences in performance between the 15- to 30-month-old group and the 31- to 55-month-old group. Overman and his colleagues also found that performance on an object reversal task develops earlier in boys than girls, with differences disappearing at approximately 3 years of age (Overman et al., 1996; Overman et al., 1997). The findings from Kerr and Zelazo (in press) on a child version of Iowa Gambling task fit nicely with Overman's research. As reviewed earlier, they have found a developmental progression from 3 to 4 years of age on a child version of the gambling task.

Finally, the ability to use conscious knowledge of choices to guide behavior develops during the preschool period as well. Research done by Mischel and his

colleagues and more recent research on the delay of gratification task suggests that preschool children are able to make choices that will benefit them in future. As noted previously, Metcalf and Mischel (1999) associated success on this task with the ability to direct attention away from the affective aspects of the rewards and instead focus on the "cooler" properties. Many of the changes that develop at 4 years of age seem to involve the ability to redirect attention, suppress preponent response, and voluntarily regulate more automatic affective processes (Carlson & Moses, 2001; Rothbart & Posner, 2001; Diamond, 2001). For instance, inhibitory skills, which have been tied to the development of the anterior attention system (Kochanska et al., 1997; Kochanska et al., 2000) show extensive development during this period.

Another interesting point to note is that the ability to inhibit and suppress preponent response has been found to show a female advantage in many studies (Carlson & Moses, 2001; Kochanska et al., 1997; Kochanska et al., 2000). Furthermore, a difference in Effortful Control trait, which has been linked to the anterior attention system, has also been consistently found to favour girls (Eisenberg, Valiente et al., 2003; Eisenberg, Zhou et al., 2003; Kochanska et al., 1997; Kochanska et al., 2000). Further, these sex differences have been found to develop early on. Diamond (1985), for instance, found sex differences, favouring girls, for the A not B task during infancy. These findings contrast the male advantage on the reversal task that depends on the OFC (Overman & Bachevalier, 2001; Overman et al., 1997). Consistent with these findings, Zelazo, Műller, Frye & Marcovitch (2003) has suggested that there may be some sex differences in the development of hot and cool systems.

**Executive Functioning and Neurological Networks Underlying Decision-Making**

The prefrontal cortex (PFC) is the brain area probably most commonly associated with decisions made over time (Samango-Sprouse, 1999). Various frameworks have been developed to describe the functions of the frontal cortex, but most authors agree that this brain area underlies goal-directed behavior and is therefore crucial for personality and social functioning (Lezak, 1995). These goal-directed behaviours are often referred to as "executive functions". Executive functions have been sometimes divided into "hot" and "cool", with the dorsolateral (DL-PFC) being associated with cool executive functions and the orbitofrontal (OFC) being associated with hot executive functions (Zelazo & Müller, 2002 for review).

As the names imply, hot functions have been more strongly associated with emotion and motivation while cool functions have been more closely to cognitive control and regulation. While hot executive functions would appear to be more closely tied to social development, it is important to keep in mind that the so-called "cool" processes are important in social functioning as well (Wood, 2003). The OFC and DL-PFC areas are connected to subcortical networks and have been found important in the development of Attention Deficit Hyperactivity Disorder and other externalizing disorders (McPherson & Cummings, 2002; Seguin, in press). Chow and Cummings (1999) suggested a third frontal-subcortical network, involving the anterior cingulate (ACC), which has also been associated with developmental disorders (Benes, 1997 for review). The ACC area appears to cut across the hot and cool distinction. The ACC has frequently been divided into an "affective" and "cognitive" division (Bush, Luu & Posner, 2000; Devinsky, Morrell & Vogt, 1995). Moreover, the cognitive division has strong connections to the

DL-PFC and may be one area by which the DL-PFC can affect the limbic area and the rest of the cortex (Duncan & Owen, 2000; Phillips et al., 2003). In fact, there is some evidence that the dorsal ACC (cognitive division) and the DL-PFC are part of a network that functions in a co-operative fashion to impose top-down regulation of both cognition and emotion (Cohen, 2002; Duncan & Owen, 2000; Phillips et al., 2003). This network is probably what underlies the trait of Effortful Control (Rothbart & Posner, 2001) and the suppression of proponent response (Diamond, 2001).

The maturation of the frontal cortex is slow in comparison to other brain areas (Benes, 2001; Klingberg, Vaidya, Gabrieli, Moseley & Hedehus, 1999; Segalowitz & Davies, in press). However, some of the functions mediated by the frontal cortex develop as early as the first year of life (Dawson, 1994; Welsh & Pennington, 1988). There is evidence that abilities such as reversal learning, thought to involve the OFC and "hot" executive functions, show development in the preschool period (Overman & Bachevalier, 2001; Overman et al., 1996). Further, there is evidence that tasks involving "cool" executive functions show considerable development during this period as well (Diamond, 2001; Műller & Zelazo, 2002; Rothbart & Posner, 2001). For instance, research on the card sort task, which has been associated with the DL-PFC and inhibition, shows an improvement at approximately 4 years of age (Carlson & Moses, 2001; Zelazo, Carter, Reznick & Frye, 1997; Zelazo, Reznick, & Pinon, 1995; Zelazo et al., 2003). The fourth year in particular marks changes in a large number of cognitive abilities.

The hot and cool division proposed by Zelazo and Műller (2002) is very similar to that proposed by Metcalfe and Mischel (1999). In fact, Kerr and Zelazo (in press) have also extended the hot/cool distinction to the gambling task. However, while Metcalfe and

Mischel have argued for an involvement of hot and cool systems in delay of gratification, Kerr and Zelazo (in press) have more closely associated the gambling task to the hot system. Nonetheless, more recent results from their lab suggests that the last phase of this task (last 20 choices) is associated with cool executive tasks (Hongwanishkul et al., 2003).

The literature on the Iowa Gambling task and similar tasks, in fact, suggests that brain areas associated with hot and cool executive functions are involved in decision making (Bechara, Damasio et al., 2000; Bechara et al., 1999; Bechara, Damasio, Tranel, & Anderson, 1998; Bechara, Tranel, Damasio, Adolphs, Rockland, & Damasio, 1995; Bechara, Tranel, Damasio, & Damasio, 1997; Critcheley & Dolan, 2001; Damasio, Bechara, Tranel, & Damasio, 1997; Rogers, Everitt et al., 1999; Rogers, Owen et al., 1999). Krawczyk (2002) reviewed the neurological basis of decision making in humans. His review indicates that a variety of cortical and subcortical areas are involved in different aspects of decision making. According to him, there are three critical regions involved in decision making; OFC, DL-PFC, and medial frontal area. The OFC region is important for making decisions based on rewards, with this region functioning as an "integration centre" for emotional information. He also noted that the OFC functions as a link between affective information and symbolic processing. The DL-PFC region, on the other hand, is critically involved in making decisions that involve several sources of information and is more clearly associated with explicit decision making. It is also involved in set shifting and response inhibition such as the extradimensional shifting. Finally, the third region, the medial frontal area, includes the ACC and the frontal pole area. This region is involved in many aspects of decision-making including error

detection, and conflict monitoring. The ACC area, in particular, may be involved in monitoring the outcome of decisions and changing behavior as a result of errors.

The functional maturation of the prefrontal area and surrounding tissue during the preschool period would suggest that this period is important for the development of decision-making. Certainly, there is evidence that the development of the OFC and other areas of the prefrontal cortex such as the DLPFC is crucial for normal social functioning (Anderson, Bechara, Damasion, Tranel & Damasio, 1999; Anderson, Damasio, Tranel & Damasio, 2000; Eslinger, Biddle & Grattan, 1997; Seguin, in press). Given that various networks appear to mature and come on-line at different ages, it is likely that children will show different patterns of choice on the Iowa Gambling task as they mature. For instance, Orzhekhovskaya (1982) found evidence that the network subserving cool executive functions matures later than that for hot executive functions, which is in line with what has been proposed by Metcalfe and Mischel (1999). Using the Iowa Gambling task with children provides an opportunity to study how this type of future oriented decision-making develops. In particular, examining the pattern of choice over different phases of the task may provide insights into how children learn to integrate more implicit type of learning with conscious choices.

## Goals of the Thesis

The Iowa Gambling task appears to measure a more complex form of future oriented decision-making. It is hypothesized to tap several abilities associated with both hot and cool systems. The main goal of this thesis was to explore the development of this more complex form of future oriented decision-making in children. Using a series of four studies, the development of future oriented decision-making was investigated. While we

know that some simpler decision-making abilities develop in the pre-school period, the development of more complex decision-making has not been firmly established yet. As noted earlier, recent research by Kerr and Zelazo (in press) suggests that this ability develops in the pre-school period, but this needs to be replicated. In order to explore the development of more complex decision-making, modified versions of the Iowa Gambling tasks were created for this thesis.

A second goal of this thesis was to look at factors associated with complex decision-making such as temperament characteristics and simpler decision-making skills. As reviewed earlier, studies performed on adult populations indicate that temperament traits such as risk taking are related to performance on the Iowa Gambling task. Further, other decision-making tasks such as temporal discounting, which is similar to delay of gratification, have been found to correlate with the Iowa Gambling task (Monterosso et al., 2001).

A third goal was to look at how changes in the reinforcement contingencies affect decision making. Studies indicate that the modification of reinforcement contingencies does not have an effect on normal adults or even the VM patients (Bechara, Tranel et al., 2000). However, since the hot and cool systems are still developing in children, it is possible that children would react differently to changes in the reinforcement contingencies. Certainly there are many types of manipulations that have not yet been investigated.

Finally, a fourth goal was to look at decision making in a population of children known to have social problems and fronto-striatal dysfunction. As reviewed above, many different populations with with dysfunction in the frontro-striatal system have difficulty

with the gambling task. One developmental disorder that has been consistently associated with dysfunction in the fronto-striatal system is Attention Deficit Hyperactivity Disorder (ADHD) (Bradshaw, 2001). Like the VM patients, this population has also been found to have real life decision-making problems and social difficulties (Barkley, 1998). Performance of ADHD children on the gambling task was therefore investigated in the last experiment.

# Chapter 2

## Experiment 1: The Development of Decision-Making

As discussed earlier, future oriented decision-making is considered to be an important executive function crucial for social adjustment. Given the wide use of the Iowa Gambling task in the adult literature and its association with social functioning, it provides a potentially useful tool for examining decision making and social functioning in children. The primary goal of this experiment was to design a child appropriate version of the Iowa Gambling task. This experiment focused on whether there were developmental differences in decision-making as measured by this task.

To explore developmental differences, a cross sectional study was conducted on three age groups: 3 year-olds, 4-year-olds, and 6-year-olds. These age groups were chosen on the basis of previous research of executive function in these age groups (e.g. Diamond, 2001; Moore, et al., 1998; Welsh, Pennington, & Groisser, 1991; Zelazo et al., 1997). The study adapted the Iowa Gambling task for children. Smarties rather than money were used. As in the original version (Bechara et al., 1994), four decks were used that approximated the reward and loss values of the adult version. Two decks were advantageous with small rewards and smaller losses while the remaining two decks were disadvantageous with large rewards and large losses. Because a group of 3-year-olds was included in our study, the number of card choices was limited to 40 rather than the 100 choices used in the original version of the Iowa Gambling task. It was felt that exceeding 40 card choices would be too difficult for this age group. Further, to compensate for differences in working memory and the lower number of card choices, reward and loss

contingencies were varied over 5 cards for each deck rather than over 10 cards in the Iowa Gambling task (see Appendix B).

An awareness test was added at the end of the game to explore children's awareness of what was occurring in the game. As reviewed earlier, Bechara et al. (1997) found that adults in the normal population reached three different periods in their conscious knowledge of what was occurring in the game. In the first phase, individuals had no idea which decks were better. Halfway through the game, normal individuals began to have a "hunch" that the two advantageous decks were "good". They termed this the *hunch* period. One hundred percent of normal individuals reached this stage while none of the brain-damaged individuals reached this period. Finally, 70% of normal individuals reached a conceptual period where they reported knowledge that the advantageous decks were good in the long run and the disadvantageous decks were bad in the long run (Bechara et al., 1997; Tranel et al., 2000). Another goal of this experiment, therefore, was to explore to the development of conscious knowledge of the game.

Given that this experiment was exploratory, there were only a few predictions. It was hypothesized that the older children, particularly the 6-year-olds, would have better developed executive functioning and would be able to make decisions that are advantageous in the future. It was therefore predicted that the older children would choose significantly more from the advantageous decks. It was predicted that the younger children would show either no difference between deck choice or would pick more from the disadvantageous deck. Finally, for the awareness test, it was predicted that older children would show greater awareness of the game than younger children would.

## Method

*Participants*

Participants were 20 three-year-olds (14 males and 6 females), ranging in age from 39-47 months (mean age = 3;8 years), 24 four-year-olds (16 males and 8 females), ranging in age from 48-59 months (mean age = 4;6 years), and 25 six-year-olds (8 males and 17 females), ranging in age from 72-83 months (mean age = 6;6 years). It should be noted that the distribution of males and females varied considerably across age because sex was not originally considered as a variable. At the time of the study, the evidence of a sex difference beyond 3 years of age was limited.

The younger group was sampled from 3 daycares and the older group was sampled from two public schools. All parents were contacted through consent forms sent home. Children were given a small gift and a certificate for their participation.

*Apparatus*

Four decks were used. There were two "advantageous" decks and two "disadvantageous" decks. Each card from the disadvantageous decks had two bears (which indicated a win of two smarties) and some cards contained pictures of tigers (which indicated loss of smarties). Each card from the advantageous decks had one bear (which indicated a win of one smartie), and some cards contained pictures of tigers (which indicated loss of smarties). Appendix A provides an example of a card from the advantageous deck. Appendix B contains the reward/loss contingencies. There were 36 cards within each deck. Given that children were asked to make only 40 choices across 4 decks, this was felt to be a sufficient number of cards per deck. In the original version of the task, individuals are asked to make 100 choices with 40 cards per deck.

Each deck was a different colour (red, blue, yellow, or green). Colours were chosen as a distinguishing feature because it was felt that this would be an easy feature for the younger children. Colour was counterbalanced across 4 sets of decks, so as to minimize the possible effect of colour preference among the participants.

*Procedure*

Children were tested in a small quiet area of their daycare or school. The four decks were placed in random order on a table. Two opaque bins were placed to the side. One had pictures of bears on it and the other had pictures of flowers on it. It should be noted that recent publications on the Iowa Gambling task report that specific instructions were provided that some decks were better than others were (Bechara, Tranel et al., 2000). Children in this study, however, were not told this. The experimenter told the child the following: "Today we are going to play the bear and tiger game with these cards". The experimenter showed the child a picture of a sample card containing one bear and one tiger." The experimenter then said: "On all these cards, there are bear pictures. The bear is good. He wants to give you smarties." The experimenter pointed to the bear symbol. For every bear picture that you see on the card, I will put a smartie in this box." The experimenter pointed to the bin with bear pictures. "So can you tell me what happens when you see the bear?" The experimenter waited for a response to continue.

Following this, the experimenter then said, "Sometimes, there will be tigers on the cards too. The tigers are mean. They like to take smarties away. For every tiger picture you see on the card, I will take away a smartie from the box. So for some cards, I will take away more smarties than I put in. Can you tell me what happens when you see tiger

pictures?" The experimenter again waited for response. "In the beginning of the game, I will put 15 smarties in this box. Your job is to try to get as many smarties in the box as you can. You can choose cards from any of these four decks. You can also change decks whenever you want. I will tell you when the game is over. At the end of the game, you can keep all the smarties in the box. Can you tell me what you will try to do in this game?" The experimenter waited for a response and explained further if necessary. The game did not proceed until child demonstrated knowledge of rules and was able to repeat what the rules of the game were.

The experimenter then said, "Do you want to play this game?" If the child indicated that they wanted to play by nodding or saying "yes", the experimenter said, "OK, let's begin then. What deck do you want choose from?" Each card selection by the child was recorded on a scoring sheet. All children received verbal reinforcement when they won smarties such as, "Good for you. There are X bears so you won X smarties." When children picked a card that contained a loss, the experimenter said, "There are X bears so you won X smarties, but oh no, there are X mean tigers so you lost X smarties. Those tigers are not nice." In between trials, children were told, "Ok, let's pick another card". The game stopped after 40 card picks.

At this point children were given four questions testing their awareness of the game. The first two questions focused on the advantageous decks while the last two focused on the disadvantageous decks. The experimenter asked the children, "Now that we are done the game, which deck was the best to pick from?" Following this, children were asked, "Why do you think this was the best to pick from?" If children chose one of the advantageous decks for the first question, they were awarded a point. If children

further were able to give an answer to the second question indicating the ratio of bears to tigers was higher for the advantageous deck, they were awarded two points. The last two questions proceeded in the same way, except that children were asked questions about the disadvantageous decks. The experimenter asked children, "Which deck was the worst to pick from?" and then "Why was this deck the worst to pick from?" Again, if children chose one of the disadvantageous decks for this answer, they were awarded one point. If they further were able to indicate that there were more tigers in this deck, they were given two points. The total score of the awareness test was a combination of the score on the first two questions and last two questions.

## Results

*Age and Sex Differences in Choosing from Advantageous Decks*

The first analysis looked at whether there were differences in patterns of decision-making among the age groups. Further, sex was added as a between subject variable due to indication in the literature that the OFC develops at different rates for males and females (Overman et al., 1997; Overman, in press). For the present experiment, choices were divided into 2 blocks of 20 choices. The number of choices from the two advantageous decks was used as the dependent measure (range is 0 - 20). A mixed factorial design was used with block as the within subject independent variables: 3 (Age Group) X 2 (Sex) X 2(Block). This was analyzed using the GLM procedure of the SPSS statistical package to correct for unequal cell size.

Table 1

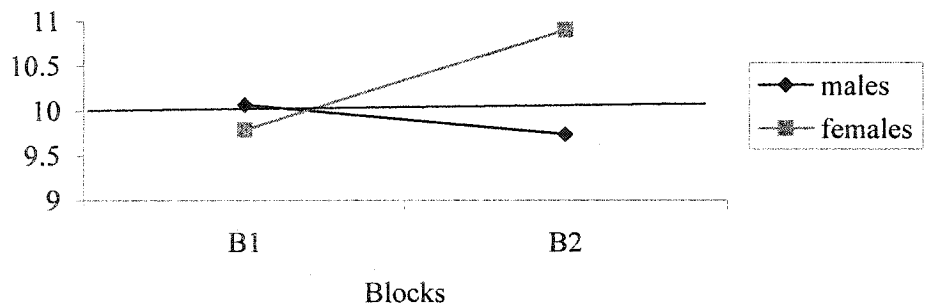
*Marginal Means of the Number of Choices from the Advantageous Decks as a Function of Age group*

| Age Group | Block 1 | Block 2 |
|---|---|---|
| 3 year olds | 9.56 (.44) | 9.76 (.43) |
| 4 year olds | 10.16 (.39) | 10.31 (.38) |
| 6 year olds | 10.09 (.39) | 10.89 (.38) |

(standard error of the mean in brackets)

Results of this analysis indicated no significant main effects or interaction of Age Group X Block. Nonetheless, inspection of table 1 indicates that the means for block 2 were in the direction predicted. There was a significant Sex X Block interaction, $F(1, 63) = 8.57, p < .01$. No other effects were found to be significant. Follow-up to the Sex X Block indicated Sex differences occurred on block 2, $F(1, 67) = 11.95, p < .01$, with females choosing more from the advantageous decks. The sex difference was not significant on block 1, $F(1, 67) = .14, p > .05$. Follows up t-tests, with Bonferroni-type adjustment, were conducted to examine whether choice from the advantageous deck differed from chance on the second block. This comparison was significant for females, $t(30), = 3.37, p < .01$, but not for males, $t(38) = -1.33, p > .05$. Figure 1 shows the choices from the good decks as a function of sex.

*Figure 1* . Number of choices from good decks as a function of gender.




*Age and Sex Differences within Different Deck Types*

The four decks differed not only on whether they were advantageous, but also in frequency of loss. For example, one of the advantageous decks and one of the disadvantageous decks had two losses occurring every 5 cards while the remaining two decks had only one loss occurring every 5 cards (see Appendix B). These two types of decks also differed on when the first loss occurred and the regularity of pattern for the losses. Given the unexpected Sex interaction effect and lack of age effect, it was decided to look at choices within these two different deck types more closely.

Two separate analyses were conducted, using choices from the frequent loss decks for one analysis and choices from the infrequent loss decks for the other. The dependent variable was percentage of choices from the advantageous deck for each deck type. The two dependent variables were calculated as follows:

1) # choices advantageous frequent loss deck/ total # choices both frequent loss decks

2) # choices advantageous infrequent loss deck/ total # choices both infrequent loss decks

Both analyses used the same independent variables as in the original analysis, with block as the within subject variable and age group and sex as the between subject variables.

For the frequent loss decks, there was a significant Block X Sex interaction, $F(1, 63) = 9.42, p < .01$. No other effects were found to be significant. Follow up analysis indicated that the sex difference occurred in the second block, $F(1, 67) = 7.01, p < .05$, with females again choosing significantly more from the advantageous decks than males.

For the infrequent loss decks, there was a significant main effect of block, $F(1, 63) = 4.45, p < .05$. This indicated that children were choosing more from this advantageous deck as the game progressed. The age main effect approached significance, $F(2, 63) = 2.45, p < .1$. Furthermore, the Age Group X Sex X Block interaction approached significance for this analysis, $F(2, 63) = 3.11, p = .05$. Given the a-priori predictions in age differences, this interaction was explored further. Separate analyses were conducted for each age group. None of the effects were significant for the three-year-olds. For the four-year-olds, the Sex X Block interaction approached significance, $F(1, 22) = 3.67, p = .07$, with females outperforming males on the second block. Analysis for the 6-year-olds indicated a significant block main effect, $F(1, 23) = 8.81, p < .01$, with 6-year-olds choosing significantly more from the advantageous infrequent deck in the second block compared to the first. While these analyses should be interpreted with caution, they do suggest age and sex differences vary depending on differing reward contingencies.

*Awareness of Game*

Analysis was performed to assess whether there was a difference between the age groups and sex in awareness of the game. As indicated earlier, this test was scored out of 4, with 0 indicating no awareness of what was occurring in the game and a score of 4 indicating that the child understood not only which decks were good and bad, but also

that the reward to loss values were better for the advantageous decks. Table 2 shows the means for males and females within each age group on this variable. As can be seen in this table, there is a progressive increase in this score over the age groups, with the 6-years-olds showing a higher awareness of the game. An analysis of variance (ANOVA) with sex and age group as the independent variables and score on awareness test as the dependent measure was conducted. No sex main effect or interaction effects were found. There was a significant age effect, $F(2, 63) = 10.19, p < .001$, indicating that the three age groups differed on the awareness variable. Post-hoc follow-up using Bonferroni type adjustments were conducted to see which of the age groups differed from one another. This analysis indicated no significant difference between 3- and 4-years-olds, $t(42) = 2.033, p > .05$, and a significant difference between the 6-year-old group and the 3- and 4-year-old groups, $t(43) = 5.32, p < .001$, $t(47) = 2.87, p < .05$, respectively.

Table 2

*Marginal Means of the Awareness Test as a Function of Age Group and Sex*

| Age Groups | Score on Awareness Test |
|---|---|
| 3 years olds | |
| males | 1.21 (.34) |
| females | 1.17 (.52) |
| total | 1.19 (.31) |
| 4 years olds | |
| males | 2.06 (.32) |
| females | 1.88 (.45) |
| total | 1.97 (.28) |
| 6 years olds | |
| males | 3.00 (.45) |
| females | 3.06 (.31) |
| total | 3.03 (.27) |

(standard error of mean in brackets)

*Awareness and Performance*

In order to explore the possibility that awareness of the game was accounting for the sex effects in performance on the gambling task, two repeated ANOVAs were conducted. The first ANOVA entered awareness test score as the between subject variable and block as the within subject variable. This analysis was conducted to assess whether reported awareness alone could account for choices from the decks. This analysis revealed a main effect of awareness, $F(1, 67) = 14.18$, $p < .001$, indicating that those with higher awareness were choosing more from the advantageous decks. A second ANOVA was conducted with the sex and age variables entered and the awareness test used as a covariate to see whether the level of awareness could account for the sex differences found. The sex interaction effect, however, remained unchanged, $F(1, 62) =$

8.43, $p < .01$, suggesting this effect was not due to differences in awareness of the test. Further, the awareness main effect remained significant, $F(1, 62) = 8.56, p < .01$. This indicated that both awareness and sex were accounting for unique variance in number of choices from the advantageous decks

*Correlation of Performance and Awareness*

Another area of interest was the relation between awareness of the game and choosing from the advantageous decks in the last block. Given the sex difference in performance, this relation was explored separately for males and females. Age in months was entered as a covariate to partial out the variance attributed to age. These age partialled correlations indicated a significant correlation between score on the awareness test and number of cards chosen from the advantageous decks in the last block for females, $r = .51$, $p < .01$. This relation was not significant for males, $r = .14$, $p > .05$. This indicated that awareness in females accounted for 25% of the variance in their choices on the second block. Fisher r-z transformation, however, indicated that the difference between these two correlations only approached significance, $z = 1.66$, $p < .1$.

