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Complex decision-making in early childhood☆

Nancy Garon and Chris Moore*

Dalhousie University

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Abstract

Decision-making over time is an important aspect of adaptive social functioning. The main goal of this study was to investigate the development of this ability in young children. A simplified version of the Iowa Gambling Task was given to 69 children at 3 ages (3, 4, and 6 years). Children were also given an awareness test to assess their knowledge of the task. Significant age differences were found for awareness of the task while significant sex effects were found for performance on the task. Females chose significantly more from the advantageous decks than would be expected by chance in the second block. Males demonstrated no significant difference in choice of decks. Further analysis indicated female superiority in the task was not due to greater knowledge of the game. One interpretation of these results is that there are two systems affecting decision-making over time.

1. Complex decision-making in early childhood

Decision-making over time is an important aspect of adaptive social functioning. When operating in a complex social world, individuals must be able to consider events in the past, monitor the present environment, and make predictions about future possibilities. This important ability is included among the list of "executive functions" (Samango-Sprouse, 1999). Executive functions include abilities such as planning across time and monitoring ongoing behaviour that are thought to underlie goal-directed behaviours. Research has closely associated these abilities with systems involving the prefrontal cortex (Lezak, 1995).

In the last decade, due in part to the research of Damasio and his colleagues, decision-making across time has received considerable attention. Damasio (1994) reported on a series of experiments conducted on individuals with lesions in the ventromedial (VM) area of the prefrontal cortex (PFC). While these individuals experienced severe social problems, they demonstrated normal scores on a variety of psychological tests, including intelligence tests. One task, created by Bechara, Damasio, Damasio, and Anderson (1994) to mimic real life situations, provided evidence that these individuals were unable to use past experience to make decisions about the future. In this task, which has been referred to as the Iowa Gambling Task, individuals had to choose among four card decks. Every card led to a win while some of the cards led to a loss. Two of these decks led to more wins over the course of the game while the other two decks led to a net loss. The two disadvantageous decks contained large wins and large losses. The advantageous decks contained small wins and small losses. While normal individuals eventually chose more from the advantageous decks, individuals with brain damage chose more from the disadvantageous decks. Damasio (1994) hypothesized that the VM patients were influenced by large, immediate rewards rather than long term rewards.

To account for the deficits in decision making by these individuals, Damasio (1994) proposed the somatic marker hypothesis, which argued that the VM area network was involved in associating somatic (bodily) states with various situations. When a situation has been associated with a particular somatic state, then encountering this situation will lead to a reactivation of

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* Corresponding author. Present address: Department of Human Development and Applied Psychology, OISE/UT, Toronto, Ont. Canada M5S 1V6.
E-mail address: cmoore@oise.utoronto.ca (C. Moore).

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this somatic state via this network. Damasio (1994) hypothesized that these somatic states will bias decision-making. According to this theory, normal individuals performing the Iowa Gambling Task should develop affective associations to the decks that would bias their decisions. Various studies have supported this theory, indicating that control subjects develop anticipatory skin conductance responses (SCRs) before choosing from decks while individuals with lesions in the ventromedial area do not develop these SCRs (Bechara, Damasio, & Damasio, 2000; Bechara, Damasio, Tranel, & Damasio, 1997).

Given that children's brains are still maturing, one would expect their decision-making skills to be still developing as well. Particularly, the prefrontal cortex, which is hypothesized to play a critical role in decision-making, matures slowly in comparison to other brain areas (Benes, 2001). There is evidence that an intact orbitofrontal cortex (OFC), which forms part of the ventromedial area of the PFC, is necessary for normal social development. For example, Anderson, Bechara, Damasio, Tranel, and Damasio (1999) compared individuals with early and late OFC lesions on social and moral functioning measures. They found that individuals whose orbitofrontal lesions occurred before the age of 16 months suffered more severe impairment than individuals whose lesions occurred in adulthood. Other authors have reached similar conclusions about the PFC (e.g., Anderson et al., 1999; Price, Daffner, Stowe, & Mesulam, 1990; Williams & Mateer, 1992).

We hypothesized that performing well on the Iowa Gambling Task requires the development of at least three inter-related skills. First, it requires the ability to imagine future scenarios and be motivated by the affective properties of that image. The term "affective" is defined in the same way as Damasio (1994, 2000) to refer to somatic or bodily states. This imagery must be strong enough to influence behaviour. Second, it requires the ability to inhibit and reverse previous learning of a reward/stimuli contingency. This ability would allow children to flexibly adjust behaviour in response to feedback from the environment. Third, the decision-making task presumably requires the ability for sophisticated calculations of reward and punishment values over repeated instances. The decision-making task contains conflicting feedback for each deck. While the bad decks consistently provide higher rewards, they also provide inconsistent higher punishment. This yields a lower net outcome when calculated over a period of time. Research indicates that the first two abilities emerge during the preschool period. Research on the third, more complex ability is just beginning.

There is some research indicating that beginning in the preschool period children are able to make decisions that are advantageous in the future. Mischel, Shoda, and Rodriguez (1989) reviewed research from their lab on the ability to delay rewards during the pre-school period. During this task, 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. Their research indicates that the ability to wait for a larger future reward begins to emerge during the pre-school period. Further, they found that this ability in 4-year-olds was linked to success and social ability in adolescence (Mischel, Shoda, & Peake, 1988; Shoda, Mischel, & Peake, 1990).