## Discussion

The primary goal of this experiment was to explore developmental changes in decision-making as assessed by a modified version of an adult gambling task. It was hypothesized that as children matured, development in the OFC and other brain areas would lead to improvement in decision-making. Further, it was hypothesized that children's awareness of the task would also improve as they got older. The data only partially supported this hypothesis. Further, an unexpected sex interaction was found in

the direction opposite to what would be predicted from the literature. The findings on age effects will be briefly discussed before turning to the findings on sex differences.

As expected, there was a significant main effect of age group for the awareness test with the 6-year-olds outperforming the two younger groups. This indicates that as children get older, they are better able to understand what is happening in the game. When looking at performance on the gambling task overall, however, there was no significant Age X Block interaction as had originally been predicted. It is possible that the lack of age effect in the first analysis was due to the small number of trials used, which reduced power to find learning differences. Tranel et al. (2000) reported differences beginning only in the second block for adults. Similarly, research on other decision-making task involving multiple trials on normal populations of adults have shown that it takes many trials for learning to begin (Busemeyer & Myung, 1992; Kleinmuntz & Thomas, 1987). It is possible that adding a third block would have led to a significant difference between the age groups.

To explore the choices from different decks in more detail, separate analyses were conducted on decks that had frequent losses and decks that had more infrequent losses. Although these analyses should be interpreted with caution, they suggest an age interaction effect for the infrequent decks. Follow up indicated only the six-year-olds showed a significant block effect, where children were choosing more from the advantageous deck in the second block. While the evidence is weak, it is in accord with other studies that have found age improvements on this task (Blair et al., 2001; Kerr & Zelazo, in press; Overman, in press). Other studies, using different decision-making tasks have also found age-related changes, depending on the task difficulty (Byrnes &

McClenny, 1984; Byrnes, Miller, Reynolds, 1999). It is interesting that the age effect was found in the infrequent decks rather than frequent decks. However, the infrequent decks may have been a more powerful test of age differences as it contained fewer "reminders" of which deck was worse. For instance, it would have been more difficult for younger children to keep track of losses when the loss was occurring every fifth card rather than every second or third card. If younger children were more sensitive to the effects of immediate reinforcement than to the overall reinforcement history, they would be expected to perform more poorly when there are fewer losses to guide behavior.

Alternatively, another explanation for the difference in findings for the frequent and infrequent loss decks is the contrast between loss and win trials. For instance, the infrequent loss decks, particularly the infrequent bad deck, involve a larger contrast between win and loss trials. On most trials of the bad deck, children win 2 smarties, but in two out of 10 trials, they suddenly lose 13 smarties. It may be that older children were just better at noticing this discrepancy between winning and losing trials.

The significant awareness main effect for performance on the overall game does suggest a link between awareness and performance on the game. Children with higher awareness tended to choose more from the advantageous decks. Unfortunately, because of the correlational nature of our findings and the fact that our subjects were tested for awareness at the end of the game, it is impossible to know the exact nature of this relation between performance and awareness. It may be that conscious awareness guided choice or it may be that better performance led to greater awareness.

The study by Bechara et al. (1997) suggests a third factor may be partly responsible for this relation. In that study, the control group developed anticipatory SCRs

to the decks before they reported any knowledge of what was happening. Shortly after this period, they reported knowing that some decks were worse than others were. During this "hunch" period, subjects began changing their behaviour, switching to the advantageous decks. Bechara et al. (1997) interpreted this finding to mean these sensory representations covertly bias individuals to choose from the advantageous decks. As the game progresses, this covert bias and the individual's own reasoning strategies interact, leading to conscious knowledge of the rules. Their results indicate that the covert learning may be more important in changing behaviour than conceptual knowledge. While all controls reached the "hunch" period, not all controls reached the "conceptual" stage where they were able to report the reason why some decks were better, indicating that good performance on this task does not require full conceptual knowledge. In support of this idea, brain damaged participants who reached the conceptual period continued to choose from the disadvantageous decks. Given these findings, an alternate explanation for the relation between awareness and performance could be that some children developed stronger somatic markers in response to the decks and that this could then have led to a "bias" for the advantageous decks and greater knowledge.

Other research indicates that it is likely that the relation between implicit and explicit knowledge and their effect on performance is complex (Berry & Broadbent, 1987; Berry & Broadbent, 1988; Berry & Broadbent, 1995). Berry and Broadbent (1987) suggested that these two types of learning operate together in everyday life. It is likely, then, that a combination of covert mechanisms and overt knowledge affected performance on the gambling task. This is in accord with Rolls (1999)'s theory that implicit and explicit systems affect response to rewards.

The most intriguing finding in this experiment was the sex interaction effect. While a sex difference in performance is suggested in the literature on reversal tasks, the difference favours males rather than females. Further, partialling out the effect of awareness had no impact on this interaction effect for the overall game, indicating the differences in sex were not due to greater awareness by females. The analysis of awareness indicated that there were no sex differences on this measure. This is interesting given that the males and females were behaving differently. Yet despite comparable knowledge of the game, the males did not choose significantly more from the advantageous decks in the second block as the females did. The pattern of correlations between performance on the game and mean on the awareness test is in line with this idea. While performance correlated significantly with the awareness test for the females, the correlation was not significant for the males. This suggests that while there was an association between conscious knowledge and deck choice in females, there were no such relation for males. One interpretation of these data is that the females' performance on the task was guided by conscious knowledge while males were not.

As noted above, however, the relation between implicit and explicit knowledge is complex and it is likely that implicit knowledge may have affected reported knowledge and performance. There is evidence indicating that females have a higher awareness of their emotions (Lane, 2000). Another interpretation, then, is that females were simply more aware of their feeling states and that this bias in turn guided their choices.

Separate analysis of each deck type indicated that the sex effect was most evident for the frequent loss decks. As discussed earlier, these two deck types differed on number of losses. However, they also differ in two other important ways. The frequent

loss decks had losses occurring earlier and a more regular pattern than the infrequent loss decks. While one interpretation of the data is that females are more sensitive to frequent occurrences of loss, this is unlikely given the findings by Kerr and Zelazo (in press). Despite having a larger number of losses per trial, they found a trend for male superiority in the three-year-olds. There are at least three other possibilities to explain our findings that will be discussed in the following section. The first possibility is the difference in administration. The last two possibilities involve difference in pattern of reward/loss contingencies.

*Differences Between Present Task and Original Gambling Task*

Despite efforts to closely model the Iowa Gambling task in this experiment, there are some important differences that may have contributed to the unexpected sex interaction. As noted previously, later studies on the Iowa Gambling task provided explicit instructions that some decks were better. The instructions for this version did not contain information about some decks being advantageous. Berry and Broadbent (1988) reported that explicit instructions might lead to different modes of learning. Further, Schmitt, Brinkley & Newman. (1999) found no difference in performance on the Iowa Gambling task between controls and psychopaths, with both controls and psychopath performing poorly. Given that they did not provide participants with the explicit instructions, the authors hypothesized that explicit instruction may lead individuals to more readily develop a preference for the advantageous decks. A later study conducted by Mitchell et al. (2002) supported this idea. They found significant differences in performance between control and psychopathic inmates when using the explicit instructions for the Iowa Gambling task. The failure to use explicit instructions in the

current experiment may have lowered performance in the control participants. Further, it may have been one of the factors responsible for the sex difference. In the study by Schmitt et al. (1999), participants who were anxious chose significantly more from the advantageous decks than low anxious participants did. It is possible that less explicit instruction leads to an advantage for anxious participants and that the females in our experiment were more anxious than the males. Certainly, there is evidence of sex differences in anxiety (Pujol et al., 2002).

A second difference between the present task and the Iowa Gambling task is the availability of feedback on overall performance in the game. While this study used opaque bins to store the candy, later versions of the Iowa Gambling task used computerized administration, which provided participants with feedback on overall performance during the whole game. Similarly, Kerr and Zelazo (in press) used clear containers, which provided children with overall feedback on their performance. This again, may have led to a different mode of learning for our task. Participants in the current experiment would have had to rely more on immediate feedback and a general "sense" of how they were performing. Research indicates that the type of feedback given can affect decision-making (Hogarth, Gibbs, McKenzie, & Marquis, 1991). Again, this could have been another factor contributing to sex differences in this experiment.

The most significant difference, however, may have been the pattern of reward and loss contingencies. While the original gambling task had a specific number of losses occurring over ten cards in a specific deck, the present version had losses occurred over 5 cards. Having losses occur over 5 cards rather than 10 may have led to a more regular pattern. In particular, the current frequent loss decks had a more regular pattern than that

found in the original gambling task. For instance, the pattern of loss from card 1 to 10 was repeated in card 11 to 20. Furthermore, the advantageous frequent loss deck and disadvantageous frequent loss deck had the same pattern of losses. Similarly, the two infrequent loss decks had the same pattern of losses (See Appendix B). Having decks with the same pattern of losses may have made it easier to detect a pattern and made it more predictable. In the original version of the Iowa Gambling task, the advantageous and disadvantageous decks did not have the same pattern. It may be that the more regular, predictable pattern in our decks led to the female advantage in this experiment. The finding of an overall sex difference in the frequent loss decks, which had the most regular pattern, supports this idea.

Finally, another significant difference is that the losses in this experiment occurred earlier. This may have led to a failure to develop an initial preference for the disadvantageous decks as there is not as much of an opportunity to develop a preference in the current version of the task. The results do indeed suggest that the children did not develop an initial preference for the disadvantageous decks. This is different from the data reported by Tranel et al. (2000) where an initial preference for the disadvantageous decks developed in the first block. As such, the present task cannot be considered to strongly assess the ability to reverse associations. This may partially explain our apparently contradictory findings.

However, while the lack of reversal component may explain why males were not superior on this task, it does not explain why females were superior. If the findings were solely due to the lack of "object reversal" component in the task, then one might expect no sex differences. The fact that females were outperforming males suggests that there

may be another mechanism operating, whether covert or overt. As discussed in the introduction, it is likely that the Iowa Gambling task assesses a variety of skills. Four of these skills were suggested. While the current gambling task does not appear to assess the ability to reverse associations, it can be argued that it assesses the other skills. Our results would suggest that there is a female advantage for one or more of these skills. One of these skills involves the cool system and attention control. As noted previously, females have been reported to show an advantage on this skill (Kochanska et al., 1997).

A theory proposed by Tucker, Luu, and Pribram (1995) may be relevant to this discussion. They proposed two neurological systems that closely parallel the hot and cool systems discussed earlier. The first system consists of the (orbital) ventral pathway linking the orbital PFC with the olfactory cortex of the limbic areas. The second, a dorsomedial system, links PFC areas such as the cingulate to limbic areas such as the hippocampus. Each of these "systems" is hypothesized to lead to differing motivational biases. Tucker et al. suggest that evolution may have resulted in two separate motor systems in the frontal lobe to function adaptively in the world. More importantly, these two systems are hypothesized to play complementary roles in dealing with the future. The (orbital) ventral system is necessary for dealing with unforeseen, unpredictable events. It is a reactive system that adapts flexibly to unexpected environmental stimuli. This system would be ideally suited for reversal of association, which has been hypothesized to develop earlier in males. The dorsomedial system, on the other hand, "is concerned with projecting actions based on probabilistic models of the future" (p. 221). This system leads to an internal model of the world based on previous experiences in similar situations. This system would enable individuals to choose from the decks based

on an internal model of the task. Tucker et al. noted that while the dorsomedial system is poorly suited for unpredictable events, the (orbital) ventral system is ideally suited.

More interestingly, the two systems are very similar to the hot and cool systems proposed by Metcalfe and Mischel (1999). The OFC system that they proposed seems closely linked to the hot system while the ACC system seems more closely linked to the cool system. For instance, the two systems have similar neurological correlates and similar proposed functions. One possible interpretation of the data then is that there is sex difference in development of these two hypothesized systems for dealing with time. Certainly, there is some evidence from the developmental literature that males and females show different patterns of development of the hot and cool executive functions (Kochanska et al., 1997; Carlson & Moses, 2001; Overman & Bachevalier, 2001; Zelazo et al., 2003). One possibility is that the present version of the gambling task may have been more strongly dependent on the cool system, given its lack of a reversal component and more predictable pattern. This may be what led to a female advantage.

*Conclusion and Future Directions*

In conclusion, the results of the present experiment suggest at least two areas that require further investigation. The next two experiments will address these issues. First, the present findings contrast with findings from Kerr and Zelazo (in press) in the development of this more complex form of decision-making. The current experiment found only developmental differences for the infrequent loss decks and not for the overall analysis. As discussed earlier, this was probably due to many factors. However, given that the preschool period has been consistently found to be important for the development

of abilities hypothesized to be assessed by the gambling task, this needs to be investigated further.

Another area requiring further investigation is the female advantage found in the present version of the gambling task. This finding suggests that varying the administration of the task may lead to differences in abilities assessed by the task. In particular, varying the pattern of reward/loss may have an important impact on differences in decision making among children. The results of the current experiment suggest that there are at least three important factors when varying the pattern of reinforcement. The first is frequency of loss, which may be more important in terms of development. As noted previously, frequent losses would be easier for younger children, providing more frequent reminders of which decks lead to greater loss. Regularity of pattern and first occurrence of loss may be more relevant for sex differences. These two variables may influence predictability of loss. Unfortunately, in the present experiment, there was a confound between these three factors and so we can only hypothesize as to which is important. Again, this area needs to be investigated more systematically.

# Chapter 3

## Experiment 2: Decision-Making in Pre-schoolers

The research reviewed in chapter 1 indicates that the pre-school period is critical for the development of executive functioning and decision making. The primary goal of the present experiment was to explore further decision-making in the pre-school period. The gambling task used in experiment 1, which assesses complex decision-making skills, showed a developmental shift from 4- to 6-years-old for the infrequent deck type, but not from 3- to 4-years-old. This may be due to a number of factors. First, it may simply be that children in the pre-school period have not developed this skill yet. Alternatively, it may be that children at this age are just starting to develop the ability to calculate rewards and losses over time. If this second possibility is true, then pre-school children should do better on a simpler version of the task. A simpler version would be more likely to show development differences between 3 and 4-year-olds if they do exist. The findings of Kerr and Zelazo (in press) supports this possibility. They have just completed a study on this age range where they used a two-deck rather than four-deck version. They found significant developmental differences between 3 and 4 years. Finally, another possibility is the number of card turns used. The Bechara et al. version used 100 card turns. Adults were just beginning to show a preference for the good deck in the second block of 20 cards. In the first experiment, only 40 card turns were used. This small number of card turns may have led to only a weak preference emerging in the second block. For this experiment, therefore, it was decided to add 20 turns. Adding another block of 20 cards would give children more time to acquire a preference.

The decision task used in the current experiment was very similar to that used in the first experiment. As noted above, a two-deck version was used. Also, 20 card turns were added. One deck was advantageous with small rewards and smaller losses and the other deck was disadvantageous with large rewards and larger losses. Rather than just having smarties as reward, children were asked to choose their favorite reward; smarties, skittles, or stickers. This was done to assure that children would receive the reward that they liked. Finally, the first loss occurred at card 5, and the pattern of loss was not identical for the bad and good decks as had been the case in experiment 1. Using this version, an Age X Block interaction was predicted, with 4-year-olds choosing significantly more from the good deck in the last two blocks.

A second goal was to explore the relationship of complex decision-making with a simpler decision-making task such as delay of gratification. As discussed in chapter 1, the future oriented choice task (Thompson et al., 1997) examines how children can make decisions that will benefit themselves and others in the future. The future oriented prudence component represents a variation of the delay of gratification paradigm. Further, future altruism and prudence components have been found to correlate. As well, the two components show a developmental shift from 3- to 4-years-old. Given that delay of gratification tasks have been linked to "cool" strategies such as the use of attention (Mischel et al., 1989), this type of task is hypothesized to be linked to later phases of the decision making process, when decisions are more conscious. It was therefore predicted that scores on this task should be correlated with the last two blocks of the gambling task.

The future oriented choice task used the same protocol as earlier studies such as Thompson et al. (1997). Three types of choices were given to children. The children

made a total of 9 choices, with 3 choices for each type. In the sharing with cost type, children were asked whether they would like 2 stickers now for self or 1 for self and 1 for the experimenter now. In the future altruism component, children were asked if they wanted 1 sticker for self now or 1 sticker each later. In the future prudence component, children were asked whether they wanted 1 sticker now or 2 stickers later. When children chose to have stickers now, they were given the stickers immediately to put in their sticker books. When they chose to wait until later, their stickers were put in an envelope and given to them at the end of the game. For all components, children were given a score of 1 for every choice to delay reward or share.

A third goal of this experiment was to look at the relationship between temperament and decision-making. The research by Bechara and Damasio indicates that individuals who have lesions to the ventromedial area develop drastic changes to their personality (Damasio, 1994; Bechara et al., 1994). These individuals become irresponsible, impulsive, and insensitive to others. This suggests that the inability to make decisions over time is also accompanied by certain personality variables. As noted earlier, research does support the idea that personality variables are associated with the pattern of choices made on the gambling task.

It was argued in chapter 1 that performing well on the child's version of the Iowa Gambling task should involve both "hot" and "cool" aspects of executive functioning. Earlier stages of the Iowa Gambling task should rely more heavily on "hot" processes. These processes would allow children to feel the motivation to get rewards (Metcalf & Mischel, 1999). The cool processes would allow children to detach themselves from the hot aspects of the reward and make voluntary decisions based on goals (accumulating

smarties) rather than immediate affective properties (desire for immediate gratification) (Metcalf & Mischel, 1999). The idea of hot and cool executive functions overlaps with the idea of automatic and voluntary emotion control system in the temperament literature. This line of reasoning suggests that the temperament scales assessing more automatic aspects of emotion regulation such as those of the Extraversion/Surgency and Negative Affectivity will be correlated with earlier stages of the gambling task while the Effortful Control scales should be correlated with later stages of the gambling task.

In the adult literature, Peters and Slovics found an association between scores on the BIS and avoidance of high loss decks. Correspondingly, it was expected that the shy and fear scales would correlate positively with choices from the good deck. Finally, it was expected that the Effortful Control scales would correlate with the last two blocks of the gambling task since later choices should involve more conscious aspects of decision-making.

## Method

*Participants*

Participants were 23 3-year-olds (13 males, 10 females), ranging in age from 41 months to 47 months (mean age = 3;8 years) and 21 four-year olds (11 males, 10 females), ranging in age from 55 months to 59 months (mean age = 4;10 years). Parents were contacted from a list of parents who had participated in past studies and had agreed to be contacted again. Children were predominantly from middle class families in the Halifax region. Children received a small gift and certificate for their participation.

Some children failed to finish the tasks due to irritability or tiredness. It was decided that only data from children who had made at least 50 choices would be used in

analysis of the gambling task. Using this criterion, only one child (a three-year-old male) did not complete this task. The final analysis for the gambling task therefore included 22 three-year-olds (10 females and 12 males) and 21 four-year-olds (10 females, 11males). Two other children only made 50 choices (again 3-year-old males). Given that some children had not made all 20 choices on the last block, proportions rather than number of choices were used in the analysis. Finally for the future-oriented choice task, two children failed to finish this task (2 3-year-old males). The analysis of this task therefore included 21 three-year-olds and 21 four-year-olds. All parents completed the CBQ questionnaire.

*Apparatus*

Two decks rather than four were used. There was one advantageous deck and one disadvantageous deck. Once again, the bad deck had 2 bears on each card while the good deck had 1 bear on each card. Some of the cards had pictures of tigers, indicating a loss (see Appendix C for reward/loss contingencies). Each deck was either green or yellow, with colour counterbalanced across two sets of decks so as to minimize the possibility of colour preference.

For the future-oriented choice task, a wide variety of stickers were used, chosen to be attractive for children of this age. A bin with divisions was used to keep stickers separated for the different trials. Children were given a choice between three colourful sticker books; a book shaped like a bus, a book in the shape of a star, and a book in the shape of frog.

*Procedure*

Children were given three tasks, with only two tasks considered for this project. Parents and children were tested in the lab in the Dalhousie Life Science Building. The first experimenter (E1) explained the study to parents and got their signed consent. Parents were then given the CBQ questionnaire to fill out. During this time, the second experimenter (E2), engaged the child in play. This was done in order to allow the child to warm up and help establish a rapport between the two. This rapport with the second experimenter was important for the future-oriented choice task when children were asked if they would like to share with the second experimenter. Once children were sufficiently at ease, they were invited to play a game with the first experimenter.

*The Child Behavior Questionnaire*

All parents were asked to fill out the Children's Behavior Questionnaire (CBQ; Rothbart, 1996). The CBQ was constructed to measure temperament characteristics of children 3 to 8 years of age (Rothbart, Ahadi et al., 2000). The CBQ is based on years of research by Rothbart and her colleagues on dimensions of temperament in adults and young children. Factor analysis indicates that the CBQ cluster into three large factors. The first factor was labelled this factor Extraversion/Surgency to reflect its similarity with the extraversion factor frequently found in other studies. Individuals who score high on this factor are characterised as risk takers and have low anxiety in new social situations. The second large factor, Negative Affectivity seems to reflect automatic emotion regulation abilities. Finally, Effortful Control, reflects the ability to exercise a high degree of voluntary control on their focus of attention and behavior.

*Gambling Task*

The procedure was identical to that of experiment 1, with three exceptions. First, children were asked to choose between three rewards. The experimenter said the following at the start of the game, "We are going to play a game where you can win rewards. I want you to choose what you like the best." E1 than showed the child smarties, skittles, and stickers. Children were allowed to sample the candy if they wished and to examine the stickers. Once children chose the preferred reward, the game began. The second difference was in the number of cards children were asked to choose which was increased from 40 to 60. Finally, children were given the awareness test twice rather than once. The first awareness test was given after 40 cards were chosen. The second awareness test was given at the end of the game. This was the same awareness test given in experiment 1.

*Future Oriented Prudence and Altruism Tasks*

For this task children were asked to choose a sticker book in which to place their immediate rewards. Children were also given an envelope in which to save their future rewards. Children were told the following, "(Child's name ), in this game, I'm going to show you some stickers and ask you questions about them. You'll get to pick who gets the stickers. Sometimes you might want that just you gets a sticker, and sometimes you might want E2 to get a sticker. And you'll also get to pick how many stickers you want, and when you want to get the stickers. Sometimes, you might want to have your stickers right away so you can put them in your sticker book, and sometimes you might want to wait and get your stickers at the end of the game. When you think that you want to wait for your stickers, I'll put your stickers right here in this envelope to save them for you,

and I'll put E2's stickers in this other envelope to save them for her. Then at the end of the game, I'll take the stickers out of the envelopes and give them all back to you and E2 so you can put them in your sticker books."

First, as a practice, children were asked to choose between one or two stickers now. For the task proper, children were asked three types of questions. The sharing question was as follows. "Here are 2 stickers. " The child was then shown the stickers. "You can have two stickers for you or you can have one for you and one for E2. What would you like to do?" Once the child made a choice, E1 repeated the choice to make sure that the child understood the choice made. For the future prudence question, E1 said, "You can have one sticker for your sticker book right now or you can have two stickers to save in your envelope until the end of the game. What would you like to do?." Finally, for the future altruism question, E1 said, "You can have one sticker for your sticker book right now or you can have one sticker for you and one sticker for E2 to save in your envelopes for the end of the game. What would you like to do?" Three blocks of trials were administered and in each block, one of each trial type occurred (randomised presentation order).

## Results

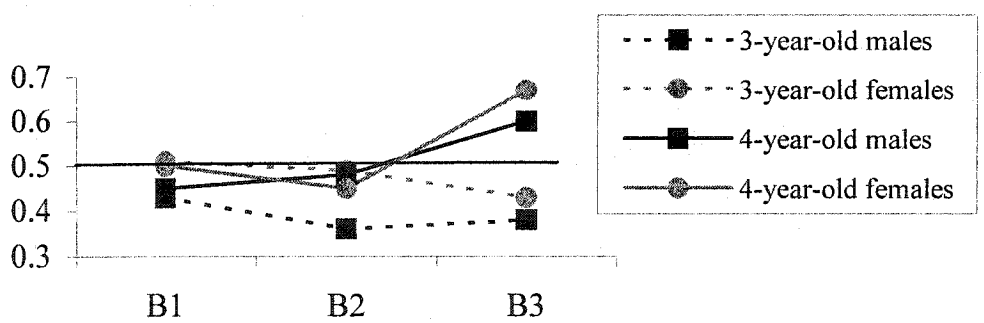
*Age and Sex Differences in Choosing from Advantageous Deck*

The first analysis looked at age and sex differences in choosing from the advantageous deck. The variables used in this analysis were same as that used in the first experiment. Age and sex were used as between subject variables while block was used as the within subject variable. The 60 choices were divided into 3 blocks of 20 choices. Given that 2 of the younger children did not finish the third block, the proportion of

choices from the advantageous deck was used as the dependent variable rather than the total number of choices. The data was again analyzed using the GLM procedure of the SPSS statistical package: 2 (Age Group) X 2 (Sex) X 3 (Block). It should be noted that the more conservative Greenhouse-Geisser test was used for significance level whenever Mauchley's test of sphericity was significant.

Results of this analysis indicated that the age main effect approached significance, $F(1, 39) = 3.35, p < .08$, with older children choosing more from the good deck.. The block main effect approached significance, $F(2, 78) = 2.71, p < .08$. More importantly, the Age X Block main effect was significant, $F(2, 78) = 7.17, p < .01$. No other effects approached significance, including the Sex X Block interaction. Inspection of figure 2 indicates that the 4-year-olds appeared to be showing a preference for the good deck on the third block while the 3-year-olds, particularly males appeared to be showing a trend for preference of the bad deck in the last two blocks.

*Figure 2.* Proportion of choices from the good deck as a function of sex and age group.



Follows up t-tests, with Bonferroni-type adjustment, were conducted to examine whether choice from the advantageous deck differed from chance on the second and third block. This comparison indicated that 4-year-olds chose significantly more from the good deck on the third block, $t$ (20) = 2.47, < .05, but not for the second block, $t$ (20) = -.69, $p$ > .05. In contrast, the three-year-olds showed a trend for choosing more from the bad deck in the second, $t$ (21) = -1.87, $p$ < .08, and third block, $t$ (21) = -1.98, $p$ < .07.

*Awareness of Game*

Analysis was performed to assess possible age and sex differences in awareness of the game. In contrast to the first experiment, awareness was assessed twice. It was measured after choice 40 and again at the end of the game. A mixed ANOVA was therefore used to assess differences in awareness, with age group and sex as the between subject variables. Test time (Test 1 & Test 2) was the within subject variable. The dependent variable was the score on each test. This analysis indicated a highly significant age main effect, $F$ (1, 38) = 18.03, $p$ < .001, with 4-year-olds outperforming the younger children as expected. Table 3 provides the average score on the awareness test for each age group. The test time effect approached significance, $F$ (1, 38) = 4.11, $p$ = .05, with children's awareness of the game improving over time. The Age X Test Time interaction was nonsignificant, indicating both age groups improved their awareness over time. There were no sex differences in awareness for this game.

Table 3

*Marginal Means of the Awareness Test as a Function of Age Group and Test Time*

| Age Groups | Score on Awareness Test |
|---|---|
| 3-year-olds | |
| test 1 | 1.10 (.33) |
| test 2 | 1.35 (.29) |
| 4-year-olds | |
| test 1 | 2.45 (.33) |
| test 2 | 3.14 (.29) |

(Standard error of the mean in brackets)

*Awareness and Performance*

In order to explore the possibility that awareness of the game was accounting for the age effects in performance on the game, the score on test 1 was used as a covariate to remove the variance associated with this variable. The awareness variable was significant, $F(1, 38) = 11.82, p < .01$. Children who scored higher on the awareness test tended to choose more from the good deck. While the F-value was reduced, the Age X Block interaction remained significant, $F(2, 76) = 3.68, p < .05$, indicating that differences among 3- and 4-year-olds were not entirely attributable to differences in awareness.

The performance of the younger children, in fact, seemed to indicate dissociation between knowledge and performance. Children were divided into three awareness levels to further explore this. Children in awareness level 1 were children who scored 0-1 on the awareness test. These were children who had no idea that the good deck was better to choose from. Children in awareness level 2 (score 2) were children who knew what deck

was better, but did not know why. This loosely corresponded to adults who had reached the "hunch" period in the Bechara et al.(1997) study. Children in awareness level 3 (score 3-4) were children who not only knew which deck was better, but why it was better. This loosely corresponded to the "conceptual" phase for adults in the Bechara et al. study. Figure 3 and 4 show the performance of each age group according to awareness level. As can be seen, the two age groups differ most strongly on block 3. Knowing which deck is better seems to lead to a preference for the good deck in older children, but not the younger children.

*Figure 3.* Proportion of choices from the good deck as a function awareness for 3-year-olds.

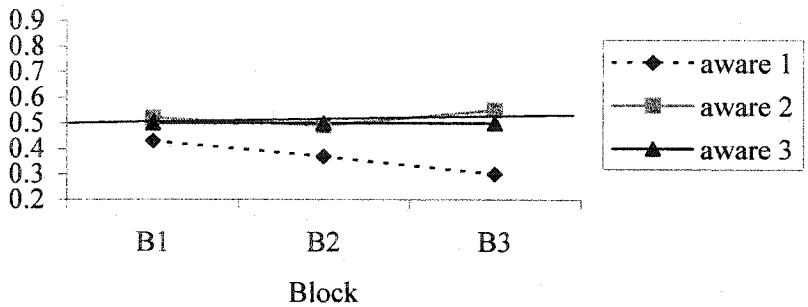
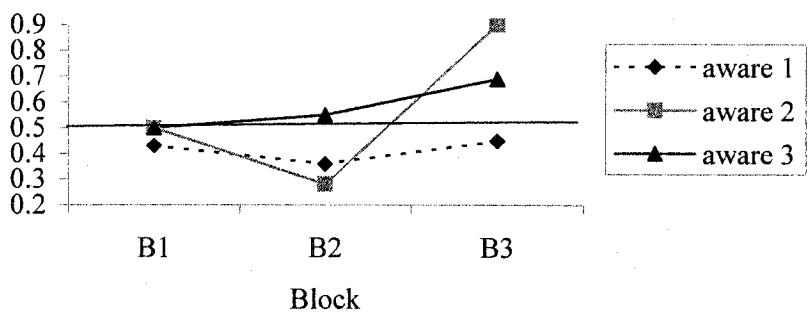



*Figure 4.* Proportion of choices from the good deck as a function of awareness for 4-year-olds.




In the Bechara et al. study, all normals reached at least the hunch period. As discussed earlier, these adults knew which decks were better, but not why. One possibility is that having this knowledge helps normal individual to go with their "gut feeling" and choose more from the good decks. While this conscious knowledge seems to help normal individuals, it does not appear to have the same effect on VM patients. It is possible that the same is true for younger children who have an immature frontal cortex.

It was decided to explore whether reaching the hunch period was associated with more choices from the good deck in the last block. Based on binomial probabilities, children who had reached at least the hunch period (2-4 score on awareness test) were divided into two groups. Children who chose 13 or more cards from the good deck ($p$ = .07) in the last block were classified as preferring the good deck. The remaining children were classified as showing no preference for the good deck. Using this classification, only 22.2% of 3-year-olds who reached the hunch period at card 40 subsequently chose more from the good deck in the last block. In contrast, 64.3% of the four-year-old who reached the hunch period chose more from the good deck in block 3. A chi-square test indicated that this differences was significant, $\chi 2 = 3.88, p < .05$. This suggests that the 4-year-olds were more similar to the adults in the gambling studies. These children's actions tended to be consistent with what they reported knowing.

*Age and Sex Differences for Future Oriented Tasks*

The future-oriented choice task was analysed using a mixed ANOVA with age and sex again as the between subject variables. The within subject variable was the type of choice (Sharing, Prudence, Altruism). The dependent variable was the number of times children chose to share or delay. The sex main and interaction effects were non-significant so sex was removed from subsequent analysis to increase power. Using this analysis, there was a significant main effect of choice, $F(2, 80) = 6.42, p < .01$. Inspection of table 3 indicates that children tended to have higher scores on the Sharing component as expected. The Age X Choice interaction only approached significance, $F(2, 80) = 2.44, p = .1$. Given a priori assumptions and significant main effect of choice, it was decided to analyse each type of choice individually. The age main effect was non-

significant for both Altruism and Sharing, $F(1, 40) = .56, p > .05$ and $F(1, 40) = .72, p > .05$, respectively. The age main effect approached significance for the Prudence choice task, $F(1, 40) = 3.10, p < .09$. Table 4 indicates that the older children showed a trend towards delaying more when there was a benefit to self.

Correlation analysis between the different components of this task resulted in some of the expected patterns of correlations (see Table 5). Age in months was partialled out to control for this variable. For the 3-year-olds, only Altruism and Prudence were positively correlated. For 4-year-olds, Prudence and Altruism were significantly correlated while the Prudence and Sharing components were not significantly correlated. Altruism and Share, however, were significantly correlated for the 4-year-olds.

Table 4

*Means of the Three Choice Tasks as a Function of Age Group*

| Age Group | Sharing | Altruism | Prudence |
|---|---|---|---|
| 3-year-olds | 1.67 (.26) | 0.81 (.25) | 0.62 (.19) |
| 4-year-olds | 1.38 (.21) | 1.05 (.20) | 1.19 (.26) |

(Standard error of the mean in brackets)

Table 5

*Correlations Between Sharing, Future Oriented Altruism and Future Oriented Prudence*

| Age Group | Altruism | Prudence |
|---|---|---|
| 3-year-olds | | |
| Sharing | .27 | .16 |
| Altruism | | .66** |
| Prudence | | |
| 4-year-olds | | |
| Sharing | .51* | .16 |
| Altruism | | .44* |
| Prudence | | |

* $p < .05$ ** $p < .01$

*Correlations between Two Decision-Making Tasks*

It was hypothesized that decisions to delay for the future, either for self or other, should be correlated with performance on the last two blocks of the gambling task. Age in months was partialled out to control for the effects of this variable. For the 3-year-olds, the only correlation that approached signifance was found between the last block on the gambling task and the Prudence task $r$ (17) = .40, $p < .1$. This indicated that children who chose to delay for self tended to also choose more from the good deck in the last block. For the 4-year-olds, none of the correlations between performance on this delay of gratification choice task and the gambling task were significant.

*Temperament and Deck Choices*

Given that this analysis was exploratory, the subscales were correlated with all three blocks of the gambling task. Age in months was again partialled out. For the three-year-olds, correlational analysis revealed a number of significant associations,

particularly the first block and the Extraversion/ Surgency scales. For these scales, Impulsivity $r$ (19) = -.45, $p < .05$, Activity level $r$ (19) = -.45, $p < .05$, and High Intensity Pleasure $r$ (19) = -.48, $p < .05$ were all negatively correlated with the number of choices from the good deck, first block. The Shy scale was positively correlated, $r$ (19) = +.43, $p < .05$ with the number of choices from the good deck on the first block. None of the correlations with block 2 and block 3 were significant for the Extraversion scales. For the Negative Affectively Scales, score on Discomfort was negatively correlated with block 2, $r$ (19) = -.43 and block 3, $r$ (19) = -.47, both $p < .05$. For the Effortful Control scales, only Inhibitory Control correlated positively with the number of choices from the good deck on block 1, $r$ (19) = +.55, $p < .05$. Interestingly, for this age group, the scores on the Effortful Control scales were not correlated with the last two blocks as originally predicted.

For the 4-year-olds, the majority of significant correlations seemed to occur with performance on block 2. This may have resulted because of the higher variability of performance on this block for this age group. There were no significant correlations with the Extraversion/Surgency scales. For the Negative Affectivity Scales, there was a significantly negative correlation between the Sad scale and the number of choices on block 1, $r$ (18) = -.40, $p < .05$ and the Anger subscale and block 2, $r$ (18) = -.51, $p < .05$. There was a significant positive correlations for Falling Reactivity and block 2, $r$ (18) = +.60, $p < .05$. Finally, for the Effortful Control scales, there were significant positive correlations between Low Intensity Pleasure and block 2, $r$ (18) = +.47, $p < .05$. The Attention Shifting scale was positively correlated with both block 1, $r$ (18) = +.46, $p < .05$ and block 2, $r$ (18) = +.43, $p < .05$.

*Effortful Control Scales and Future Oriented Choice Tasks*

It was hypothesized that the scales from the Effortful Control scales would be significantly positively correlated with number of delayed choices on the future oriented prudence and altruism components of the sticker task. For three-year olds, the score on the future oriented prudence correlated significantly with only the Attention Focus scale, $r\ (17) = .48, p < .05$ and approached significance for the Inhibitory Control scale, $r\ (17) = .37, p = .06$. The score on the altruism task was significant correlated with Attention Focus, $r\ (17) = .39, p < .05$. For 4-year-olds, none of these correlations were significant.

*Sex Differences in Temperament*

The literature suggests that males and females consistently differ on a number of temperament characteristics (Kochanska et al., 1997). A series of one-way ANOVAs were conducted to explore sex differences on the scales. The results of these analyses indicated significant sex differences for the High Intensity Pleasure scale, $F\ (1, 41) = 5.57$ and the Impulsivity scale, $F\ (1, 41) = 4.65$, both $p$'s $< .05$. Females scored significantly lower on High Intensity Pleasure and Impulsivity. Further, sex differences approached significance for the Activity level scale, Approach Scale, $F\ (1, 41) = 3.49$ and Inhibitory Control scale, $F\ (1, 41) = 2.88$, all $p$'s $< .1$. As expected, males were higher on the activity level and lower on inhibitory control.

## Discussion

The most significant finding of this experiment was the Age X Block interaction effect. This finding is consistent with Kerr and Zelazo (in press) and it suggests that the ability to make "complex decisions" develops sometime after 4 years of age. This finding indicates that varying the task alters its sensitivity to age differences in the pre-

school period. While reducing the number of decks from four to two likely had an impact, it appears from inspection of the data, that adding a third block had the greatest impact. The 4-year-olds were not choosing significantly more from the good deck when compared to chance until the 3rd block. This is actually consistent with the results from experiment 1 where there was a significant block effect (block 1 & 2) for the 6-year-olds for the infrequent loss decks. The younger children, including 4-year-olds did not show a significant block effect. The decks used in the present experiment are very similar to the infrequent loss decks of experiment 1 in that they contain 2 losses every 10 cards, with the first loss occurring at the 5th card. It may be that young children take longer to learn contingencies and so require more choices.

While 4-year-olds chose significantly more from the good deck when compared to chance, the 3-year-olds showed a trend to choose more from the bad decks. Findings from Kerr and Zelazo (in press) also support this assertion. There are many possible explanations for the behavior of the three-year-olds. One simple explanation is the difference in conscious knowledge about the game between the two age groups. It is possible that the older children were able to choose more from the good deck just simply because they were more aware of what was going on in the game. Certainly, the significant difference in score on the awareness test supports this idea. By the end of the second block, only 43.4% of 3-year-olds had reached the hunch phase while 66.6% of 4-year-olds had. While this no doubt accounted for some differences in performance, there is reason to believe that this was not the only factor affecting performance. Moreover, when the variance from the awareness test was partialled out, the main age effect and age

by block interaction remained significant. This suggests at least a second factor operating.

This factor may be immaturity of the OFC and the hot system. Research suggests that the amygdala develops early in children while the PFC is much slower in its development (Schore, 2003). Such an explanation would be consistent with both the somatic marker hypothesis and Roll's explanation of the function of the amygdala versus the OFC (Damasio, 1994; 2003; Rolls, 1999; 2000). The somatic marker hypothesis proposes that the amygdala is needed for learning simple stimulus/response associations and that the OFC/VM area is needed for more complex, higher order asssociations. Rolls (1999), on the other hand, argues that the amygdala and OFC perform similar functions, but that the amygdala network is much slower than the OFC.

While there are some similarities between the two theories, they would make different predictions. Rolls' theory would predict that children with immature OFC could eventually learn stimulus/response associations given enough time. The somatic marker hypothesis, on the other hand, would predict that individuals with a poorly functioning OFC would not be able to learn such complex, conflicting associations.

The data in the current experiment is more strongly supportive of the somatic marker. The younger children did not show any trends for improvement over time. In fact, they actually showed a trend to prefer the bad decks in the second and third block. This immaturity of the OFC may lead young children to focus more on reward information since this information occurs more frequently than loss information. At this age, consistent, frequently occurring reinforcement information seems to have more impact than infrequent information. It may be that they are able to focus on simple

associations and ignore conflicting losses. Alternatively, it may be that the information on which deck is better changes so frequently that the 3-year-old with an immature OFC is unable to keep track of this information. This would be more consistent with Rolls' theory.

A related possibility, therefore, is that 3-year-olds are unable to "reverse" learning of associations. For instance, in experiment 2, the bad deck appeared to be better until card 5, when the first loss occurred. If children are alternating between the two decks initially (a pattern found in the majority of children) then it would take 8-9 cards before they suspect the bad deck is actually worse. However, the pattern of finding for the 4's and 3's in this thesis makes this unlikely. In the first block of experiment 2, there appeared to be no preference for either deck for both age groups. In fact, figure 2 suggests that preference for the bad deck appeared to increase across blocks for 3-year-olds.

Bechara et al. (1997) suggested that implicit knowledge gained from somatic markers will affect conscious knowledge. They, in fact, suggested an interaction between implicit and explicit processes in decision-making. Many other writers have suggested that decision-making involves both implicit and explicit processes as well (Berry & Broadbent, 1987; Berry & Broadbent, 1995; Rolls, 1999). A fourth possible explanation, then, for the behavior of 3-year-olds is a partial dissociation between implicit and explicit processes. There is evidence that while implicit and explicit memory are correlated for adults, there is a dissociation for children (Bullock-Drummey & Newcombe, 1995; Newcombe & Fox, 1994). This may reflect immaturity of more distant connections between brain networks at this age (Luciana & Nelson, 1998). Even among 3- and 4-

year-olds of similar awareness level, there was a difference in performance. Most of the three-year-olds who reported that the good deck was better were still not choosing more from the good deck by the end of the game. This is reminiscent of VM patients who were able to report that the good decks were better, but were still not changing their behavior. In contrast, the majority of 4-year-olds who reported that the good decks were better subsequently chose more from the good deck in the last block. This was especially true of children who had not yet discovered exactly why the deck was better (hunch stage). These children appeared to show the most dramatic behavior change.

Finally, another related possibility is the inability of 3-year-olds to use the "conscious" system to guide behavior when it is most appropriate. Rather than a problem with communication between implicit and explicit systems, it may be that 3-year-olds are not able to "switch" to the more conscious system (or switch off the implicit system) to guide behavior when implicit and explicit processes are in conflict. More specifically, it may be that 3-year-olds have more difficulty inhibiting a dominant response to perform a subdominant response (Rothbart & Posner, 2001). As discussed earlier, this may strongly relate to the development of the Effortful Control system or cool system. Diamond's research indicates that the anterior attention system, which involves both the ACC and DLPFC will be taxed when combining both working memory effort and inhibition of subdominant response (Diamond, 2001). While 3-year-olds may be able to perform certain tasks which depend on this network successfully, increasing working memory load or conflict between responses would make it more difficult for them and lead to a choice of subdominant response. Also, in support of this possibility is the difference in performance between 3- and 4-year-olds when choice is more explicit such as the delay

of gratification paradigm or future-oriented prudence task. Findings from this task indicates that 3-year-olds have difficulty choosing the larger, delayed option when it is paired against a smaller, immediate option. One study also indicates that even when preschoolers think delaying for a larger reward is the "smart" thing to do, they still choose the immediate, smaller reward (Nisan & Koriat, 1977).

Younger children may not able to use their awareness of a "feeling state" to guide behavior when there is conflict with a more dominant response. As Damasio (1994) hypothesized, this accumulation of somatic markers may only "bias" people to act a certain way. Even if individuals feel negatively about something, they may not act on this feeling state. Mayer and Salovey (1997) indicate that being able to use emotions to facilitate thinking develops after understanding one's own emotions.

Once children reach 4 years of age, they are more likely to choose from the good deck. Results from experiment 2 provide evidence that this age group is choosing more from the good deck when compared to chance. It is possible that further developments of the hot and cool systems combine to lead to the ability to form somatic markers more efficiently, to use this information to report knowledge verbally, and to use this bias and conscious information to guide behavior. Indeed, the results of experiment 2 indicate that it may be a combination of bias and conscious knowledge that enable the largest change in behavior. While some children were beginning to show preference for the good deck in block 2, this increased dramatically in block 3. Using a criteria of 13 or more cards from the good deck, only 9.5% of 4's were choosing more from the good deck at block 2. After being asked the awareness question, this jumped to 47.5%. This indicates that just being asked questions about the decks may have allowed these children to access and use

knowledge accumulated about the deck. Further, this percentage was higher for children who had at least reached the hunch period. For this group of 4's, the percentage of children showing a preference for the good deck went up from 14.3% in block 2 to 64.3% in block 3.

These data indicate that while somatic marker may bias children toward a certain behavior, it is the combination of somatic knowledge with conscious knowledge that may lead to the largest preference for the good deck. When conscious knowledge and implicit "bias" are in agreement, children do not experience as much conflict and can presumably choose more from the good deck. Interestingly, very few older 4's who had not at least reached the hunch period by the end of block 2 chose more from the good deck (13+ cards). Out of this group of children, only 14.3% in experiment 2 chose more from the good deck in block 3.

Similarly, in adults, the largest number of choices from the good decks occurred in later trials, once adults had reached at least the hunch phase. While it may be that their increase in choices resulted from somatic markers becoming stronger, it is possible that having conscious knowledge gave individuals more confidence to follow their "gut" feeling. Bechara et al. (1997) reported that during the "pre-hunch" phase, normal adults began generating anticipatory SCRs, but despite this, they were still not yet choosing more from the good deck. It was not until the hunch period, that these individuals chose more from the good deck. This parallels the findings from the present experiment for the 4-year-olds.

*Association of the Gambling task with Future Oriented Choice Tasks and Temperament*

Another interesting finding of this experiment was the correlation of the prudence portion of the delay of gratification choice task with the last block in the gambling task for 3's. The correlation with the last block approached significance. This fits with the notion that the future oriented prudence choice task is assessing more conscious decision making processes. This correlation did not approach significance for the 4-year-olds, however. One explanation may be that the lower individual variability for the 4-year-olds in the gambling task. In the last block, the majority of the 4-year-olds were choosing more from the good deck. Another possibility for this pattern of findings is the greater role of inhibition for both tasks in the 3-year-olds. Three-year-old children who reported being "aware" of which deck was better seemed to stop themselves from choosing more from "bad" cards than their age mates who were not aware. Children who chose to delay on the prudence task had to inhibit a natural tendency to get the reward now. Supporting this view, Moore et al. (1998) found an association between an inhibition task and future oriented prudence for 3-year-olds but not for older children.

Finally, the pattern of association between the CBQ scales and the gambling task indicates that temperament traits are associated with different phases of decision-making. As expected, the Extraversion/ Surgency scales were associated with choosing more cards from the bad deck in the first block for the three-year-olds. This indicates that the scales associated with BAS are more important for determining choices when children are just learning the game. It may also reflect how quickly children learn that one deck (bad) is giving them rewards. This fits with the reward anticipation function of the BAS.

Lack of significant association for the 4-year-olds may reflect the development of the Effortful Control system, which modulates both BAS and BIS, at this age.

For the Negative Affectivity scales, there were significant associations for both age groups. The Negative Affectivity Scales can be seen as assessing more "automatic" emotion regulation systems. For both age groups it seemed that children who had a tendency to be negative chose more from the bad deck. For 3-year-olds, those children who displayed discomfort more easily were more likely to choose from the bad deck. This negative emotionality may have interfered with 3-year-olds being able to exert control on behavior. For the 4-year-olds, those who had a greater tendency to express sadness and anger were more likely to choose from the bad deck. Again, this may reflect children who have less control over their behavior and emotions. In this respect, it is interesting that children who were better at regulation affect after getting over excited or upset (Falling Reactivity scale) were more likely to choose from the good deck mid-way through the game. It is possible, that as suggested by Kochanska (1993) excessive arousal makes it more difficult to encode somatic markers properly.

The most interesting association occurred between Effortful Control scales and performance on the gambling task. For 3-year-olds, greater inhibitory control was strongly associated with choosing more from the good deck early in the game. While this is contrary to expectation of more conscious control in later phases of the game, it does fits with the notion that the natural tendency for 3's is to pick from the bad decks and greater inhibition just allows children to stop themselves from choosing more from this deck. Interestingly, Rothbart, Ahadi et al. (2000) linked the Inhibition scale to both the BIS and Effortful Control. Further, Nigg (2000) argued that there are two types of

inhibition, one linked with the BIS and one with Effortful Control. For the inhibition linked with the BIS, children would avoid the bad deck because of fear of large loss. The Effortful Control inhibition would allow children to voluntarily avoid the bad deck once they knew it was bad. It may be that the correlation between inhibition and the first block of the gambling task for the three-year-olds was due to variations in the BIS rather than Effortful Control.

For the 4-year-olds, attention control seems more important. Children who displayed greater attention control chose more from the good deck in block 2. Further, children who enjoyed low intensity activity such as drawing chose more from the good deck as well. This association of Effortful Control scales with block 2 fits with the idea of the greater importance of a cool system in the last phase of the task. It is interesting that most of the significant association for the 4's occurred in block 2. This is probably due to the fact this block had the largest individual variability. Figure 4 indicates that while some 4-year-old children showed preference for the bad deck, some were starting to show preference for the good deck by block 2. Indeed, it appeared that children with the highest awareness were the ones who showed the highest number of choices from the good deck in block 2. In contrast, children who had reached the hunch period (at the end of this block) showed the highest proportion of choices from the bad deck during the second block.

Indeed the correlation between Effortful Control scales and the choices from block 2 may reflect the different strategies from these 2 groups of children. The "hunch" children may reflect children with lower Effortful Control who had to receive a lot of losses from the bad deck before becoming aware that it was "bad". The "conceptual"

children may be children with greater Effortful Control who were able to consciously figure out the game earlier on without receiving as many losses. In order to explore this possibility, 4-year-old children who reached the hunch period by the end of block 2 were compared to children who reached the conceptual period on the Effortful Control scales. Consistent with this interpretation, children who reached the conceptual period were found to score significantly higher on attentional focusing, $t$ (12) = -3.66, $p < .01$, falling reactivity, $t$ (12) = -2.43, $p < .05$, inhibitory control, $t$ (12) = -3.65, $p < .01$, and low intensity pleasure, $t$ (12) = -1.91, $p < .05$. This difference approached significance on attention shifting, $t$ (12) = -1.50, $p = .08$. Although these findings need to be interpreted with caution given the small number of children, they do indicate that children who reach the conceptual period early on may differ in significant ways from those who reach the hunch period.

Finally, the failure to find a sex difference in the main analysis of the gambling task needs to be addressed. Given the low number of participant per cell and subsequent low power, lack of significance is not surprising. However, it may also be due to the fact the pattern of loss was more irregular than in experiment 1. While experiment 1 had the same pattern of loss for both bad and good deck of each deck type, this experiment had different patterns of loss for the good and bad decks. This may have made it more difficult to find a pattern and removed the previous advantage for females. Alternatively, it may be that having 4 decks and therefore more conflict is what leads to a sex difference in young children. Possible variables affecting sex differences is addressed in the next experiment.

# Chapter 4

## Experiment 3: Variables Affecting Decision-Making

The results of experiment 1 suggest that certain variables such as frequency of loss, timing of loss, and pattern regularity may have an impact on performance, particularly for younger children. Further, discrepancies between the results of Kerr and Zelazo (in press) and experiment 1 suggest that variations in administration and reinforcement contingencies may have an impact on age and sex differences found. Certainly, the results of experiment 2 indicate that reducing the number of decks and adding more trials increases sensitivity to find age differences. While there have been many studies on the Iowa Gambling task, only a few have manipulated reinforcement contingencies. Further, there is at present no study that has systematically manipulated timing of loss or pattern regularity.

The primary goal of this experiment was to further explore age differences in performance on this task. The results of experiment 2 indicate that the ability to calculate conflicting rewards and losses develops by 5 years of age. Only older 3's and older 4's were used in this experiment. The experiment indicated dramatic changes between these two age groups. Given this finding, it is difficult to know how young 4's would perform on this task. This experiment explored more specifically the developmental trajectory of this ability in 4-year-olds. As such, young and older 4's were used.

The older 4's of experiment 2 chose significantly more from the good deck for the last block only. This conflicts with findings from Kerr and Zelazo (in press). They found that 4's chose more from the good deck earlier (card 21-30). Further, they used young and old 4's. One possible explanation for this difference in finding is the frequency of

loss. While the decks from experiment two had 2 losses per 10 cards, the decks used by Kerr and Zelazo had 5 losses per 10 cards. As discussed earlier, this would provide more reminders for young children. It was therefore decided to increase the number of losses (keeping absolute magnitude of loss the same per 10 cards) from 2 to 3 losses per 10 cards. This was expected to lead to faster learning of contingencies. It was expected that older 4's would again choose significantly more from the good deck when compared to chance on the last block, and perhaps in the second block. Finally, it was expected that older 4's would choose significantly more from the good deck when compared to young 4's.

The second goal of the current experiment was to explore the effect of manipulating reward contingencies on the Iowa Gambling task. In experiment 1, it was suggested that the timing of first loss and regularity of pattern may have an impact on sex differences. While males were hypothesized to be more heavily dependent on a responsive system, females were hypothesized to be more dependent on an internal model system (Tucker et al., 1995). It was hypothesized that the responsive system would allow males to change behavior in response to sudden changes in contingencies. The internal model system, on the other hand, would lead females to create an internal model of the game in order to guide behavior. One way to do this would be to try to guess what the pattern of reinforcement was. Hence, if this argument is correct, manipulating the two variables linked to these two systems should lead to sex differences. Males should do better when reinforcement contingencies are more unpredictable while females should do better when reinforcement patterns are regular. Theoretically, a more regular pattern should allow females to form a conscious internal model of the game and act accordingly.

The gambling game used in experiment 1 was not thought to assess reversal learning ability since children in this experiment did not show an initial preference to the bad decks. This may have been due to differences in the timing of first loss between this version and the original task. In the original Iowa Gambling task, reward/loss contingencies occurred over 10 cards rather than the 5 cards for experiment 1 and 2. For the Bechara et al. version, the first loss occurred at the third card for deck A and the 9$^{th}$ card for deck B. The first loss for experiment 1 in this thesis occurred at the 2$^{nd}$ card for deck A and the 5$^{th}$ card for deck B. The fact that losses occurred earlier may have made it more difficult to develop a preference for the bad decks initially. Given that timing of loss can affect whether or not reversal learning is tapped, manipulation of this variable may affect sex differences.

Another difference among the decks that may have affected decision making is the regularity of pattern. In experiment one, the female advantage was stronger in the deck type with a more regular pattern of loss. Research suggests that males may be more sensitive to changes in reinforcement than females (Kollins, Lane, Shapiro, 1997; Overman et al., 1996; Sonuka-Barker, Lea & Webley, 1989). This suggests that males may be able to respond more flexibly to changes in pattern of reinforcement. Further, probability learning studies indicate that females attempt to find a "pattern" even it is detrimental to learning (Dusek & Hill, 1970; Kreitler & Zigler, 1990; Kreitler, Zigler & Kreitler, 1984). This suggests that females may be more actively trying to find a pattern in the gambling task than the males are.

These two variables were therefore manipulated for this experiment. Children were randomly assigned to one of three variations of the gambling task. In the first

version, the first loss occurred early (2nd card), and losses were irregular. The second version of the deck had the same irregular pattern (see Appendix D) as the first version, but the losses began late (on the 8th card). A comparison between the first version and second version should therefore provide an indication of timing of the first loss on subsequent decision making. In the third version, the first loss also occurred at the 2nd card, but losses were highly regular, with the same pattern repeating over every ten cards. Comparison between the first and third versions should provide an indication of the effect of pattern regularity on decision making.

Two main analyses were planned. One analysis compared the late irregular and early irregular conditions to explore the effect of timing of loss on performance. A Sex X Block effect was expected where males would outperform females in both conditions since both decks were irregular. Further, a Condition X Sex X Block interaction was expected whereby the Sex X Block interaction would be stronger in the late irregular condition. This condition was expected to function more like a reversal task, which pre-school boys have been found to do better at. It was expected that with a more difficult reversal task, older males would show an advantage. It was also expected that females should encounter difficulty in the Irregular late condition since this condition would initially result in consistent feedback that the bad deck is better (for approximately 18 card turns). This theoretically would lead to an initial "model" of the game that the bad deck is best. Further, constructing an initial model might make it more difficult to switch to a different model (that the good deck is best).

The second analysis compared the early regular and early irregular conditions to explore the effect of pattern regularity. A Condition X Sex X Block interaction was

expected whereby males would show better performance than females on the irregular condition while females would show a better performance on the regular condition. If the females are trying to find a pattern to guide their behavior, then having a more regular pattern should more quickly lead to an internal model of the game.

The gambling task was very similar to that used in the first experiment. Children chose either smarties, skittles, or stickers for rewards. As with the third experiment, 60 card turns were used. One deck was advantageous with small rewards and smaller losses and the other deck was disadvantageous with large rewards and large losses.

## Method

*Participants*

Participants were 66 young 4's (30 females, 36 males) ranging in age from 47 to 53 months (mean = 4;3 years) and 75 older 4's (38 females, 37 males) ranging in age from 54 to 59 months (mean age = 4;9 years). Children were recruited from 22 daycare in the Halifax region and included children ranging from both lower and middle class. Once again criteria for completing the gambling task was at least 50 choices. Two children (1 female and 1 male) failed to complete this task and were not used in the analysis. One of the younger 4-year-old boys completed only 50 choices so again proportions rather than total number of choices was used.

*Apparatus*

Three different sets of decks were used. Set 1 had losses occurring late with irregular pattern of loss. Set 2 had losses occurring early and an irregular pattern of loss. Finally, set 3 had loss occurring early and a regular pattern of loss (see Appendix D for reinforcement contingencies). There were 60 cards in each deck and colours were again

counterbalanced. As with the second experiment, children were asked to choose between smarties, skittles, and stickers as rewards.

*Procedure*

The exact same procedure as in experiment 2 was used for the administration of the gambling task. Children were randomly assigned to one of the three card versions described above. Random assignment was made within sex and age group.

**Results**

*Timing of Loss*

The first analysis looked at manipulating timing of first loss. Once again, a mixed factorial design was used. The between subject variables were age (young 4's and old 4's), sex, and condition (Early loss, Late loss). The within subject variable was block (20 choices per block). The dependent variable was the proportion of choices from the good deck. This analysis revealed a significant block main effect, $F$ (2, 174) = 8.75, $p < .01$, indicating that children chose more from the good deck over time. The main age effect was not significant, $F$ (1, 87) = 1.80, $p > .05$. There was a significant Sex X Condition X Block interaction effect, $F$ (2, 174) = 3.42, $p < .05$.

Inspection of figures 5 and 6 indicates that differences were not linear. Contrast analysis indicated a non-significant linear interaction, $F$ (1, 87) = 2.20, $p > .05$, but a significant quadratic interaction effect, $F$ (1, 87) = 7.45, $p < .01$. The interaction effect was followed up with separate analysis of block 1 to block 2 and block 2 to block 3. For block1 to block 2, the main effect of block was significant, $F$ (1, 91) = 8.38, $p < .05$, indicating that children increased the number of choices from the good deck from block 1 to block 2. However, the Sex X Condition X Block was not significant, $F$ (1, 91) = .63, $p$

> .05, suggesting that there were no differences between males and females in pattern of choices made on the first two blocks. For block 2 to block 3, the block effect was again significant, $F(1, 91) = 4.70, p < .05$. However, this was qualified by a Sex X Condition X Block interaction effect, $F(1, 91) = 8.67, p < .01$. No other effects were significant.

This significant interaction was followed up with two ANOVAs for each condition. For the Irregular Late condition, the Sex X Block effect approached significance, $F(1, 46) = 3.84, p < .06$. The Sex main effect was non-significant. For exploratory purposes, the interaction was followed up, but should be viewed with caution. This follow-up indicated that the block main effect approached significance for females, $F(1, 22) = 3.18, p < .09$, but not for males, $F(1, 24) = 1.054, p > .05$. Further, t-tests with Bonferonni corrections indicated that females chose significantly more from the good deck when compared to chance on block 2, $t(22) = 2.41, p < .05$ and block 3, $t(22) = 2.91, p < .05$. Males did not chose significantly more than chance for either block 2 or block 3.

For the Irregular Early condition, the block main effect was significant, $F(1, 45) = 6.44, p < .05$ and the Sex X Block effect was significant, $F(1, 45) = 4.82, p < .05$. Follow-up indicated that the block effect was significant for males, $F(1, 23) = 7.10, p < .05$, but only approached significance for females, $F(1, 21) = 3.62, p = .07$. T-tests indicated that males chose significantly more from the good deck when compared to chance on the third block, $t(22) = 2.23, p < .05$, but not in block 2, $t(22) = -.16, p > .05$. For this comparison, females chose significantly more from the good deck when compared to chance on the second block, $t(22) = 2.36, p < .05$, but this only approached significance on the third block, $t(21) = 1.77, p = .09$. These comparisons indicated that

by the end of the game, females were doing better than males in the Irregular Late condition. In contrast, by the end of the game, males were doing better in the Irregular Early condition.

*Pattern Regularity*

The analysis for pattern regularity was the same as that used for timing of loss with the exception that the Irregular Early and the Regular Early conditions were used for this comparison. This analysis once again resulted in a significant block main effect, $F$ (2, 170) = 8.51, $p < .05$, which indicated that children chose more from the good deck over time. There was also a significant age main effect, $F$ (1, 85) = 5.85, $p < .05$, with older 4's choosing more from the good deck overall than the younger 4's.

The Sex X Condition X Block main effect was nonsignificant, $F$ (2, 170) = 1.37, $p > .05$. However, it should be noted that within-subject contrast analysis indicated that the quadratic Sex X Condition X Block interaction effect was significant, $F$ (1, 85) = 4.66, $p < .05$. This indicated that males and females had different patterns of choice over time for the two different conditions. Follow-up indicated that the Sex X Condition X Block interaction effect only approached significance for both the block 1 to block 2 ANOVA, $F$ (1, 89) = 2.81, $p < .1$ and block 2 to block 3 ANOVA, $F$ (1, 89) = 2.81, $p < .1$.

Given that one a priori hypothesis was that females' performance was affected by regularity of pattern, it was decided to also do a follow-up within each sex group (rather than within each condition). This follow-up indicated that the quadratic Condition X Block interaction was significant for females, $F$ (1, 43) = 4.76, $p < .05$, but not for males.

This suggested that manipulating the pattern regularity had an effect on the females' performance, but not males.

Again, the quadratic effect for females was followed up with two analyses, exploring the interaction for block 1 to 2 and block 2 to 3. This resulted in a non-significant Condition X Block interaction effect for block 1 to 2, $F(1, 43) = 2.66, p > .05$ and block 2 to 3, $F(1, 43) = 2.05, p > .05$. This suggests that while pattern regularity affected choice in females, the nature of this effect is unclear. However, exploratory t-test analysis did indicate a trend toward increase in choices from the good deck for block 2 to 3 for the Regular Early condition, $t(21) = 1.90, p = .07$, with no improvement for the Irregular Early condition, $t(21) = .40, p > .05$. Further, females in the Regular Early condition showed a trend toward choosing more from the good deck when compared to chance on block 3, $t(21) = 1.96, p = .06$, but not for block 2, $t(21) = .75, p > .05$.

*Figure 5.* Proportion of choices from the good deck in the irregular late condition as function of sex.

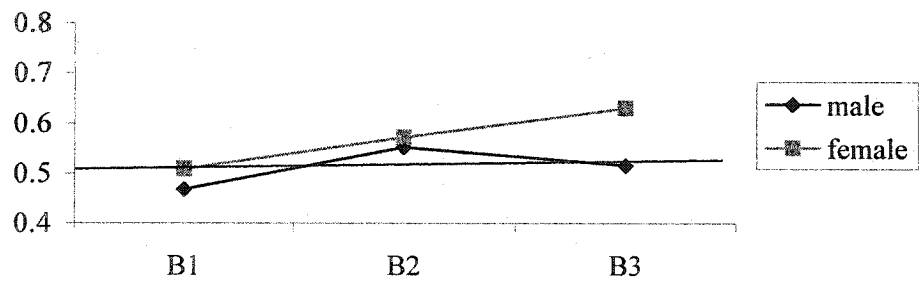



*Figure 6*. Proportion of choices from the good deck in the irregular early condition as a function of sex.

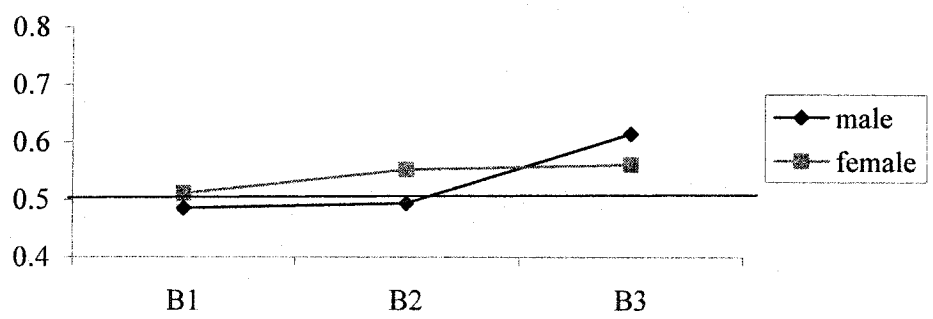
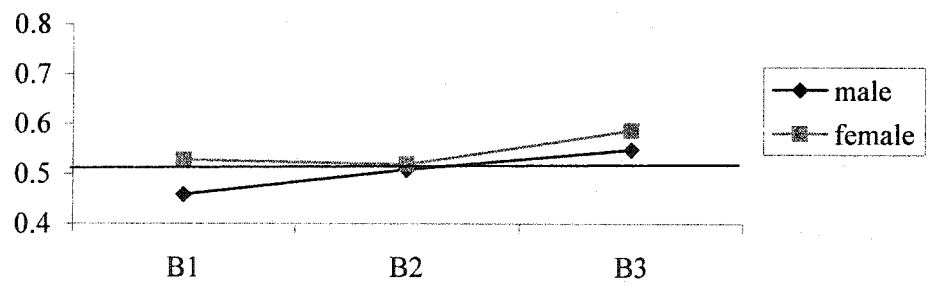



*Figure 7.* Proportion of choices from the good deck in the regular early condition as a function of sex.



*Overall Age Differences*

In order to look at the overall effect of age on choice from the good deck, all subjects from the three conditions were included in an analysis, while controlling for sex and condition effects. This resulted in a significant main effect of age, $F(1, 129) = 4.16$, $p < .05$, with the older children choosing significantly more from the good deck than the younger children. Further, the performance of each age group was compared to chance for each block. It was predicted that children would choose more from the bad deck on the first block, but more from the good deck in the second and third block. The t-test for the first block was thus conducted on choices from the bad deck and for the last two blocks on the good deck. For the young fours, only the t-test for the first block was significant, $t(65) = 2.21$, $p < .05$, with younger children choosing more from the bad deck than would be expected by chance. For the older fours, the t-tests were significant for the last two blocks, $t(74) = 2.87$, $p < .01$ and $t(74) = 3.77$, $p < .01$, respectively. Older fours chose significantly more from the good deck than would be expected by chance in the last two blocks. Table 6 shows the marginal means for the two age groups.

Table 6

*Marginal Means of the Proportion of Choices from the Good Deck as a Function of Age Group.*

| Age Group | Block 1 | Block 2 | Block 3 |
|---|---|---|---|
| Young 4's | .47 (.01) | .51 (.02) | .54 (.03) |
| Older 4's | .51 (.02) | .55 (.02) | .60 (.03) |

(standard error of the mean in brackets)

*Awareness of Game for Timing of Loss*

For this analysis, sex, age, and condition were again used as the between subject variables. The test time (test 1 and test2) was used as the within subject variable, with the score on the test as the dependent measure. This analysis revealed no significant main effects, but a Test X Condition interaction, $F(1, 87) = 12.04, p < .01$. This two-way interaction was qualified by two three-way interactions. There was significant Age X Condition X Test interaction effect, $F(1, 87) = 5.89, p < .05$ and a significant Sex X Condition X Test interaction effect, $F(1, 87) = 4.35, p < .05$.

Follow-up to the Age X Condition X Test interaction indicated that the Condition X Test interaction was significant for the older 4's, $F(1, 47) = 14.59, p < .001$, but not for the younger 4's, $F(1, 40) = .77, p > .05$. Follow-up to the significant interaction for the older 4's indicated that the condition effect was significant for the second awareness test only, $F(1, 47) = 5.44, p < .05$, but not for the first awareness test, $F(1, 47) = 1.11, p < .05$. Specifically, the older children in the Irregular Late condition seemed to score higher when compared to children in the Irregular Early condition on the second test.

Follow-up to the Sex X Condition X Test interaction indicated that the Condition X Test interaction was significant for females only, $F(1, 42) = 9.78, p < .01$, but not for males, $F(1, 45) = 1.95, p > .05$. As with the younger children, the condition effect for females was significant for test 2 only, $F(1, 42) = 11.26, p < .01$, indicating once again that females in the Irregular Late condition were more aware of the game than females in the Irregular Early condition. Table 7 and 8 show the marginal means for younger and older fours on test 1 and test 2.

Table 7

*Marginal Means of the Two Awareness Tests as a Function of Age Group and Sex for the Irregular Late Condition*

| Age Group | Test 1 | Test 2 |
|---|---|---|
| Young 4's | | |
| Females | 1.80 (.48) | 2.30 (.47) |
| Males | 1.75 (.44) | 1.75 (.43) |
| Older 4's | | |
| Females | 1.69 (.42) | 2.92 (.41) |
| Males | 1.46 (.42) | 2.08 (.41) |

(standard error of the mean in brackets)

Table 8

*Marginal Means of the Two Awareness Tests as Function of Age Group and Sex for the Irregular Early Condition*

| Age Group | Test 1 | Test 2 |
|---|---|---|
| Young 4's | | |
| Females | 1.46 (.46) | 1.27 (.44) |
| Males | 1.27 (.46) | 1.46 (.44) |
| Older 4's | | |
| Females | 2.00 (.44) | 1.25 (.43) |
| Males | 2.08 (.42) | 1.85 (.41) |

(standard error of the mean in brackets)

*Awareness of Game for Pattern Regularity*

The analysis for pattern regularity was the same as that for the timing of loss, with the exception that the Irregular Early and Regular Early conditions were compared. This analysis revealed a main effect of age, $F(1, 85) = 5.56$, $p < .05$, with older children showing a higher awareness of the game. As well, the Sex X Test condition approached significance, $F(1, 85) = 3.82$, $p < .06$. No other effects were found to be significant. The marginal means for the Regular Early condition are shown in Table 9.

Table 9

*Marginal Means of the Two Awareness Tests as Function of Age Group and Sex for the Regular Early Condition*

| Age Group | Test 1 | Test 2 |
|---|---|---|
| Young 4's | | |
| Females | 1.78 (.46) | 1.44 (.47) |
| Males | 1.31 (.38) | 1.54 (.39) |
| Older 4's | | |
| Females | 2.23 (.38) | 2.31 (.38) |
| Males | 2.46 (.42) | 2.55 (.42) |

(standard error of the mean in brackets)

*Awareness and Performance*

In order to explore whether the age effects could be due to differences in awareness level, the main age analysis was again conducted with score on the first awareness test as a covariate. Again, as with the first two experiments, the awareness covariate was significant, $F(1, 128) = 58.34, p < .001$. Children who showed a higher awareness of the game tended to choose more cards from the good deck. In contrast to experiment 2, the age main effect became non-significant, $F(1, 128) = 1.59, p > .05$. This indicated that the age difference in performance on the gambling task may have been due to differences in awareness of the game.

As with experiment 2, children were grouped in different awareness levels, based on awareness score on test 1. Figures 8 and 9 shows the performance of the two age groups as a function of awareness level. In contrast to experiment 2, children of different age levels had similar performance when their awareness level was matched.

For both age groups, children with the lowest level of awareness showed no tendency to prefer the good deck. For awareness level 2 (hunch stage), children did not appear to show preference until the last block. For the highest awareness level (conceptual stage), children of both age groups seemed to begin showing a preference for the good deck even in the second block. This pattern of performance is similar to the behavior of older 4's in experiment two.

*Figure 8.* Proportion of choices from the good deck as a function of awareness for young 4-year-olds.

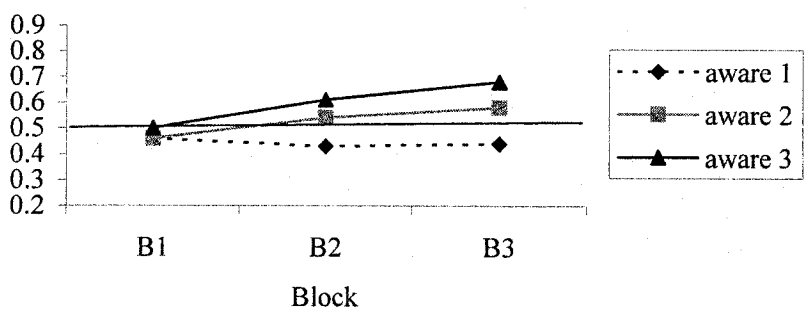
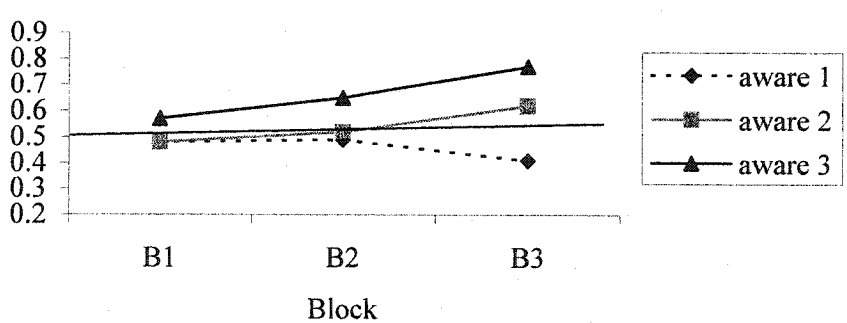



*Figure 9.* Proportion of choices from the good deck as a function of awareness for old 4-year-olds.



*Reinforcement Information*

It was expected that males would do better than females on the late irregular condition. Not only did females appear to perform better on the last block, but males actually seemed to show a drop in performance from block 2 to block 3 (see figure 5). Given this unexpected finding for the comparison for timing of first loss, it was decided to do some exploratory analyses. Specifically, it was noted during administration of the task that males appeared to be more responsive to reinforcement feedback than females. Research does indicate a greater sensitivity to changes in reinforcement by males (Kollins et al., 1997; Overman & Bachevalier, 2001; Sonuga-Barke et al., 1989). While the Irregular late and Irregular early cards were identical from card 11 onward, there was a difference in this information in the first 10 cards. The reinforcement information (loss information) seemed to vary more abruptly for the Irregular late condition. For this condition, there was a long period where the bad deck appeared to be better, with no losses occurring. This would be particularly true if children were sampling from both decks initially (as many children did). Then on card 8 of both decks, children received three losses in a row from each deck. This would be experienced as a sharp change in reinforcement.

A reinforcement score for each trial was calculated for the good deck by adding reward information and subtracting loss information. This score reflects reinforcement information that would be associated with tendency to choose from this deck. For instance, if a child picked a card that had 1 bear but no tiger, this score would be +1 and would support a tendency to choose from this deck on the next trial. However, if the

child got 1 bear but two tigers (1 –2), this would result in –1 and a tendency not to choose this deck on the next trial.

Similarly, a reinforcement score was calculated for the bad deck by adding the reward and subtracting the loss information. Hence, if a child got 2 bears and no tigers, this would result in a score of +2 for this deck, and support a tendency to choose more from this deck in the next trial. Finally, given that there were only two decks to choose from, the tendency to choose from the good deck would be inversely related to tendency to choose from the bad deck. Moreover, tendency to choose from the good deck would depend not only on reinforcement information from this deck but also reinforcement information from the bad deck. The tendency to prefer the good deck should be a combination of both types of information.

Specifically, if children are more responsive to immediate feedback, then their choices from the good deck should be positively correlated with reinforcement information from the good deck and negatively to information from the bad deck. Since it was possible to choose from only one deck per trial, reinforcement information would either be from the good or bad deck. In order to create a variable that would reflect both these tendencies, reinforcement information for each trial was multiplied by +1 for good deck choices and –1 for bad deck choices. This would result in the following equation for each trial:

Reinforcement information for each trial = + 1 (win – loss) if choice is from good deck

– 1 (win – loss) if choice is from bad deck

Reinforcement information (averaged across subjects) for each trial was then correlated with choice from the good deck (0 or 1) on the next trial. This correlation was

found to be significant for males in the Irregular late condition, $r$ (58) = .37, $p < .05$, but not for females in this condition, $r$ (58) = .10, $p > .05$. This indicated that males were more responsive to immediate reinforcement information in this condition. For instance, if they received a reward and no loss on the good deck in the previous trial, then they were more likely to choose from the good deck (and so less likely to choose from bad deck) in the next trial. The correlations for Irregular Early loss were not significant for either males or females.

**Discussion**

The most consistent finding from the last two experiments was an age effect in performance on the gambling task. This suggests a development in the network subserving this ability during the pre-school period. Moreover, the pattern of findings from the last 2 studies suggest that children develop the ability to pass this task at approximately 4.5 years of age. The findings suggest three possible stages in the development of decision making. At 3 years of age, children are choosing more from the bad deck. By 4 years of age, they no longer show a preference for the bad deck, but do not yet show a preference for the good deck. Finally, at 4.5 years of age, children show a significant preference for the good deck.

However, it should be noted that lack of significance for the younger 4's may be due to the sensitivity of the present task. Kerr and Zelazo, using both young and old 4's, found that 4's chose more from the good deck in later trials. They did not differentiate between older and younger 4's so it is impossible to know whether their data would show differences between the two age groups. They also had more frequent losses per 10

cards. It is possible that if losses were increased that younger 4's would choose significantly more from the good deck as well.

Another interesting comparison between experiment 2 and 3 is the difference between older 4's in the second block. While older 4's did not choose significantly more from the good decks by block 2 in the second experiment, the older 4's of experiment 3 did choose more from the good deck by block 2. A t-test indicated significant differences between the older 4's of experiment 2 and 3 on block 2, $t\,(94) = 2.0, p < .05$. A likely explanation for this difference is an increase in the number of losses (from 2 to 3 losses per 10 cards). This is consistent with the hypothesis that increasing the frequency of losses makes the task easier for younger children. The inclusion of more "frequent" reminders may help children learn faster, particularly for younger children when the ability to calculate conflicting reinforcement information over time is just emerging.

While the finding of a developmental effect is relatively clear-cut, the findings on sex differences are not as clear. It was hypothesized that females would perform better when presented with decks having a regular pattern of loss partly because this would lead to the formation of an internal model of the decks. The results of experiment 3 did not support the hypothesis. While females' performance appeared to be more affected by differences in regularity of pattern than males' performance, there was no clear advantage of the regular pattern as had originally been predicted. One problem with this experiment may have been how regularity was defined. While the regular loss decks had patterns of losses that repeated every 10 cards, the difference between the irregular and regular condition may not have been great enough to be a sensitive test of this variable. Even the

irregular pattern deck could be considered predictable and 'regular' in that it had 3 losses of 9 or 8 rewards every 10 cards.

Timing of loss seems to have had more impact on sex differences, but in the direction opposite to that predicted. While males and females behaved in the direction predicted on the irregular early condition, they behaved in the direction opposite to that predicted on the irregular late condition. Similarly, for the irregular late condition, females actually seemed to perform better in the last two blocks, having a significant block effect. Given that this deck's pattern of loss was actually the most irregular, this finding was perplexing. One would expect females to have the greatest difficulty with this version of the gambling task. Late loss should have encouraged females to form an internal model that the bad deck was better. If females have more difficulty responding to changes, then they should continue to respond to the decks with an internal model that the bad deck was better.

However, the results of the awareness tests and observations during administration of tasks provided some clues as to what was happening. First, females never appeared to show an initial preference for the bad deck as anticipated. Instead, females appeared to show no preference for either deck in the first block. It appeared that if females were forming some sort of "internal model", they were taking more than 20 card choices to do this. In fact, comparing choices in block 1 with chance led to a non-significant result for girls in this condition, $t\ (22) = .58, p > .05$. Further, in the 1st block, most children were alternating between both decks. This pattern of choosing may have made the differences in loss between the good and bad deck more obvious since these decks had 3 consecutive losses. Many children ended up losing rewards in quick

succession. Following this type of loss, many of the girls spontaneously reported that they knew what deck was better. The analysis of the awareness test indicates that females, in fact, seemed to be more aware of the game by test 2 in the irregular late condition when compared to the irregular early condition. This was also true of older children as well.

One interpretation of these data is that males and females are responding to different aspects of the irregular late condition. Females seemed to respond to knowledge of the game based on losses while males seemed to respond to changes in relative losses. Inspection of figure 5, indicates that males in the irregular late condition showed an interesting pattern of increase of choices from the good deck in block 2, followed by a decrease in block 3. Males may have been responding to changes in frequency of loss. Looking at Appendix D shows that losses in this condition were very frequent in the middle part of the game. There were 3 consecutive losses followed by two more consecutive losses shortly after in the bad decks. The losses after this were then more spaced, particularly in the bad decks. This may have led to the perception that losses were more frequent in the middle part of the game. Further, this condition seemed to have led males to be more responsive to changes in losses immediately following trials. In support of this, there was a significant correlation between loss on a trial and choices immediately following this trial for males. This suggests that males may be responsive to changes in reinforcement.

In conclusion, most of the findings of sex differences were not in the direction predicted. The only finding that fits with predictions was the sex difference on the irregular early condition. In this condition, males were doing better than females. It may

be that as predicted males in this condition were able to cope better with the irregular pattern. This would fit with the idea of males using a responsive decision making system more heavily. However, given the other results, it is impossible to be confident of this interpretation. Females actually did better in the irregular late condition, indicating that they were quite capable of doing well when the pattern was irregular. One explanation for this discrepancy is that females were better because they were able to form a conscious model in this particular condition. This explanation would be consistent with females being superior with the use of the cool system. Finally, the results of the regular early condition suggest that there are no clear advantages for females when the pattern is regular. It may be that for females, the most important factor is whether they are able of forming a conscious model of the game. Again, this is only a tentative interpretation and more research is needed to explore this issue fully. Hence, while this experiment suggests that there are sex differences under certain circumstances, it is still not clear what variables lead to these sex differences.

# Chapter 5

## Experiment 4: Decision Making in Children with ADHD

Conduct problems affect an estimated 6 to 12% of school age children (Frick, 1998b). Frick (1998b) includes various disorders in this category such as Attention Deficit Hyperactivity Disorder (ADHD), Oppositional Defiant Disorder (ODD), and Conduct Disorder (CD). ADHD affects between 3 to 5% of children (Barkley, 1998). The ratio of boys to girls having this disorder is much higher, estimated to be about 3 times as frequent in boys (Barkley, 1998; Frick, 1998b). Further, ADHD has a high rate of co-morbidity with other conduct problems such as CD and ODD (Barkley, 1998; Bradshaw, 2001; Frick, 1998b). Research indicates that there is a strong genetic basis to ADHD (Burt, Krueger, McGue, & Iacono, 2001; Epstein et al., 2000; Faraone et al., 2000). However, it is likely that biological and environmental influences interact in a complex way to lead to the specific manifestation of this disorder (Burt et al., 2001; Hindshaw et al., 2000)

The disorder's primary symptoms include inattention and impulsiveness, although many authors agree that it is a heterogeneous disorder (Banaschewski et al., 2003; Bradshaw, 2001; Colledge & Blair, 2001; Swanson et al., 1998). These children experience many social problems, including excessive aggressiveness, conflict with authority, and problems interacting with peers (Barkley, 1998; Frick, 1998a).

The literature suggests that children with ADHD demonstrate problems that should affect their ability to perform well on the Iowa Gambling task. For instance, there is evidence that they have emotion processing deficits, executive functioning difficulties, alterations in reinforcement sensitivities, and dysfunction in brain areas hypothesized to

be involved in the Iowa Gambling task. This evidence will be reviewed in the next section. As noted, ADHD is a heterogeneous disorder and its co-morbidity with other disorders such as anxiety and conduct disorder will lead to different symptoms and deficits. This issue and its possible link to performance on the gambling task is explored. Finally, the small amount of work conducted on the Iowa Gambling task with ADHD individuals is reviewed.

**ADHD and its Associated Problems**

While the specific areas of dysfunction may be contested, most researchers agree that ADHD involves a dysfunction in the frontro-striatal system (Barkley, 1998; Bradshaw, 2001). Research has supported the involvement of fronto-striatal system. For instance, Casey, Castellanos et al. (1997) gave ADHD children a response inhibition task and found that performance on these tasks correlated with anatomical changes in the fronto-striatal system. Neuroimaging indicates that the areas involved in ADHD include the cognitive division of the ACC, prefrontal cortex, caudate, and globus pallidus (Bush et al., 1999; Casey, Trainor et al., 1997; Rubia et al., 1999). Further, three main neurochemicals have been implicated in this disorder; serotonin, dopamine, noradrenaline (Andersen & Teicher, 2000; Johansen et al., 2002; Oades, 2002; Quist & Kennedy, 2001).

Along with this fronto-striatal dysfunction, children with ADHD demonstrate a variety of executive function deficits such as working memory, inhibition, and time perception (Barkley, 1998). In exploring executive functioning differences between different developmental disorders, Pennington (1997) concluded that ADHD children demonstrate primary deficits for inhibition tasks and planning tasks such as the Tower of

Hanoi. Barkley (1997) suggested that ADHD children demonstrate a general deficit in behavioral inhibition, which in turn affects a variety of executive functioning abilities such as working memory, self-regulation of affect and arousal, internalization of speech, and being able to analyze and synthesize behavior. He suggested that these deficits should lead to various difficulties in temporal processing. Research has been supportive of this proposal, with ADHD individuals showing deficits in time processing, including tasks such as temporal discounting, which resembles delay of gratification (Barkley, Edwards, Laneri, Fletcher & Metevia, 2001; Barkley, Koplowitz, Anderson & McMurray, 1997; Kerns, McInerney & Wilde, 2001; Seri, Kofman & Shay, 2002). Since other populations with fronto-striatal dysfunction have been found to show deficits on the Iowa Gambling task, it is very possible that ADHD children will show a deficit on this task. Further, difficulties with working memory, inhibition and time processing should have an effect on performance.

Another deficit that is likely to affect ADHD children's performance on the Iowa Gambling task is their difficulty with emotional processing and regulation (Corbett & Clidden, 2000; Friedman et al., 2003; Singh, Ellis, Winton, Singh, Leung, & Oswald, 1998; Vander Meere & Stemerdink, 1999). Given that the somatic marker hypothesis assumes that decision making on the Iowa Gambling task is partially dependent on being able to associate an emotional response with decks of card, this suggests that ADHD children should experience difficulty with this task. Various studies have indicated that children with ADHD show an impairment in emotion perception. For instance, Corbett and Glidden (2000) found that ADHD children had difficulty perceiving affect and that errors made indicated that they were not encoding cues properly. Similarly, Singh et al.

(1998) found a deficit in recognizing facial expressions in children with ADHD. Other research indicates that emotion perception difficulties may differ depending on diagnosis (Cadesky, Mota, & Schachar, 2000).

Another ADHD problem that should affect performance on the Iowa Gambling task is reinforcement learning. Johansen et al. (2002) reviewed the literature on reinforcement learning and argued persuasively that ADHD can be explained by problems with reinforcement and extinction learning. While ADHD children have no difficulty with simple reinforcement processes such as classical conditioning (Pliszka, Hatch, Borcherding, & Rogeness, 1993), they experience difficulty under more complex paradigms involving partial and inconsistent reinforcement schedules (Douglas & Parry, 1994; Wigal, Swanson, Douglas, & Wigal, 1998).

In considering reinforcement learning, the BIS and BAS, discussed earlier, are particularly pertinent. Gray (1987) proposed that the Behavior Activation System (BAS) would enable an organism to be motivated by reward. The Behavior Inhibition System (BIS), on the other hand, would enable an organism to inhibit ongoing behavior when cues of non-reward or punishment are present. Further, the BIS has been linked to anxiety (McNaughton & Gray, 2000). The BAS would therefore be more relevant when there are cues of reward while the BIS would be more relevant when there are cues of punishment. The ADHD children's difficulty in modulating their behavior and trouble with inhibition has led many to suggest that ADHD children have problems with the BIS (Patterson & Newman, 1993; Quay, 1997). While there has been some evidence to support a dysfunctional BIS in ADHD children (Iaboni, Douglas & Ditto, 1997: O'Brien, Frick & Lynam, 1994), the evidence has been stronger for a dysfunctional BAS in ADHD

children (Crone, Jennings & van der Molan, 2003; Sagvolden, Aase, Zeiner & Berger, 1998; Tripp & Alsop, 1999; Tripp & Alsop, 2001). For instance, children with ADHD have been found to have a bias for immediate rewards and to be more influenced by immediate reinforcement than overall reinforcement history (Tripp & Alsop, 1999; Tripp & Alsop, 2001).

**Anxiety and ADHD**

The idea that children with ADHD have a weak BIS is difficult to reconcile with the fact that ADHD shows a high co-morbidity with anxiety disorders (Braaten et al., 2003; Nigg, 2001). Barkley (1998) suggested that as many as 27-30% of children with ADHD also meet the criteria for anxiety disorder. Braaten et al. (2003) found that when they assessed children with ADHD for co-morbid anxiety, they found 35% had anxiety. When they assessed them 4 years later, this number had gone up to 45%.

High anxiety would suggest an active BIS (perhaps even overactive). It may be that children with co-morbid anxiety represent a separate subtype, with different underlying pathology. For instance, Vance, Costin & Maruff (2002) found that children with co-morbid anxiety and ADHD combined type show a significantly higher increased diastolic blood pressure from a sitting to standing position than children without co-morbid anxiety. Further, Barkley (1998) indicated that these children are more responsive to tricyclic antidepressants than children without anxiety. Finally, ADHD children with co-morbid anxiety do not show the same response inhibition deficits (Manassis, Tannock, & Barbosa, 2000; Pliszka, 1992; Pliszka, Borcherding, Spratley, Leon, & Irich, 1997). Pliszka (1992), for instance, found that anxiety level negatively correlated with the number of commission errors on the continuous performance test.

They further found that ADHD children made significantly more commission errors than either control or co-morbid children. Co-morbid children and controls did not differ. There were other differences such as off task behavior and total number of ADHD behaviors. Pliszka concluded that co-morbid ADHD and ADHD alone are etiologically distinct.

Further, children with both internalizing and externalizing disorders have been found to differ from children externalizing disorder alone, showing lower sympathetic activation, placing them between children with internalizing and externalizing disorders (Boyce et al., 2001). Manassis et al. (2000) found that this group of children showed reduced auditory emotion recognition, suggesting a left hemisphere deficit in emotion processing. Manassis et al. argued that ADHD with anxiety appeared to be cognitively distinct from children with anxiety alone or children with ADHD alone.

Nevertheless, it may be that anxiety and ADHD are due to separate factors, but that the presence of the two produces a slightly different set of symptoms because the disorders offset one another (Corr, 2002). Indeed, there is evidence that anxious children show a faster inhibition than control children (Oosterlaan & Sergeant, 1998). Braaten et al. (2003) explored the association of these two disorders and concluded that the evidence indicates the two disorders are inherited independently in families. Corr (2002) suggested a reformulation of Gray's theory, which he called the joint subsystems hypothesis. This theory suggests that anxiety is directly related to the BIS and impulsivity is directly related to the BAS. High anxiety suggests an overactive BIS while high impulsivity suggests an overactive BAS. Although the two systems are separate, they interact with one another. For instance, an individual with high impulsivity and high

anxiety would show less inhibition than an individual with high anxiety and low impulsivity. The presence of high impulsivity would moderate the effect of high anxiety. Similarly, anxiety would moderate the effect of high impulsivity. Individuals with high impulsivity and high anxiety will engage in fewer reward seeking behaviors, especially when there is the possibility of punishment than individuals with high impulsivity and low anxiety. Corr (2002) found support for this theory that anxiety moderated the effects of impulsivity and that impulsivity moderated the effects of anxiety. For instance, during presentation of negative slides, those individuals with high anxiety and low impulsivity showed a higher physiological reaction than individuals with high anxiety and high impulsivity. This indicated that the presence of impulsivity moderated anxiety reactions.

In support of this, there is evidence that disruptive behavior is less common in children with behavior inhibition problems, indicating a protective effect (Biederman et al. 2001). There is further evidence that these two temperament traits are linked to specific types of psychopathology. For instance, Johnson, Turner, and Iwata (2003) found that BIS was linked to a vulnerability to depression and anxiety while BAS Fun Seeking to drug and alcohol abuse. Further, when they looked at the link between externalizing disorders and BIS/BAS, they found no difference for BIS, but individual with a lifetime diagnosis of ADHD reported higher levels of BAS drive. No link between co-morbid conduct was found. Similarly, high externalizing and high internalizing have been found to show specific paraympathetic and sympathetic profiles (Boyce et al., 2001).

## ADHD Subtypes and Co-morbidity

The main symptoms of ADHD are impulsivity/hyperactivity and inattention. ADHD has been classified in accordance to symptoms of inattention, hyperactivity/ impulsivity or a combination of both. While this may seem straightforward, the concepts of attention and impulsivity are very complex (Gerbing et al., 1987; Swanson et al., 1998). The literature is full of varying definitions of attention and impulsivity.

Swanson et al. (1998) discussed the different attention networks in relation to ADHD. They suggested that there are three main attention networks. The first, alerting, involves the ability to suppress background neural noise and is involved in sustained attention. They linked this type of attention deficit to ADHD inattentive subtype where children have difficulty with sustaining attention and finishing projects. The second attention network, orienting, involves the ability to prepare for an input and selective attention. They linked this network to another subtype of ADHD inattentive where children are easily distracted by extraneous stimuli and fail to pay close attention. Finally, the third attention network, executive control, involves voluntary attention control and is associated strongly with the CBQ Effortful Control factor. They linked a dysfunction in this network to ADHD with combined subtype, having problems with both attention and impulsivity. They associated three symptoms from the DSM-IV symptoms to this network; blurts out answers, interrupts or intrudes, and can't wait.

These three attention networks have different neurological substrates. The alerting network is associated with the right frontal cortex and right parietal cortex. The orienting system is associated with the posterior parietal cortex, superior colliculus, and thalamus. Finally, the executive control is associated with the ACC cognitive division.

This theory suggests a nice framework for thinking about the different subtypes of ADHD.

Nigg (2001) provided a similar framework for ADHD combined type. Nigg suggested dividing inhibition into motivational inhibition, which is linked to BIS, and executive inhibition, which is linked to Effortful Control. He reviewed the literature in this area, and concluded that children with ADHD combined type have problems with executive inhibition rather than motivational inhibition. He also noted that ADHD co-morbid with anxiety and conduct disorder may show a different pattern. Interestingly, he hypothesized that co-morbid anxiety partially compensates for poor behavior inhibition.

An important factor in considering neurological dysfunction and symptom profile is the presence of co-morbidity with conduct problems. Nigg (2001) hypothesized that weak BIS may be more strongly linked to conduct problems. As noted above, there is a high co-morbidity of ADHD with other conduct problems such as CD and ODD. ADHD combined type seems to be more strongly associated with the risk of co-morbid conduct problems (Hart, Lahey, Loeber, Brooks, & Fricks, 1995). Further, there is some suggestion that ADHD only, conduct problems only, and ADHD with co-morbid conduct problems are distinct disorders, and not merely additive (Banaschewski et al., 2003).

ADHD with co-morbid conduct problems has been linked to psychopathy (Herpertz et al., 2001; Lynam, 1996). Herpertz et al. (2001) found that ADHD children with co-morbid CD showed more rapid habituation to aversive startle stimuli compared to ADHD children without co-morbid CD. This parallels findings in adult diagnosed with psychopathy. These individuals have been found to have lower physiological reactions during fearful imagery and presentation of victim slides (Levenston, Patrick,

Bradely, & Lang, 2000; Patrick, Cuthbert, & Lang, 1994). Lynam (1996), in fact, suggested that ADHD children with co-morbid conduct problems such as CD are similar to adults diagnosed with psychopathy. Gresham, Lane, and Lambros (2000) also referred to these children as "fledgling psychopaths", noting that these children are highly resistant to intervention. Lynam (1998) found that these children significantly differed from ADHD children without co-morbid conduct problems on various measures such as delay of gratification and delinquency scores, therefore providing evidence for his theory.

Other researchers have argued that this is not an accurate way of identifying children with psychopathic tendencies (Barry et al., 2000). Frick, O'Brien, Wootton & McBurnett (1994) created a child version of the psychopathy checklist, the Psychopathy Screening Device (PSD) and argued that this was a more accurate way to assess psychopathy. The PSD contains an Impulsivity/Conduct Problem scale (I/CP) and a Callous Unemotional scale (CU). Frick et al. (1994) found that while the I/CP correlated highly with traditional measures of conduct problems, the CU factor correlated only moderately. Supporting this view, Loney, Frick, Clements, Ellis, and Kerlin (2003) found that impulsivity and callous-unemotional traits showed different patterns of association with emotional processing. In particular, the CU dimension may be more strongly linked with developmental psychopathy as children who are higher on the CU dimension have been found to be more difficult to parent (Cavell, & Hughes, 2003; Wootton, Frick, Shelton, & Silverthorn, 1997). While parenting relates to behavior problems with other children, it is unrelated in high CU children.

Burns (2000) criticized the PSD in terms of its heavy overlap with symptoms of ADHD, CD, and ODD. This overlap, however, is probably due to the I/CP factor.

Colledge and Blair (2001) directly explored this issue of overlap among the different constructs of attention, impulsivity, and the two factors of the PSD. They found that all four dimensions were highly correlated. However, when they conducted partial correlations, they found that the inter-correlations were mainly due to the association between impulsivity component of ADHD and the I/CP component of the PSD. For instance, when they partialled out impulsivity, they found that the inattention component of ADHD was not associated with either the I/CP or CU components of the PSD. Similarly, when I/CP was partialled out, CU was not associated with either impulsivity or inattention. They further noted that the high co-morbidity between psychopathy and ADHD may be due to overlapping brain and neurochemicals involved in these two disorders. Like Swanson et al., they hypothesized that the impulsivity factor may be due to ACC dysfunction while inattention may be due to right frontal dysfunction. A general dysfunction of the frontal cortex and surrounding areas would lead to both inattention and impulsivity, explaining the frequent co-occurrence of these two components. Similarly, dopamine dysfunction would affect both ACC and amygdala since these two areas are rich in dopamine receptors. A general dopamine dysfunction might explain the frequent co-occurrence of impulsivity, conduct problems, and CU.

**ADHD, Psychopathy and the Iowa Gambling task**

ADHD children have also been found to have problems with decision making and social information processing (Matthys, Coperus, & Van Engeland, 1999; Millich & Dodge, 1984; Murphy, Pelham, & Lang, 1992). For instance, Millich and Dodge (1984) found children with ADHD have difficulty encoding social cues and generating solutions to social problems. It is not surprising that their real life decision-making problems

extend to the laboratory. There is some preliminary evidence suggesting that ADHD individuals do not process the Iowa Gambling task in the same way as normal individuals. Ernst, Grant et al. (2003) gave the Iowa Gambling task to adolescents 12-14 years of age who had behavioral disorders. A large portion of these adolescents had ADHD. The adolescents performed more poorly on this task than control children, but only on the second testing session.

Further, in another study, Ernst, Kimes et al. (2003) gave the task to adults with a diagnosis of ADHD and to a control group. Neuroimaging data indicated that both groups activated the DLPFC and insula. However, the groups differed on activation of some brain regions such as part of the ACC and the hippocampus. Scores on the control group were correlated with activation in the right ACC, ventral PFC, right middle and dorsal PFC, left hippocampal gurus and left insula. In comparison, scores for ADHD were correlated with activation in right ventral PFC, right middle frontal gurus, and right hippocampus. This indicated that ADHD individuals were using a different network to perform the task. Interestingly, the authors reported that while the ADHD adults did use a different network to process this task, they did not differ significantly on choices from the good decks. This indicated that by adulthood, ADHD individuals may be able to compensate for dysfunction in brain areas.

As discussed previously, research indicates that individuals with psychopathy have difficulty with the Iowa Gambling task (Mitchell et al., 2002; Blair et al., 2001). Mitchell et al. found that adult psychopaths demonstrated deficits in both the Iowa Gambling task and a reversal task. Blair et al. (2001) found that boys with psychopathic tendencies did not learn to choose more from the good decks, but in contrast to adults, did

not demonstrate deficits in reversal learning. This suggests that performance on the Iowa Gambling task may differ from reversal tasks, despite the fact that both assess OFC functioning.

**Goals of Experiment 4**

The primary goal of this experiment was to look at decision-making over time, using the gambling task in a child population known to have dysfunction of the frontal striatal system and real life social problems. As such the study included a sample of children with ADHD. Given the high rate of co-morbidy of ADHD with the other childhood conduct problems such as ODD and CD, the majority of these children also had a co-morbid diagnosis of CD or ODD. The practice of using this type of group to examine children with social difficulties is common in the literature. For example, Matthys et al. (1999) used a group with ADHD alone and ADHD combined with another disorder to examine social decision making. Similarly, O'Brien, Frick, and Lyman (1994) used a similar clinical sample when giving children a decision-making task with rewards and loss. As noted previously, while some findings indicate problems with ADHD in the gambling task, there is as yet no study on young children with ADHD.

A secondary goal was to look at different groups of children within the ADHD population. In particular, it was of interest to look at children with co-morbid anxiety since these children have been found to do better on inhibition tasks. Another area of interest was psychopathic tendencies since this has been associated with performance on the Iowa Gambling task. For this experiment, psychopathy was operationally defined in two ways based on previous research. One definition was the presence of ADHD and co-morbid CD and the second was the elevation of scores on the CU subscale of the PSD.

A third goal was to investigate whether these children would perform more poorly on reversal learning. As noted previously, simple object reversal seems to develop during the pre-school period (Overman et al., 1997). This task assesses the ability to flexibly change behaviour that has previously been reinforced. In this task, the child must choose between two objects. In the beginning, one object is consistently rewarded. Once the child has reached criterion, the reinforcement is switched to the other object. A more difficult task that is similar to object reversal is the intradimensional reversal shift of the intradimensional/extradimensional shift task. In the reversal portion of this task, a series of two pictures are presented sequentially. The subject needs to learn which dimension/category is being reinforced. Once the subject consistently picks the correct pictures, reward contingencies are reversed and previously non-rewarded pictures are now rewarded. Performance on this reversal task has been associated with the OFC in primates (Dias et al., 1996). This task has been adapted to humans within a test battery called CANTAB (Luciana & Nelson, 1998). Children begin approaching adult-like performance on the ID reversal at approximately 8-years-old (Luciana & Nelson, 1998).

For this experiment, it was therefore decided to adapt the ID shift & reversal aspect of this task to card format. Two decks of cards were placed in front of the child with one card from each deck turned for each trial. Cards differed on shapes, number, and colors. Initially, the card with the larger number of symbols was rewarded with one token for each correct choice. Once the child made 6 consecutive correct choices, the contingencies were reversed and smaller number of shapes was rewarded. Reversals occurred twice, with a maximum of 80 card turns. The dependent measure was the number of errors.

The clinical and control groups were matched on age and sex, with SES and IQ statistically controlled. The gambling task was the same as the one used in experiment one with a few modifications. As in the original version, four decks were used that closely approximated the reward and loss values of the adult version. Two decks were advantageous with small rewards and smaller losses while the remaining two decks were disadvantageous with larger rewards and larger losses.

Tokens were used for rewards. The reward system used was similar to that used by O'Brien et al. (1994). The most tokens that could be won from the gambling and ID reversal games were 96. Children were told that the tokens could later be exchanged for 3 sets of prizes designed to be of varying attractiveness to children. There were 3 prize bags. The children were told that they could exchange their "tokens" for a prize in the first bag if they won 1-30 tokens. This bag contained only sheets of stickers. They were told that they could exchange their tokens for a prize in the second bag if they won between 31-60 tokens. This bag contained bags with a sheet of stickers plus some candy treat. Finally, children were told that they could exchange their tokens for a prize from the third bag if they won more than 60 tokens. This bag contained bags with stickers, a candy treat, and a prize (marbles, Pokemon cards, a necklace/earrings, stuffed toy). Regardless, of how many tokens the children won, they were always allowed to choose from the 3rd bag at the end of the game.

A separate analysis was performed for each dependent measure. For the gambling task, it was expected that ADHD would choose significantly less from good decks when compared to control children. It was also expected that co-morbid anxiety would be associated with higher choice from good decks within the clinical group. Finally, it was

expected that children with psychopathic tendencies would choose significantly less from the good decks.

For the reversal task, it was expected that ADHD children would make significantly more reversal errors when compared to controls. Children with psychopathic tendencies were not expected to do worse on this task, given previous findings (Blair et al., 2001).

## Method

*Participants*

Participants were 42 children from the Halifax region and ranged in age from 6 years to 13 years of age (mean = 9.8 years). The ADHD group consisted of 21 children (4 girls, 17 boys) participating in Summer Treatment Program (STP) for ADHD at Dalhousie University. All 21 children met the criteria for a *Diagnostic and Statistical Manual of Mental Disorders* (3rd ed., rev: DSM-III-R; American Psychiatric Association, 1987) diagnosis of ADHD. Diagnostic information was collected using several sources, including the parent and teacher Revised Disruptive Behavior Disorders (DBD) Rating Scale. This scale assesses symptoms of the disruptive behavior disorders (Pelham, Gnagy, Greenslade, & Milich, 1992). Parents also completed a structured interview which consisted of the DSM-III-R descriptors for ADHD, Oppositional/defiant disorders (ODD) and conduct disorder (CD). Seventeen children in the ADHD group had a co-morbid diagnosis of ODD. Eight of these also had a co-morbid diagnosis of CD. Diagnoses were made if a sufficient number of symptoms were endorsed (using both parent and teacher sources) to meet the criteria for ADHD. The control children consisted of 21 children recruited through the summer camp and participants who had

participated in past studies. These children were matched for age and sex to the clinical group. To screen for psychiatric problems, parents were given the DBD and the Achenbach Child Behavior Checklist. All children completed all tasks.

*Apparatus*

For the gambling task, the same four sets of decks as in experiment 1 were used. Each set contained two "advantageous" decks and two "disadvantageous" decks. Each card from the disadvantageous decks had two bears (which indicated a win of two tokens) and some cards contained pictures of tigers (which indicated loss of tokens). Each card from the advantageous decks had one bear (which indicated a win of one token), and some cards contained pictures of tigers (which indicated loss of token). Appendix B contains the reward/loss contingencies. Each deck contained 80 cards.

Each deck within a set was a different colour (red, blue, yellow, or green). Colour was counterbalanced across sets, so as to minimize the possible effect of colour preference among the participants.

For the Reversal task, 2 decks of cards were used. Each deck contained 80 cards. Each card had shape (s) that could differ from one another on color (blue, yellow), shape (circle, square), or number of shapes (1 to 5). Two cards were turned at a time, one from each deck. Any two pairs of cards differed on at least two categories.

*Procedure*

The order of the gambling task and the reversal task were counterbalanced across participants. In the beginning of the experiment, the experimenter showed children three prize bags and said, "We are going to play two games where you can win tokens. There are three prize bags." The experimenter then showed children the prize bags and allowed

them to examine each. "If you have 1-30 tokens at the end of the game, you can get a prize from this bag. If you have 31-60 tokens, you can pick from this prize bag. If you have more than 60 tokens, you can pick a prize from this bag."

*Gambling task*

The instructions for the gambling task were the same as those given in the last three studies. After 40 cards, children were given the first awareness test. The game stopped after 80 card turns and the same awareness questions were given again at the end of the game. The awareness test was slightly different from that used in the first three studies. Instead of being asked to choose 1 deck that was the best and 1 deck that was the worst, children were asked to choose 2 decks they considered to be the best and 2 decks they considered to be the worse. One point was awarded for each correct choice. Combined with answering the conceptual questions (e.g., Why do you think these are the best decks to pick from?), this led to a range of 0-6 points rather than 0-4 points.

*ID Reversal Task*

Two decks were placed in front of the subject. (E) pointed to the decks and said, " In this game, I will ask you to pick between two cards. These cards will have different colors and shapes on them." (E) gave an example of two cards. "I cannot tell you ahead of time which cards are the right ones. I want you to pick a card. Each time you pick the right card, I will give you a token. Remember at the end of the 2 games, you can exchange your tokens for a gift. The object of the game is to try to get as many tokens as possible. Can you tell me what you will try to do in this game?" If a child did not give appropriate response, the game was explained again. "Would you like to play this game with me?"

Each task took approximately 10-15 minutes to complete. Children were given a break in between tasks. At the end of the session, they were allowed to pick a gift from the third gift bag, regardless of how well they performed. They were told, "Guess what? I'm going to let you pick out of the third bag. I told you that you needed a lot of tokens for this gift so that you would try your best at these games, and I know that you did that. Thanks for helping me out."

*Weschler Intelligence for Children* (WISC-III: Weschler, 1990).

Children were given the Block Design and Vocabulary subtests of the WISC-III. Intelligence Quotient was estimated from these two subtests using procedure provided by Sattler (1992).

*Questionnaires*

All parents were given the Achenbach Child Behavior Checklist (CBCL) and the revised DBD as indicated previously. They were also given a Demographic Form to estimate SES. SES was estimated based on family income.

*Demographics Form* – This included information on parents' education and household income. Social Economic Status for this experiment was based on household income. Income was rated on a scale of 1 to 12 with 1 being an annual income of $0 - $9,999 and 12 being an annual income of above $125, 000.

*Diagnostic Interview Schedule for Children* – Parents of the children in the summer camp program were asked to complete the Diagnostic Interview Schedule for Children (DISC; Fisher, Wicks, Shaffer, Piacentini, & Lapkin, 1992) on the computer. The DISC is a structured interview based on DSM symptoms.

*Child Behavior Checklist* – Parents completed the Child Behavior Checklist (CBCL; Achenbach, 1991). The CBCL includes 113 behaviors rated on a 3-point scale and includes a Total Problem, Internalizing, and Externalizing Problems scales as well as several subscales. Whenever possible, the CBCL was filled out by both parents and averaged scores were used.

*Revised Disruptive Behavior Disorder Rating Scale* – This questionnaire was given to all parents. It contained 57 items that were integrated from two separate questionnaires; the Disruptive Behavior Disorder Rating Scale (DBD; Pelham et al., 1992) and the callous/unemotional scale of the Psychopathy Screen Device (PSD; Frick et al., 1994). The DBD measures disruptive behavior disorder symptoms using DSM-IV criteria. Behavior is rated on a four-point Likert Scale ranging from 0 (not at all) to 3 (very much). The PSD was designed to closely approximate the adult version of the Psychopathy Checklist-Revised (PCL-R; Hare, 1993). It is scored on a 3 point Likert scale ranging from 0 (not at all true) to 2 (definitely true).

## Results

*IQ and SES estimates*

Analysis indicated that the clinical and control group did not differ significantly on the SES factor, $F(1, 40) = 1.44, p > .05$. The groups did not differ significantly on IQ estimate as well, $F(1, 40) = 3.57, p > .05$. Despite the lack of significant differences on these two variables, it was decided to use these as covariates nonetheless given that the children had not been matched on these two variables. Table 10 shows the means and standard deviations for participant characteristics of each group.

Table 10

*Means and Standard Deviations for Participant Characteristics*

| Item | M | SD |
|---|---|---|
| *Clinical Group* (N = 21) | | |
| Age in Years | 9.86 | 1.71 |
| IQ estimate | 95.76 | 17.18 |
| Social Economic Status | 5.52 | 3.30 |
| CBCL raw score | | |
| Attention problems | 12.90 | 3.60 |
| Oppositional/Defiant problems | 6.10 | 2.16 |
| Conduct Disorder problems | 5.24 | 4.38 |
| Depression/Anxiety subscale | 7.86 | 5.24 |
| Externalizing Problems | 18.43 | 8.24 |
| Internalizing Problems | 13.52 | 9.55 |
| Total Problems | 66.29 | 23.25 |
| *Control Group* (N = 21) | | |
| Age in Years | 9.81 | 1.94 |
| IQ estimate | 104.81 | 13.66 |
| Social Economic Status | 6.67 | 2.87 |
| CBCL raw score | | |
| Attention problems | 0.62 | 0.86 |
| Oppositional/Defiant problems | 1.43 | 1.80 |
| Conduct Disorder problems | 0.71 | 1.42 |
| Depression/Anxiety subscale | 1.19 | 1.50 |
| Externalizing Problems | 3.19 | 4.07 |
| Internalizing Problems | 2.14 | 2.33 |
| Total Problems | 8.81 | 7.96 |

*Group Differences for the Gambling Task*

The data was analysed in the same way as previous studies. Choices were divided into blocks of 20 choices. A mixed ANOVA was used with group as the between subject variable and block as the within subject independent variable: 2 (Group) X 4 (Block). Given that the participants were not matched on IQ and SES, these were used as covariates. As well, anxiety, as measured by the CBCL subscale, was used as a covariate, in keeping with other research indicating that this an important variable to control for in this population.

Whenever Mauchley's test of sphericity was significant, the more conservative Greenhouse-Geisser test was used for the analyses. The SES and IQ covariate were non-significant, with both $F's < 1$. The main effect of the anxiety covariate approached significant, $F(1, 37) = 4.08$, $p = .05$. Further, the Block X Anxiety interaction was significant, $F(3, 111) = 3.102, p < .05$. Children who were high on anxiety seemed to choose more on the good deck, particularly in the last blocks.

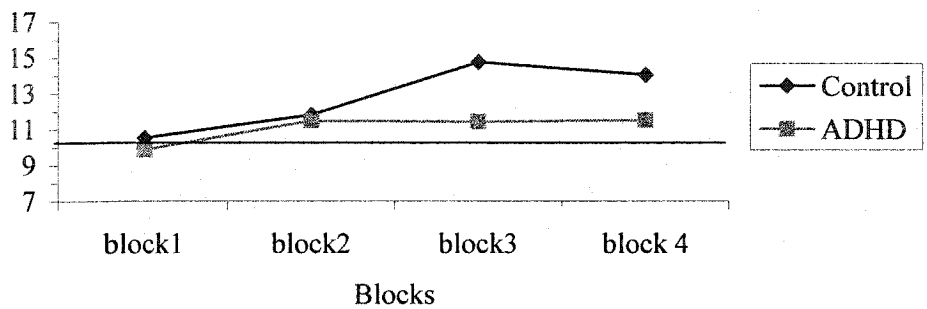
The group main effect was significant, $F(1, 37) = 7.83, p < .01$, with the control children choosing more from the good decks overall. As well, the Group X Block interaction was significant, $F(3, 111) = 5.15, p < .01$. Follow-up to the Group X Block interaction indicated a highly significant block main effect for the control group, $F(1, 57) = 7.45, p < .001$. The linear contrast was significant, indicating that children in the control group chose more from the good deck over the 4 blocks, $F(1, 19) = 14.01, p < .01$. The block effect was not significant for the clinical group, $F < 1$.

Comparison to chance (with Bonferroni-type adjustment) indicated that the control group chose significantly more from the good decks when compared to chance in

block 2, $t$ (20) = 2.77, block 3, $t$ (20) = 6.08, and block 4, $t$ (20) = 5.3, all $p$s < .05. For the clinical group, only choice from the second block approached significance, $t$ (20) = 2.22, $p < .1$. Figure 10 shows the choices from the good deck for the control and clinical group.

Given the effect of anxiety, it was of interest to determine whether there was a group difference without using anxiety as a covariate. The same analysis was therefore performed without anxiety, keeping the same variables and covariates. When this was done, the group main effect and Group X Block interaction still approached significance, $F$ (1, 38) = 3.55, $p < .07$ and $F$ (3, 114) = 2.28, $p = .1$, respectively. The SES and IQ covariates were again non-significant, both $F$'s < 1. Therefore, in order to increase power, both of these covariates were removed from the analysis. In this new analysis, both group main effect and Group X Block interaction was significant, $F$ (1, 40) = 4.43, $p < .05$ and $F$ (3, 120) = 3.20, $p < .05$. These results suggest that while anxiety has an important influence on performance, group membership also was important in determining performance.

*Figure 10*. Number of card choices from the good decks as a function of group.




*Comparison of Anxiety Groups with Clinical Children*

Children within the ADHD group were divided into two groups based on T-scores of 65, which marks the borderline clinical range on the CBCL anxiety/depression subscale. A t-score is a standardized score that reflects where children fall in comparison to other children of the same gender and age group. A t-score of 65 means that a child scored higher than 93% of children in that gender and age group for that particular scale. Using this criteria, 10 children (2 females, 8 males) were classified as high anxious while 11 children (2 females, 9 males) were classified as low anxious.

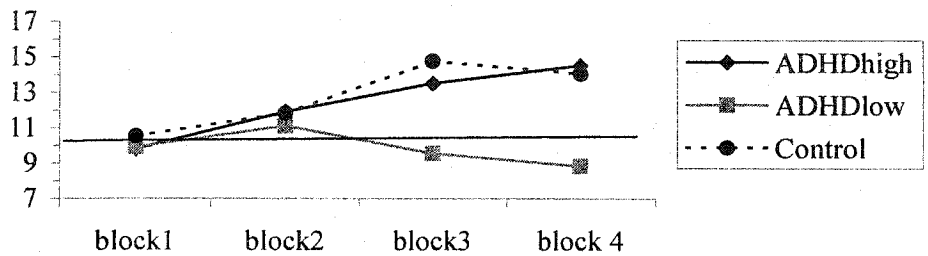
Univariate ANOVAs indicated that the two groups were not significantly different on SES level, IQ, Sex, and Age, with all $Fs < 1$. As before, SES and IQ were used as covariates. These covariates were non-significant, with both $F's < 1$. This analysis revealed a significant effect of anxiety group, $F(1, 17) = 4.74, p < .05$, with the high anxious group choosing more from the good decks overall. There was also an Anxiety Group X Block interaction, $F(3, 51) = 4.57, p < .01$ (see figure 11). Follow-up of the

Anxiety Group X Block interaction indicated a significant block effect for the high anxious group, $F(3, 27) = 4.60, p < .05$. The within-subject contrast resulted in a significant linear effect for block, $F(1, 9) = 8.59, p < .05$, indicating that tendency to choose from the good deck increased over time in this group. The block effect was non-significant for the low anxious group, $F(3, 30) = 1.69, p > .05$.

Comparison with chance for each group indicated that the high anxious group chose significantly more than would be expected from chance for block 3, $t(9) = 3.28, p < .05$, and block 4, $t(9) = 3.05, p < .05$. None of these comparisons were significant for the low anxious group.

It is possible that the low anxious and high anxious children differ on some other important variable such as co-morbid diagnosis of ODD and CD. These two groups were therefore compared on presence of ODD and CD co-morbid diagnosis. They were not significantly different for CD diagnosis, $F < 1$. They were significantly different on the ODD diagnosis, $F(1, 19) = 5.17, p < .05$. However, the difference was in the direction opposite to what would be expected, with a higher number of high anxious children having a co-morbid diagnosis of ODD than low anxious children. Further, when the analysis was redone using ODD diagnosis as a covariate, this had little impact on the results, with all effects (Anxiety Group and Anxiety Group X Block) remaining significant. This indicated that the crucial difference between the two groups was anxiety level.

*Figure 11.* Number of card choices from the good decks as a function of anxiety group.




*Children with Psychopathic Tendencies*

Another area of interest was children with psychopathic tendencies. Some authors suggest that children with co-morbid ADHD and CD form a group of children at risk for developing later psychopathy. Another approach is to use the callous/ unemotional (CU) dimension of the PSD to classify children at risk of psychopathy. It was decided to explore whether either one of these would be related to performance on this version of the gambling task.

For the first analysis, ADHD children with a co-morbid diagnosis of CD were compared to ADHD children without CD. Using this criteria, 8 children were classified as having psychopathic tendencies and 13 were classified as low in psychopathic tendencies. The between subject variable was group and the within variable was block. Covariates used were IQ, SES, and anxiety. The group and Group X Block interaction effect were non-significant with both $F$s $< 1$.

For the CU trait, children were placed in high callous group when they received a score of greater than 7 on the CU scale, using the criteria suggested by Barry et al. (2000). Barry et al. (2000) noted that this group represents the upper quartile of a clinic sample. Using this criteria, 10 children were classified as having psychopathic

tendencies. Interestingly, many of these children also had a co-morbid CD diagnosis (N = 6), which suggests an overlap between the two methods of classification. Again group (low CU, high CU) was the between subject variable and block was the within subject variable. The same covariates were used as in previous analysis. The group main effect and interaction with block were non-significant, with both $F$s < 1. Further, for both analyses in this section, none of the covariates were significant.

*Correlations of Gambling Task with Impulsivity and CU*

Some studies suggest that psychopathy involves both an impulsivity/conduct problem component and a CU component. Many studies do not separate these and combine the score from both dimensions. However, research indicates that the impulsivity is highly related to hyperactive symptoms of ADHD children (Colledge & Blair, 2001). To further explore the relation between impulsivity symptoms (DBD subscale), CU, and choices of the good decks, a series of partial correlations were conducted.

When anxiety was controlled for, CU score correlated negatively with choices on the good decks in block 4, $r$ (39) = -.38, $p < .05$ and this correlation approached significance for block 3, $r$ (39) = -.31, $p = .05$. Similarly, when anxiety was controlled for, impulsivity score correlated negatively with the number of choices on the good decks in block 3, $r$ (39) = -.41, p < .01 and block 4, $r$ (39) = -.33, $p < .05$. Impulsivity and CU were highly correlated, however, $r$ (42) = .83, $p < .001$. In order to partial out the separate contributions of both factors, the correlation of these factors were conducted with the other variable partialled out. When both anxiety and impulsivity were partialled out, none of the correlations between the CU and choices from the good decks were

significant. In contrast, when anxiety and CU were partialled out, correlation between impulsivity and choice on block 3 only approached significance, $r$ (38) = -29, $p$ = .07, and correlation with the last block became non-significant. This indicates that the correlation between impulsivity, CU, and block 4 were due to variance common to both factors. It also suggests that impulsivity contributed some unique variance to the prediction of performance on block 3.

*Social Ability and Performance on the Gambling Task*

One area of interest was whether poor performance on the gambling task was related to poor social ability. In order to explore this, number of choices from each block was correlated with subscales of the CBCL thought to be more closely associated with social functioning; social problems, rule breaking, aggression behaviour, internalizing problems, externalizing problems, and total problems. Since this was only exploratory, two-tailed tests of significance were used. None of these correlations approached significance. Even when anxiety was controlled for, only the correlation between total problem and block 3, $r$ (39) = -.35 and block 4, $r$ (39) = -.36 were significant, with both p's < .05. The correlation between aggression and block 3 approached significance, $r$ (39) = -.28, $p$ = .08.

*Group Differences within Different Deck Types*

As with the first experiment, it was of interest to see whether different deck types affected performance. The decks differed on the frequency of loss. Two decks (good and bad) involved frequent loss (4 out 10 cards) and the other involved less frequent loss (2 out 10 cards). Variables were again created using proportion of good cards picked from each deck type (see experiment 1 for further detail).

For the frequent loss decks, none of the covariates were significant, although anxiety approached significance, $F(1, 37) = 3.19, p = .08$. The group main effect was significant, $F(1, 37) = 7.53, p < .01$ with control children again choosing more from the good deck. The Block X Group interaction effect was also significant, $F(3, 111) = 5.23$, $p < .01$. Follow-up to the interaction indicated that the block effect was significant for the control children, $F(3, 60), p < .05$ while this effect was non-significant for the clinical group, $F(3, 60) = 1.55, p > .05$. Control children increased their choices from the good deck from 53% in the first block to 75% in the last block. Children in the clinical group did not show such learning, going from 50% in the first block to 49% in the last block.

For the infrequent loss deck, none of the covariates were significant. The group main effect approached significance, $F(1, 37) = 3.95, p < .06$, with control children having a tendency to choose more from the good deck overall. While control children chose 66% of cards from the good deck, clinical children only chose 54% of cards from the good deck. The Block X Group interaction effect was non-significant, $F(3, 111) = 1.03, p > .05$.

This analysis was also performed to compare the anxiety subgroups on the different deck types. For the frequent loss decks, again the SES and IQ covariates were non-significant. The anxiety group main effect was not significant, $F(1, 17) = 1.38, p > .05$. However, the Block X Anxiety Group interaction was significant, $F(3, 51) = 2.99, p < .05$. As expected, the block effect for the low anxious clinical children was non-significant with these children choosing 52% from the good deck in the first block and 43% in the last block. The block effect was also non-significant for the high anxious

clinical children, $F(3, 30) = 2.08, p > .05$. Despite this non-significant effect, these children did increase their choices from the good deck from 49% in block 1 to 69% in the last block.

For the infrequent loss deck, SES and IQ covariates were non-significant. The anxiety group main effect was significant, $F(1, 17) = 5.58, p < .05$. The Block X Anxiety Group interaction was also significant, $F(3, 51) = 3.32, p < .05$. Again, the low anxious clinical children showed no significant block effect, going from 48% of good deck choices on block 1 to 49% on block 4. In contrast, there was a significant block effect for the high anxious clinical children, $F(3, 27) = 5.17, p < .01$. For this deck type, they showed a large increase, going from 49% of good deck choices on block 1 to 78% on block 4. These results suggest that although the clinical children with high anxiety seemed to perform better on both types of deck, this was more pronounced for the infrequent loss decks.

*Awareness of Game*

Analysis was performed to assess whether there was a difference between the clinical and control group in awareness of the game. This test was given twice, once after 40 choices had been made and at the end of the game. A mixed ANCOVA was used to analyze the results of the two awareness tests. IQ estimate, SES, and anxiety were used as covariates. The between subject variable was group (clinical vs. control) and the within subject variable was awareness test (test 1 and test 2). The dependent measure used was score on the awareness test. Anxiety was the only significant covariate, $F(1, 37) = 7.57$, $p < .01$. There was a main effect of group, $F(1, 37) = 9.06, p < .01$, whereby the control group scored significantly higher on the tests than the clinical group.

The test main effect was non-significant, indicating that children's awareness did not improve from the end of block 2 to block 4. The Group X Test interaction was non-significant, $F < 1$. Interestingly, the anxiety covariate was significant, $F(1, 37) = 7.57, p < .01$, suggesting that higher level of anxiety helped children become more aware of what was occurring in the game.

Children within the clinical group were again divided into high and low anxious groups. Again, none of the covariates were found to be significant. This analysis resulted in a main effect of anxiety group, $F(1, 19) = 10.53, p < .01$, with more highly anxious children showing greater awareness. The test main effect and Anxiety Group X Test interaction effect were both non-significant. Table 11 provides the means of the control and two clinical groups on the two awareness tests.

Table 11

*Means of Awareness Tests as a Function of Group*

| Group | Test 1 | Test 2 |
|---|---|---|
| Control | 5.14 (.35) | 5.05 (.33) |
| Clinical | | |
| Low anxious | 3.09 (.27) | 3.55 (.65) |
| High anxious | 5.00 (.42) | 5.50 (.27) |

(standard error of the mean in brackets)

*Awareness and Performance*

In order to explore the possibility that awareness of the game was accounting for the group (clinical vs. control) differences, the score from awareness test 1 was used as a covariate in the analysis of the gambling task. Only the awareness was significant for

this analysis, $F(1, 36) = 8.16, p\ .01$. Further, in this analysis, the group main effect and the Group X Block interaction become non-significant, $F(1, 36) = 1.95, p > .05$ and $F(1, 108) = 1.88, p > .05$, respectively. Similarly, both anxiety group main effect and Anxiety X Block interaction effects became non-significant when awareness score was used as a covariate. However, the awareness covariate was significant, $F(1, 16) = 5.19$, $p < .05$. This suggests that at least some of the differences in performance between the two groups might have resulted from differences in awareness of the game.

*Group Differences on the Reversal Task*

For the reversal task, a mixed ANCOVA was again used for the analysis. Group (clinical vs. control) served as the between subject variable. The stage (concept acquisition, reversal) served as the within subject variable. Covariates included SES, IQ, and anxiety. The dependent variable was the number of errors children made on each stage.

Unfortunately, this task was more difficult for children to perform than anticipated. Only 26 children reached the conceptual stage and 1 reversal within the 80 card turns. This included 13 clinical children and 13 control children. None of the covariates were significant. The group main effect was nonsignificant, $F < 1$ as was the stage main effect, $F(1, 21) = 1.34, p > .05$. Finally, the Group X Stage interaction was also non-significant, $F(1, 21) = 1.17, p > .05$. Therefore, there was no evidence that ADHD children had more difficulty reversing associations than control children. Given the small number of children completing the task, group differences within the ADHD sample were not examined.

It was decided to look at another measure of reversal to explore possible group differences further. Children who were able to complete the concept phase within 80 card turns were scored as 1 on Concept Learning while the remaining children were given a score of 0. This measure would presumably reflect to some degree reward learning since children who were able to figure out the initial rule within 80 cards displayed faster learning than those who did not. A second measure, Reversal Learning, was constructed using the number of reversals completed within the 80 card turns. This second measure, with concept learning partialled out, would hypothetically reflect flexibility of reward learning since children who are able to complete more reversals are presumably better able to flexibly adjust learning.

A new ANOVA using Reversal Learning as the dependent, with Concept Learning partialled out, was performed. As with previous analysis SES, IQ estimates, anxiety estimate were used as covariates. Group (Clinical vs. Control) was the independent measure. Despite including a larger number of participants, the group difference was still not significant, $F(1, 36) = 2.25, p > .05$.

Comparison of subgroups within the ADHD sample was also conducted. The comparison of the anxiety subgroups was not significant, $F(1, 16) = .728, p > .05$. Further, the comparison for co-morbid CD was also non-significant, $F(1, 15) = .04, p > .05$. Similarly, comparison of callous/unemotional subgroups was also non-significant, $F = .057, p > .05$. Further, it should be noted that for all of the analysis in this section, none of the covariates were significant.

*Concept Learning*

While children with ADHD did not differ from controls on reversal learning, controlling for concept learning, it is possible that they differ on their ability to learn concepts, given rewards. Certainly, the literature indicates that ADHD children show some abnormalities in reward learning. To explore this possibility, ADHD children were compared with control children on their ability to complete the initial phase of the reversal task. The Concept Learning variable was used as the dependent, with anxiety, IQ, and SES again used as covariates. Only the IQ covariate was significant, $F$ (1, 37) = 7.27, $p < .05$. Children who had a higher IQ tended to finish the concept stage more than those whith lower IQ. The difference between groups, however, was not significant, $F$ (1, 37) = .29, $p > .05$. This indicates that ADHD children in this sample, at least, did not differ in their ability to learn concepts, when given rewards.

Children within the ADHD sample were also compared. Particularly, the anxiety subgroups were of interest. Their superior performance on gambling task may have been the result of greater ability to learn when given rewards. This comparison approached significance, $F$ (1, 17) = 3.78, $p < .07$, with a larger number of children in the high anxiety group tending to complete the conceptual phase than those in the low anxiety group. This suggests a possible reason as to why children with higher anxiety score were able to do better on the gambling task. Again the IQ covariate was significant, $F$ (1, 17) = 5.17, $p < .05$. Comparison of the CD groups and CU groups were both non-significant for this dependent measure, with both $F$'s < 1. The IQ covariate approached significance for the CD and CU analyses, $F$ (1, 17) = 4.3 and $F$ (1, 17) = 4.23, both $p$'s = .05.

*Association between Gambling task and Reversal Task*

Another area of interest was the association between performance on the gambling task and reversal task. Given that the OFC is hypothesized to underlie performance on both tasks, they should show some association. Correlation analysis was conducted between number of choices on the good deck for each block and errors to reversal 1, with errors to concept partialled out. None of these correlations were significant, all $p$'s > .05.

Interestingly, however, the correlations with concept learning and reversal learning variables were significant for the last two blocks. Concept learning was significantly correlated with the number of choices of the good deck on block 3, $r$ (42) = .31, $p$ < .05, and block 4, $r$ (42) = .38, $p$ < .05. Reversal learning was positively correlated with the number of choices from the good deck in block 3, $r$ (42) = .38, $p$ < .05, and block 4, $r$ (42) = .46, $p$ < .05. These correlations indicate that the ability to learn concepts more quickly is correlated with better performance on the gambling task. More impressive is the significant correlation between performance on the gambling task and reversal learning when concept learning is partialled out. Partialling out concept learning, reversal learning was significantly correlated with choices on block 3, $r$ (39) = .28, $p$ < .05, and block 4, $r$ (39) = .36, $p$ < .05. This indicates that being able to flexibly change responses when environmental contingencies change is related to better performance on the gambling task in the last two blocks.

## Discussion

The findings support the hypothesis that children with ADHD demonstrate problems on this version of the Iowa Gambling task. Children with ADHD selected

fewer cards from the good decks overall. Further, they failed to show learning over the course of the game, with the block effect being non-significant for this group. These results are consistent with previous findings indicating altered reinforcement sensitivity for this group.

While the findings do support a dysfunction for the ADHD on this task, they do not indicate the source of dysfunction. Other findings in this experiment, however, suggest some possibilities. The findings from concept learning analysis indicate that it was not due to differences in ability to learn concepts when given rewards. Children with ADHD did not differ from control children in their ability to learn the concept phase within 80 card turns.

Nigg (2001) and Swanson et al. (1998) suggested that children with ADHD combined type may have a dysfunction in the Effortful Control system. Again, as discussed in chapter 1, this temperament factor has been associated with the cool system. Further, this system can be linked to more conscious processing and voluntary behavior. It has also been hypothesized to modulate the BAS (Luciana, 2001), a system that has been thought to show dysfunction in ADHD children. Experiment 2 and studies in adult population indicate that conscious processing tends to affect later phases of decision-making processes. Further, Effortful Control should be linked with awareness of the game. These two predictions are supported by the data. Figure 10 indicates that the performance of the clinical and control group was very similar until block 2. Further, the two groups differed on awareness level. When the score on the awareness test was used as a covariate, it resulted in the group and Group X Block effect becoming non-significant. This provides some support for the idea that problems of the ADHD group

were more closely linked to failure to voluntarily attend to the game and suppress subdominant responses.

*Anxiety and Performance on the Gambling Task*

Another interesting finding was the difference among anxiety subgroups. Children with higher levels of anxiety were able to perform better on the gambling test. Further, this was not due to differences in co-mordid ODD. There are at least two possible interpretations for this result. One possibility is that children with co-morbid anxiety represent a different subtype. In support of this possibility, these children behaved more like the control children on the gambling task and had a similar awareness level. This indicates that they were able to attend enough to the game to understand what was occurring in the game. Further, other evidence indicates that these children have less difficulty with inhibition tasks. It may be that these children have normal anterior attention system, but problems with the posterior attention system. Some research indicates that problems with the posterior attention system may lead to problems with emotion regulation (Gonzalez, Fientes, Carranza & Esterez, 2001). Particularly, the problems may be with automatic emotion regulation. These children may have normal reward learning under some circumstances, but difficulty with regulating emotions. The finding of differences in concept learning for the two anxiety group supports this idea. A higher number of children with high anxiety achieved the concept phase within 80 card turns in comparison to children with low anxiety.

A second possibility is that anxiety has a protective effect. Earlier discussion of BIS, BAS, and Effortful Control indicated that these systems interact with one another. High anxiety indicates higher BIS functioning. Nigg (2001) suggested that a higher

functioning BIS would require less support from the Effortful Control system when children have to inhibit subdominant responses. This may mean that ADHD children with higher functioning BIS would have less difficulty suppressing an impulse to choose from the bad decks. It may have also made it easier to switch attention from the consistently higher rewards of the bad deck and focus on losses. Alternatively, higher anxiety may have led to a stronger focus on losses. Some evidence indicates that anxiety is associated with a preconscious bias for threat information (Mineka & Gilboa, 1998). This bias to loss information may have then led to an increase in awareness of the game, which in turn led to better performance on the game in the last two blocks.

Whatever explanation is correct, the presence of anxiety in ADHD individual seems to be helpful under some circumstances. Yet despite their better performance on the Iowa Gambling task, the high anxious ADHD children in this experiment seemed to be as impaired in their daily lives as the ADHD children with low anxiety. In fact, they did not differ on CD problems and were even reported to have more ODD problems. One explanation for this discrepancy is that these children have an emotion regulation problem that prevents them from functioning well in their day to day lives. As Eisenberg, Valente et al. (2003) argued, too much emotion can be counterproductive when dealing with social situations. Newman and Lorenz (2003) suggested that while high emotions such as anxiety can make an individual more attentive to certain cues, it can also hamper a dominant response. For the Iowa Gambling task, following anxiety cues and avoiding the bad decks may be relatively simple. In real life, children often need more complex strategies than just avoiding the source of their anxiety

*Psychopathy and Performance on the Gambling Task*

It may be that children with combined ADHD and low anxiety are similar to adults with psychopathy. If this interpretation were correct, the problem with the gambling task should be due to psychopathic tendencies. However, when children high on the CU scale were compared to those with lower scores on the CU, this comparison was not found significant. Children who scored high on the CU were not found to choose less from the good decks than those low on the CU scale. Furthermore, children with co-morbid CD were not found to differ from those without co-morbid CD. This contrasts with findings from Blair et al. (2001), who found that boys with psychopathic tendencies chose significantly less from the good decks when compared to those with low psychopathic tendencies. There are several possible reasons for these findings.

First, the gambling task used in this experiment differed in several ways from that used in the Blair et al. study. They used the adult version of the task with older children which is different from the present version in several respects. These differences were discussed in experiment 1. The adult version provides more explicit instructions about the decks. In fact, a study on adult criminals that did not use the explicit instructions had findings very similar to the ones of the present experiment. They found differences among individuals with high and low anxiety levels, with those having higher anxiety performing significantly better. They also failed to find a difference among those with high and low psychopathic tendencies. It may be that not providing explicit instructions leads to an advantage for those with higher anxiety, but is not sensitive to those with psychopathic tendencies.

Another possible explanation is the difference in the measure of psychopathic tendencies used in both studies. The PSD is composed of two scales, the callous/unemotional scale and the impulsivity/conduct problem scale. The I/CP scale is highly correlated with impulsivity dimension of ADHD and co-mordid conduct problems (Colledge & Blair, 2001). Blair et al. used a psychopathic score which combined both these components. The present experiment used only the CU dimension, since the other dimension has been criticized for its association with ADHD symptoms. It is possible that differences found in the Blair et al. study were due to the I/CP factor. Alternatively, it may be that differences were due to shared variance between the two factors. Since, the present experiment only compared children who already had ADHD and were presumably high on the I/CP factor to begin with, this variance was not considered in this experiment. This possibility is supported by the partial correlations done between impulsivity, CU, and performance on the gambling task. When anxiety was controlled for, CU scores correlated negatively with choice in the last block. Similarly, when anxiety was controlled for, impulsivity scores correlated negatively with choices on block 3 and 4. This indicates that children who are high on both the CU and impulsivity dimension are more likely to choose fewer cards from the good deck in the last block. However, impulsivity and CU were highly correlated, indicating that they reflected some common variance. When both anxiety and impulsivity were controlled for, none of the correlations between CU score and choice on the good deck were significant. When both anxiety and CU scores were controlled for, only the correlation between impulsivity and block 3 approached significance. This pattern of findings indicates that the impulsivity

dimension may explain some unique variance in the performance of this version of the gambling task. Further, CU and impulsivity contribute some shared variance as well.

Finally, another reason for the lack of significant difference between the psychopathy groups is the small number of participants used. This obviously resulted in low power to find significant differences. It is quite possible that a larger number of participants would result in different findings.

*Association of Gambling Task and Reversal Task*

Another interesting finding was the association between the reversal learning variable with performance on block 3 and 4 of the gambling task. Further, this association was found to remain significant, even after partialling out the effects of concept learning. This finding indicates that both tasks are measuring something similar and supports the idea that they may be assessing OFC functioning. This finding also indicates that children who are able to change flexibly in their reinforcement learning tend to perform better on the gambling task as well. This is not surprising given that the gambling task contains conflicting information about rewards and losses.

Yet, the low correlation indicates that while they may have variance in common, they are also measuring something different as well. This is further supported by the lack of difference on the reversal variable between the clinical and control group. While this null finding may have been due to low sensitivity of this task and low power, it may also be that the reversal task and the gambling task just assess different abilities. The failure to find differences between clinical and control children on this task suggest that ADHD children are responsive to changes in environmental contingencies. It also suggests that their low performance on the gambling task was not due to problems with reversal

learning. It is likely that both the gambling task and reversal task are dependent on a wide variety of skills. Children with ADHD may have more problems with the executive attention component of the task rather than more automatic aspects. This explanation is reminiscent of Nigg's proposal that these children have difficult with the executive inhibition rather than motivational inhibition.

# Chapter 6

## General Discussion

Studies on children indicate that thinking and deciding "in time" gradually develops in childhood. The results of the first three studies in combination with studies on delay of gratification tasks provide a clearer developmental picture of future oriented decision-making. Work on the delay of gratification task indicates that even pre-schoolers are able to make conscious decisions that will profit them in the future (Mischel et al., 1989). Recent research indicates that this ability is not fully developed until approximately 4.5 years (Thompson et al., 1997; Moore et al., 1998; Lemmon, 2003). Further, research by Mischel and his colleagues on "cool" strategies indicate that voluntary directing attention and being able to switch attention to less salient aspects increase waiting time in delay of gratification tasks.

However, the delay of gratification paradigm assesses only one type of future oriented decision-making. There are more unconscious, implicit ways of considering the future. In fact, these unconscious, implicit aspects of processing time may be more common in everyday life than the conscious processing. It would be very exhausting indeed to think consciously about every social situation and try to weigh positive and negative aspects before deciding how to behave. Implicit and explicit systems, in fact, may work together to allow seemingly effortless social interactions that are typical of normal humans. The Iowa Gambling task assesses this more complex form of future oriented decision-making.

The results of this thesis indicate 'complex decision-making' develops in the pre-school period. This supports findings from Kerr and Zelazo (in press) who also found

development of this ability at approximately 4 years of age. In fact, the results from this thesis suggest a developmental progression of this ability from 3 years of age to 4.5 years of age. At three, children learn to favour the deck that leads to higher immediate rewards. The three-year-olds in Kerr and Zelazo and the three-year-olds of the second experiment displayed a tendency to choose more from the bad deck. This occurred even when loss information indicated that this deck was negative. As noted earlier, there are many possible interpretations for these findings. It may be that children this age have an immature OFC, which leads to slower and/or less flexible contingency learning. At this age, consistent, frequently occurring reinforcement information seems to have more impact than infrequent information. At 4-years of age, children may be able to inhibit choice from the bad deck, but are still not showing a strong preference for the good deck. The maturation of the hot system and/or cool system may allow children of this age to suppress their tendency to focus on the bad deck. Data from this thesis suggests that it is when children reach approximately 4.5 years of age that they show a significant preference for the good deck. Again, this is likely due to further maturation of hot and cool systems that enable children to develop somatic markers and use this information to consciously guide behavior. Interestingly, this is consistent with the time frame suggested by Lemmon (2003) on the development of future oriented thinking. Finally, data from the 4$^{th}$ experiment and other research on older children suggest that performance on the gambling task continues to improve after the preschool period.

**Hot and Cool Systems Involved in Decision-Making**

It was suggested in chapter 1 that hot and cool systems are involved in the gambling task. Results from this thesis are consistent with this view. Temperament traits associated with the hot system and more automatic emotion regulation were found to be correlated with performance on the Iowa Gambling task. Similarly, traits associated with the cool system were also found to correlate with performance.

It was further suggested that the hot system would be more strongly related with the first phase of the Iowa Gambling task and the cool system with the last phase. This prediction was only partially supported. Hot traits such as impulsivity and high activity were associated with number of good deck cards chosen on the first block for 3-year-olds. These findings fit with the idea of a hot system motivating children to gain higher rewards. However, for this age, Inhibitory Control, which is an Effortful Control scale, was correlated with card choices in the first block. As noted earlier, this may be the result of two types of inhibition abilities, one associated with the hot system and one with the cool system (Nigg, 2000). Alternatively, it may be that variability in the cool system is related to performance early on in 3-year-olds.

Interestingly, the pattern of correlations for 4-year-olds was quite different. This may in part reflect differences in the development of the cool system in 3- and 4-year-olds. As would have been predicted by the hot/cool framework, traits linked with automatic emotion regulation such as Sadness, Anger, and Falling Reactivity were correlated with the first and second blocks on the gambling task. However, while two of the Effortful Control scales correlated with the second block, none of these scales correlated with the last block. This may have been due to a lack of variability in

performance on the last block of the gambling task for this age group. In fact, asking children to decide which deck was better may have primed the cool system and reduced variability in this age group. Finally, indirect evidence of the impact of the cool system on the gambling task comes from the experiment on ADHD children. Children with ADHD combined type, which has been linked to Effortful Control, were found to differ from normal participants on the last phase of the gambling task. Their dysfunction of effortful attention would suggest these children have an underactive cool system. This again supports the idea that the cool system has more effect on the late phase of decision-making.

*Sex Differences in Performance*

The results of experiment 3 necessitate a modification of the suggestion initially proposed in experiment 1. One possible interpretation, of course, is that young females simply show a small advantage for this task. Females, for instance, showed an advantage in experiment 1 and in the late irregular condition of experiment 3. It may be that the advantage is very small and is statistically detectable only some of the time. A study with a small number of participants per cell and low power would be less likely to pick up on these small differences. For instance, when Silverman (2003) did a meta-analysis of the delay of gratification task, he found a female advantage. While a female advantage is seldom found during individual studies of this task, the increased number of participants in the meta-analysis provided increased power to find this advantage. It is possible then that a meta-analysis of multiple studies done on the gambling task in this age would show such a female advantage.

A related possibility is that the gambling task relies more strongly on the cool system when children are this age. The female advantage of the cool system would then help females perform better. This does not contradict Overman's (2004) findings of male advantage in older children. Metcalfe and Mischel (1999), for instance, suggest that given the cool system is still developing in preschool children, variability in performance on the delay of gratification would be more strongly associated with this system. They also suggested that the dominance of the cool system becomes stronger as one matures. Following this logic, it may be then that the hot system accounts for more variability in peformance on the gambling task in older children.

One problem with this explanation is that males actually performed better than females in the irregular early condition of experiment 3. Another possible interpretation for the results of experiment 3 is that females and males have different thresholds for using the two different systems. Females may tend to switch to the cool, conscious system more easily than males. For instance, they may use various cues, both internal and external to form an internal model of the decks. Research suggests that females have a higher emotional awareness than males (Lane et al., 1996). Females may use this skill to consciously access somatic markers. Information on feeling states, behavior (e.g., they notice they are choosing more from the good deck), and verbal reports to the experimenter may help females construct an internal model and use this model to guide behavior.

While males may also use the cool, conscious system when cues are strongly suggestive of what decks are better, they may still show a greater tendency to use the hot (implicit) system. Further, they may have a lower threshold to switching or using this

system, especially when reinforcers appear to be changing. As noted previously, research indicates that males are more sensitive to changes in reinforcers than females (Kollins et al., 1997). Females may respond less flexibly to environmental changes than males, particularly when they have established an internal model.

The sex differences may also be a general result of temperament differences, which are closely linked to hot and cool systems. Results of experiment 2 indicate that temperament characteristics are associated with differences in performance on the gambling test. Further, the results of experiment 2 and other research in this area also indicate that males and females differ on several temperament characteristics. In experiment 2, females were found to score significantly higher on traits that are related to the Effortful Control system. This system has been related to the cool system and again suggests a females advantage for use of the second, conscious system.

Certainly, there is longstanding evidence in the literature of sex differences in emotional development such as shame, empathy, and sympathy (Lewis, Alessandri, & Sullivan, 1992; Zahn-Waxler, Robinson, & Emde, 1992; Robinson, Zahn-Waxler, & Emde, 1994; Eisenberg et al., 1988). While there is evidence that the OFC (hot system) and the ability to reverse associations develops earlier in males, there is evidence of a female advantage in abilities thought to be mediated by the cool system (Diamond, 1985; Kochanska et al., 1997; Kochanska et al., 2000; Zelazo et al., 2003). This research suggests that there are developmental sex differences in this network.

While both the interpretations suggested fit with the findings, it is impossible to make any firm conclusions about the results. Certainly, the issue of sex differences on this task is a complex one and needs to be investigated further.

**Parallels with Adult Studies**

The findings from the experiments in this thesis parallel the findings from adult populations. The findings from children and adults, in fact, converge to provide a more complete picture of what processes are involved in decision-making over time, and the gambling task in particular.

The research on the gambling task began with a population of adults who were experiencing social difficulties despite performing normally on many traditional neuropsychological tests. Bechara et al.(1994) noted that despite having normal scores on these tests, VM patients function very poorly in life. Bechara et al. created the Iowa Gambling task to more closely mimic real life social situations and found that as predicted these individuals performed poorly on the gambling task. Results of experiment 4 indicate that at least one child population with known social difficulties also demonstrates difficulty with a version of the gambling task. However, there is reason to believe that poor social ability is not strongly related to performance on the gambling task. Correlations between scores on the CBCL relevant to social functioning resulted in very few significant correlations when anxiety was partialled out. Only correlations with scores on Total Problem were significant. These findings suggest that while individuals with social difficulties may not perform well on the gambling task, this is not the crucial factor. Rather, it is likely to be a third variable or variables that are linked to both social ability and performance on the gambling task. One such variable is probably dysfunction in the frontal-striatal system.

Another finding from this thesis that is similar to findings from adult studies is the relation of temperament traits to performance on the gambling task. Traits such as

impulsivity and shyness were related to choices on the good deck. This parallels the findings in normal adults were high BAS and high BIS have been linked performance on the Iowa Gambling task. One new finding not found in the adult literature is the relation of Effortful Control scales to performance. However, results in the adult literature are consistent with more automatic processes in the first phase of decision making and more conscious processes in the latter phase (Peters & Slovic, 2000). Given that Effortful Control has been linked with voluntary, conscious processing, this suggests that performance on the Iowa Gambling task involves similar processes for both children and adults.

Finally, another interesting finding from this thesis is the trend for a correlation between the future oriented prudence task (delay of gratification) and performance on the last block of the gambling task. Results from an adult experiment found a correlation between performance on the gambling task and a temporal discounting task, which is similar to delay of gratification tasks (Monterosso et al., 2001). As noted earlier, this task has been linked to "cool strategies" and more conscious aspects of decision-making. Supporting this idea, the attention focus subscale was found to correlate significantly with the prudence subscale. The attention focus subscale approached significance with the inhibitory control scale for 3-year-olds. Interestingly, attention focus was not found to significantly correlate with performance on the gambling task. This may suggest two slightly different mechanisms involved in conscious decision-making. For instance, attention shifting may be more related to conflict monitoring and resolution while attention focus may be more strongly related to the use of cool strategies to reach a goal.

## Future Directions

The Iowa Gambling task provides a wonderful opportunity to assess both automatic and effortful processes involved in decision-making and their interaction. Originally designed to more specifically assess the important aspects of real life decision-making, it involves many of the important aspects of social interaction. Social interaction is often "messy" with conflicts in rewards and losses involved. In trying to isolate variables, laboratory tasks sometimes lose the richness of the social process that involves co-ordinating various skills. Because of its reliance on several processes, the Iowa Gambling task provides a challenge nonetheless in its interpretation. The following are some possible interesting directions for future developmental research using this task.

*Effect of Administration Differences*

There is some indication in the literature that differences in instructions can affect performance on decision-making tasks. Berry and Broadbent (1988) reported that different instructions could lead to different modes of learning. As noted above, it is likely that the Iowa Gambling task involves both hot (implicit) and cool (explicit) processes. Varying the instructions, then, can encourage different modes of processing. Schmitt et al. (1999) did not provide explicit instructions that some decks were better than others before administration of the Iowa Gambling task. They found no difference in performance on the Iowa Gambling task between controls and psychopaths. Interestingly, the results may have been due to controls who performed poorly. A later study by Mitchell et al. (2002) used the standard instructions and did find a significant difference between controls and psychopathic individuals. The failure to use explicit instructions in the Schmitt et al. study may have encouraged a more implicit form of

learning while the use of explicit instructions may have encouraged both implicit and explicit processes. While explicit instructions seemed to help the control participants, it had no effect on the psychopaths, suggesting that they may have difficulty co-ordinating automatic and effortful systems. This is consistent with findings from Newman and his colleagues on psychopathy (Newman & Lorenz, 2003).

The possible effect of instructions on automatic and effortful systems suggests some interesting manipulations to explore the development of decision-making. Using explicit instructions may encourage children to use both implicit and explicit systems while performing the Iowa Gambling task. Providing minimal instructions, on the other hand, may encourage the use of implicit systems. A comparison of performance differing on the amount of explicit instruction at different ages might provide a glimpse of the development of both processes. Another interesting issue is how children are able to co-ordinate both implicit and explicit processes to maximise rewards. Data from experiments 2 and 3 suggests that children begin co-ordinating implicit and explicit processes at around 4 years of age. In experiment 2, children were given only minimal instructions at the beginning of the game. However, after 40 choices, children were asked which deck was better and which was worse. It can be argued that these instructions are similar to the explicit instructions given in the standard version of the Iowa Gambling task. These questions were followed by a large increase in choices from the good deck by 4-year-olds, but not by 3-year-olds. Further, even 3-year-olds who correctly reported which deck was better did not increase their choices from the good deck. This suggests difficulty in the use of conscious knowledge to guide behavior and is

reminiscent of errors reported on other tasks such as the card sort task (Zelazo et al., 2003).

*Variables Associated with Reward/Loss Contingencies*

There are various interesting possibilities in manipulating reward/loss contingencies. While this thesis explored two such manipulations, there are other possibilities. An obvious manipulation would be to reverse rewards and losses. The preference of the bad deck by 3-year-olds could be due to reliance on immediate rather than delayed reinforcers. Alternatively, it could be due to a greater sensitivity to rewards over punishment. The development literature indicates that both may be operating. For instance, research on the delay of gratification paradigm indicates that young children tend to focus on the present and show a strong preference for immediate rather than delayed reinforcers (Mischel & Grusec, 1967; Mischel & Metzner, 1962; Thompson et al.,1997; Moore et al., 1998; Lemmon, 2003; Sonuga-Barke et al., 1989). Furthermore, research indicates that while children tend to react to rewards in the same way as adults, they react differently to loss (Hare, Krebs, Creighton, & Petrusic, 1966; Mischel & Grusec, 1967). The research indicates that children are not as sensitive to delay magnitudes for loss. Reversing wins and losses would be an interesting area to pursue. There are as of yet no published studies on the reversal of wins and losses for children.

Another interesting manipulation that may have an impact on performance is frequency of loss. This manipulation could, for example, involve comparing performance on a version that contains 5 losses/ 10 cards with a version containing 2 losses/ 10 cards. While this was not manipulated directly in this thesis, comparing across experiments suggests that it may affect sensitivity to find developmental differences. As

discussed in experiment 1, the decks of the original gambling task differ not only on whether they are bad or good, but also on the frequency of loss. Two of the decks, one bad and one good, have 5 losses occurring within 10 card choices. The remaining two decks have one loss per 10 cards. Given that young children are more influenced by immediate reinforcers, the frequency of loss may impact sensitivity to find developmental differences. More frequent losses would provide more frequent "reminders" and should be easier for younger children. The results of experiment 1 suggest that this variable may have some impact on finding developmental differences. When frequent and infrequent loss decks were analysed separately, evidence of an age improvement was found for the infrequent loss decks, but not the frequent loss decks. The infrequent loss decks may have made it more difficult for younger children to calculate rewards and losses over time, and therefore, it may have been more sensitive to developmental differences.

There is also suggestion in the literature that frequency of loss may have a different impact on males and females. Overman (in press) conducted an experiment on the standard version of the Iowa Gambling task administered to a large number of adolescents and adults ranging in age from 12-65 years of age. He found a sex difference favouring males for most age ranges studied. Using this idea of frequency of loss, he looked at differences in choice of frequent versus infrequent loss decks. He found that females appeared more sensitive to the absolute frequency of loss rather than overall magnitude of loss. As the game progressed, females seemed to avoid the decks that led to frequent loss, being less sensitive to overall magnitude of loss. Males on the other hand, showed a different pattern. They seemed to avoid decks with a larger overall magnitude of loss, regardless of frequency. Overman (in press) hypothesised that the sex

differences in OFC functioning continued into adulthood and may account for different patterns of choice. This suggests that males may be more able to consider magnitude of rewards and losses over time.

Unfortunately, this is not the only interpretation of the data. The decks differed not only in the frequency of loss, but in the occurrence of 1st loss. Overman (in press) noted that the frequent loss decks also differed from the infrequent loss decks by occurrence of first loss. The frequent loss decks had a loss occurring on the 3rd card while the first loss did not occur until the 9th and 10th card for the infrequent loss decks. Given the relation of reversal with the OFC, the performance of the females may also have been due to the inability to reverse associations as efficiently as males.

A third possible manipulation would be to manipulate the frequency/magnitude of losses over the course of one deck version. An example of such a manipulation would be having a version of the gambling task where losses gradually increase over each block. The first block could have 2 losses/ 10 cards, the second block could have 4 losses/ 10 cards and the third block could have 6 losses/ 10 cards. This version of the game could be compared to another version that does not have changing frequency of losses (e.g., 4 losses/ 10 cards through the whole game). This type of manipulation would explore how children respond to changes in reinforcement over the course of the game. This type of manipulation may more heavily assess the responsive, hot system. Findings from experiment 3 indicated that males were more sensitive to changes in relative reinforcement values. In experiment 3, males' choices were significantly correlated to reinforcement that immediately proceeded the trial, but only in the Irregular Late condition. This may have occurred due to changes in relative frequency of losses in this

condition. It is possible that this condition may have primed the hot system in males. Males in this condition appeared to be adjusting their choices to the change in reinforcement. This again may be due to sex differences in OFC development. Elliott, Friston and Dolan (2000) found that OFC cells appeared to be valence blind, reacting to both rewards and loss. In particular, OFC cells reacted to the context of wins and losses. Cells in this region respond with greater activation during high reward in a wining streak and high loss in a losing streak (Elliot, Friston et al, 2000). This indicates that the OFC network is sensitive not only to the magnitude of reinforcers, but also how they might compare to other reinforcers. Further, there is evidence in the literature that male children are more responsive to changes in reinforcer than female children are (Kollins et al., 1997).

*The Impact of Hot and Cool Executive Functions on Performance*

As noted previously, several authors have suggested that a useful framework might be to divide executive function into hot and cool processes (Metcalfe & Mischel, 1999; Miller & Cohen, 2001; Zelazo et al., 2003). Further, it was suggested that both hot and cool systems should influence performance on the Gambling task, but that their influence would be more important at different stages of the task. The hot systems would more strongly affect earlier stages and the cool systems would more strongly affect later stages. One technique that may prove useful for investigating the participation of different brain areas at different stages of the gambling task are brain imaging techniques with high temporal resolution such as event-related potentials (ERPs). Segalowitz & Davies (in press) noted that all executive function can be seen as involving different brain

areas at different phases of the task. They argued that the contribution of different areas over time could potentially be assessed with ERPs.

It has also been suggested throughout this thesis that males and females may rely differently on the hot and cool systems. Further, the development of OFC has been linked to the hot system while the development of the cognitive ACC and DL-PFC has been tied to the cool system (Rothbart & Posner, 2001; Zelazo & Műller, 2002). Given that the OFC has been found to have an accelerated functional maturation in males (Overman & Bachevalier, 2001), it is quite possible that males and females differ in their dependence on these two systems. Moreover, there is evidence that the ACC/DL-PFC and OFC networks are reciprocally connected (Drevets & Raichle, 1998; Duncan & Owen, 2000; Mayberg et al., 1999). Zelazo et al. (2003) suggested that the reciprocal connection of the OFC and DL-PFC may lead to sex differences in growth of the two brain areas. Further, Tucker et al. (1995) suggested that these two networks balance one another. There is evidence that females show some superiority in cooler executive functions such as card sort (Carlson & Moses, 2001; Zelazo et al. 2003). Moreover, Kochanska and colleagues have accumulated evidence that females show superiority for inhibition tasks that have been associated with the effortful control system (Kochanska et al., 1997). In fact, female superiority for effortful control during early childhood appears to be a consistent finding. Finally, there have been findings indicating sex differences in the adult literature for the OFC, amygdala, ACC, and DL-PFC (Wager, Phan, Liberzon and Taylor, in press; Gur et al., 1995; Good et al., 2001; Pujol et al., 2002; Parsey et al., 2002; Yucel et al., 2001; Schlaepfer et al. 1995; Goldstein et al., 2001).

As discussed earlier, sex differences in developmental rate in these two systems may lead to stronger dependence on one system over the other. It is likely that even during the pre-school period, both systems would be used by males and females. However, given that both systems are thought to undergo major changes during the pre-school period, this period may represent an optimal time to find sex differences on the gambling task. While some versions of the gambling task would not lead to sex differences, some versions would be expected to lead to sex differences. These versions would most likely prime one system more heavily than the other. Given that both systems would be important for successful performance, priming different systems would theoretically have a different impact on males and females. For instance, using few instructions may potentially lead to an advantage for females who are hypothesized to use the conscious system more spontaneously. In this situation, males may end up using only the OFC system while females would use both. Given that the cool system is slower to develop during the preschool period, it is also important to keep age in mind when manipulating these systems. Priming the cool system, for instance, may be helpful for all 4-year-old children, regardless of sex. If the hot system is more dominant for young children as suggested by Metcalfe and Mischel (1999), then encouraging cool proceessing should improve the performance of both males and females. However, it may improve the performance of males more than females. Obviously this issue is complex and further research is needed to investigate these ideas.

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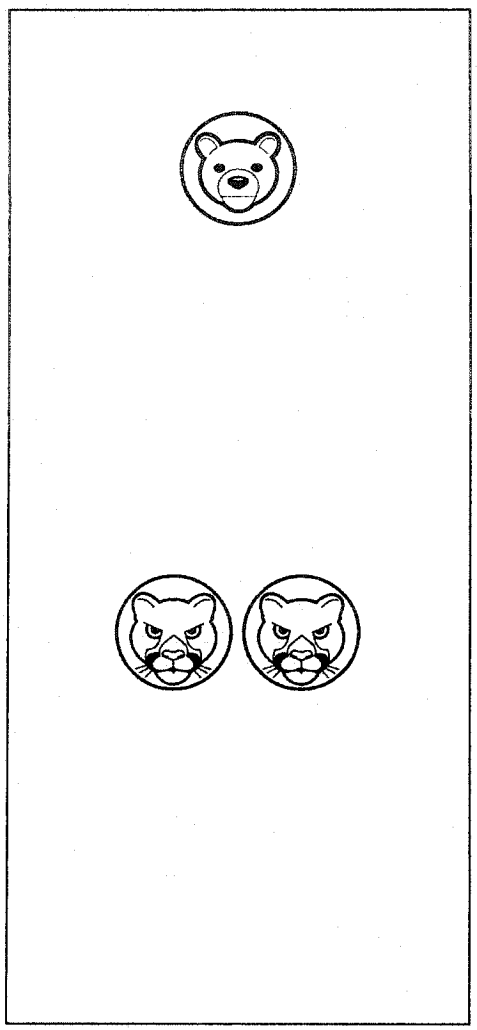
# Appendix A
## Example of Card from the Good Deck



# Appendix B
## Reinforcement Contingencies for Experiment 1 & 4

| | Disadvantageous Decks | | Advantageous Decks | |
|---|---|---|---|---|
| | Deck A | Deck B | Deck C | Deck D |
| Card | + 2 every card | | + 1 every card | |
| 1 | | | | |
| 2 | -7 | | -1 | |
| 3 | | | | |
| 4 | -6 | | -1 | |
| 5 | | -13 | | -2 |
| 6 | | | | |
| 7 | -7 | | -1 | |
| 8 | -6 | -13 | -1 | -2 |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | -7 | | -1 | |
| 13 | | -13 | | -2 |
| 14 | -6 | | -1 | |
| 15 | | | | |
| 16 | | | | |
| 17 | -6 | | -1 | |
| 18 | -7 | | -1 | |
| 19 | | | | |
| 20 | | -13 | | -2 |
| 21 | -7 | | -1 | |
| 22 | | -13 | | -2 |
| 23 | -6 | | -1 | |
| 24 | | | | |
| 25 | | | | |
| 26 | | | | |
| 27 | | | | |
| 28 | | -13 | | -2 |
| 29 | -7 | | -1 | |
| 30 | -6 | | -1 | |
| 31 | | -13 | | -2 |
| 32 | -6 | | -1 | |
| 33 | | | | |
| 34 | -7 | | -1 | |
| 35 | | | | |
| 36 | | -13 | | -2 |

# Appendix C
# Reinforcement Contingencies for Experiment 2

| | Disdavantageous Deck | Advantageous Deck |
|---|---|---|
| | 2 every card | 1 every card |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | -13 | -2 |
| 6 | | |
| 7 | | -2 |
| 8 | -13 | |
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | | |
| 13 | -13 | |
| 14 | | -2 |
| 15 | | |
| 16 | | |
| 17 | | |
| 18 | | |
| 19 | | |
| 20 | -13 | -2 |
| 21 | | |
| 22 | -13 | |
| 23 | | -2 |
| 24 | | |
| 25 | | |
| 26 | | |
| 27 | | |
| 28 | -13 | -2 |
| 29 | | |
| 30 | | |
| 31 | -13 | |
| 32 | | -2 |
| 33 | | |
| 34 | | |
| 35 | | |
| 36 | -13 | -2 |
| 37 | | |
| 38 | | |
| 39 | | |
| 40 | | |

| | | |
|---|---|---|
| 41 | | -2 |
| 42 | | |
| 43 | | |
| 44 | -13 | |
| 45 | | |
| 46 | | -2 |
| 47 | | |
| 48 | | |
| 49 | -13 | |
| 50 | | |
| 51 | -13 | |
| 52 | | |
| 53 | | |
| 54 | | -2 |
| 55 | | |
| 56 | | -2 |
| 57 | | |
| 58 | -13 | |
| 59 | | |
| 60 | | |

# Appendix D
# Reinforcement Contingencies for Experiment 3

**Early loss/Regular Pattern Decks:**

| | Disdavantageous Deck | Advantageous Deck |
|---|---|---|
| | +2 every card | +1 every card |
| 1 | | |
| 2 | -9 | -2 |
| 3 | | |
| 4 | | |
| 5 | -9 | -1 |
| 6 | | |
| 7 | | |
| 8 | -8 | -1 |
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | -9 | -2 |
| 13 | | |
| 14 | | |
| 15 | -9 | -1 |
| 16 | | |
| 17 | | |
| 18 | -8 | -1 |
| 19 | | |
| 20 | | |
| 21 | | |
| 22 | -9 | -2 |
| 23 | | |
| 24 | | |
| 25 | -9 | -1 |
| 26 | | |
| 27 | | |
| 28 | -8 | -1 |
| 29 | | |
| 30 | | |
| 31 | | |
| 32 | -9 | -2 |
| 33 | | |
| 34 | | |
| 35 | -9 | -1 |
| 36 | | |
| 37 | | |
| 38 | -8 | -1 |
| 39 | | |
| 40 | | |

| | | |
|---|---|---|
| 41 | | |
| 42 | -9 | -2 |
| 43 | | |
| 44 | | |
| 45 | -9 | -1 |
| 46 | | |
| 47 | | |
| 48 | -8 | -1 |
| 49 | | |
| 50 | | |
| 51 | | |
| 52 | -9 | -2 |
| 53 | | |
| 54 | | |
| 55 | -9 | -1 |
| 56 | | |
| 57 | | |
| 58 | -8 | -1 |
| 59 | | |
| 60 | | |

**Early loss/Irregular Pattern Decks:**

| | Disdavantageous Deck | Advantageous Deck |
|---|---|---|
| | +2 every card | +1 every card |
| 1 | | |
| 2 | -9 | -2 |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | -9 | -1 |
| 8 | | |
| 9 | | |
| 10 | -8 | -1 |
| 11 | | |
| 12 | | |
| 13 | -9 | |
| 14 | -9 | -2 |
| 15 | | |
| 16 | | -1 |
| 17 | -8 | -1 |
| 18 | | |
| 19 | | |
| 20 | | |
| 21 | | -1 |
| 22 | -8 | |
| 23 | | |
| 24 | -9 | |
| 25 | | |
| 26 | | -1 |
| 27 | | |
| 28 | -9 | -2 |
| 29 | | |
| 30 | | |
| 31 | -9 | |
| 32 | -8 | -2 |
| 33 | | |
| 34 | | |
| 35 | | |
| 36 | | -1 |
| 37 | | -1 |
| 38 | | |
| 39 | | |
| 40 | -9 | |

| | | |
|---|---|---|
| 41 | | -2 |
| 42 | | |
| 43 | | |
| 44 | -9 | -1 |
| 45 | | |
| 46 | | -1 |
| 47 | -8 | |
| 48 | | |
| 49 | -9 | |
| 50 | | |
| 51 | -8 | |
| 52 | -9 | -2 |
| 53 | | |
| 54 | | |
| 55 | | -1 |
| 56 | | -1 |
| 57 | | |
| 58 | -9 | |
| 59 | | |
| 60 | | |

**Late loss/Irregular Pattern Decks:**

| | Disdavantageous Deck | Advantageous Deck |
|---|---|---|
| | 2 every card | 1 every card |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | -9 | -2 |
| 9 | -9 | -1 |
| 10 | -8 | -1 |
| 11 | | |
| 12 | | |
| 13 | -9 | |
| 14 | -9 | -2 |
| 15 | | |
| 16 | | -1 |
| 17 | -8 | -1 |
| 18 | | |
| 19 | | |
| 20 | | |
| 21 | | -1 |
| 22 | -8 | |
| 23 | | |
| 24 | -9 | |
| 25 | | |
| 26 | | -1 |
| 27 | | |
| 28 | -9 | -2 |
| 29 | | |
| 30 | | |
| 31 | -9 | |
| 32 | -8 | -2 |
| 33 | | |
| 34 | | |
| 35 | | |
| 36 | | -1 |
| 37 | | -1 |
| 38 | | |
| 39 | | |
| 40 | -9 | |

| | | |
|---|---|---|
| 41 | | -2 |
| 42 | | |
| 43 | | |
| 44 | -9 | -1 |
| 45 | | |
| 46 | | -1 |
| 47 | -8 | |
| 48 | | |
| 49 | -9 | |
| 50 | | |
| 51 | -8 | |
| 52 | -9 | -2 |
| 53 | | |
| 54 | | |
| 55 | | -1 |
| 56 | | -1 |
| 57 | | |
| 58 | -9 | |
| 59 | | |
| 60 | | |