Thompson, Barresi, and Moore (1997) called this ability to delay gratification for a larger future reward "future oriented prudence." They tested children 3- to 5-years-old on a similar task, using stickers as a reward. In this task, children were asked three times to choose whether they wanted one sticker now or wait until the end of the game to receive two stickers. While Mischel and his colleagues used the length of delay as their outcome measure, children in this task were scored on the number of times they chose to delay. Thompson et al. also added a task hypothesized 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 the older children did. Further, they also found that future oriented prudence and altruism were significantly correlated. This indicated that being able to consider future scenarios for self and other were closely linked.

In order to explore the underlying abilities of future oriented prudence, Moore, Barresi, and Thompson (1998) tested 3- and 4-year-olds on an inhibition task and two theory of mind tasks. The inhibition task assessed the child's ability to inhibit pointing to a box with a reward in order to obtain the reward. The theory of mind tasks assessed the child's understanding of false beliefs (own and others). They found that for 4-year-olds, future oriented altruism was correlated with the theory of mind task. Further, they found that for 3-year-olds, the ability to inhibit pointing in order to gain a reward was significantly correlated with future oriented prudence. They interpreted the findings as indicating that future oriented prudence and altruism are linked to the ability to inhibit a salient response and being able to imagine conflicting mental states.

Lemmon and Moore (2001) also found a significant improvement from 3- to 4-years-old in making decisions that are profitable over time. Lemmon and Moore explored the relation between future oriented prudence, delayed self-recognition, and episodic memory. Consistent with previous research, they found age-related differences in the three abilities. Further they found evidence that the ability to consider future states is linked to the ability to consider the self in the past. This again provides evidence that the ability to imagine the self or other in non-current situations, whether in the past or future, changes from 3- to 4-years-old. Lemmon and Moore hypothesized that younger children were unable to imagine future states in the same way as present states.

Research also indicates that the ability to "reverse" associations between stimuli and reinforcers develops considerably during the preschool period. Overman, Bachevalier, Schuhmann, and Ryan (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. They also found significant differences between children and adults. These results support the idea that OFC undergoes changes during the pre-school period and continues to develop beyond this age. It indicates that the second ability needed for the decision-making test is not fully functional yet in the preschool period.

Overman and his colleagues also found that performance on an object reversal task develops earlier in boys than girls (Overman, Bachevalier, Schuhmann, & McDonough-Ryan, 1997; Overman et al., 1996). Despite the fact that these sex differences disappeared at around 3 years of age, Overman and Bachevalier (2001) hypothesized that differences in OFC persist into adulthood. They note that the ceiling effect may have prevented sex differences from emerging. Reavis and Overman (2001) also link the ability to reverse associations to the gambling task, noting that they have similar cognitive demands. They found evidence for sex differences on a modified version of the gambling task, favouring males. Furthermore, Overman (this issue) reports on evidence of sex differences on the Iowa Gambling Task in later childhood and adolescence. Finally, Kerr and Zelazo (this issue) offer evidence of a sex difference for 3-year-olds on a variation of the Iowa Gambling Task.

While we know that pre-school children are able to make simple decisions that will be advantageous in the future, research on more complex aspects of decision making is just beginning. For instance, are children able to make advantageous future decisions when the relation between reward and losses over time is not simple? This is one of the abilities hypothesized to be assessed by the Iowa Gambling Task. The gradual development of the orbitofrontal cortex and other relevant brain areas would predict a gradual improvement in decision-making ability, depending on the difficulty of the task. In support of this idea, recent work by Blair, Colledge, and Mitchell (2001) and Overman (this issue) indicates that performance on the Iowa Gambling Task improves with age during later childhood and adolescence. Further, Kerr and Zelazo (this issue) have found a significant age improvement in performance between 3 and 4 years of age on a variation of the Iowa Gambling Task.

The research discussed above indicates that not only do children develop important abilities to make decisions over time, but that these abilities are linked to social adjustment. Given the hypothesized importance of decision making to social development, the primary goal of this study was to explore a modified version of the Iowa Gambling Task on young children. This study 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 on executive function on these age groups (e.g. Diamond, 2001; Moore et al., 1998; Welsh, Pennington, & Groisser, 1991; Zelazo, Carter, Reznick, & Frye, 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 A).

An awareness test was added at the end of the game to explore children's awareness of what was occurring in the game. 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,

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Bechara, & Damasio, 2000). Interestingly, 50% of brain damaged individuals reached this period (Bechara et al., 1997). Despite this, they still continued to pick more from the disadvantageous decks than advantageous decks. Some of these patients, then, seemed to show dissociation between conscious knowledge and behaviour.

Given that this study 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.

2. Methods

2.1. Participants

Participants were 20 three-year-olds (14 males and 6 females), ranging in age from 39 to 47 months (mean age = 43.65), 24 four-year-olds (16 males and 8 females), ranging in age from 48 to 59 months (mean age = 53.79), and 25 six-year-olds (8 males and 17 females), ranging in age from 72 to 83 months (mean age = 77.60). 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.

2.2. 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). The Appendix 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.

2.3. 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, & Damasio, 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 the 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.

3. Results

3.1. 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 (Kerr & Zelazo, this issue; Overman, this issue; Overman et al., 1997). For the present study, 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) $\times$ 2 (Sex) $\times$ 2 (Block). This was analyzed using the GLM procedure of the SPSS statistical package to correct for unequal cell size.

Results of this analysis indicated no significant main effects or interaction of Age Group $\times$ Block as originally predicted. There was, however, a significant Sex $\times$ Block interaction, $F(1,63) = 8.57$, $p < .01$. No other effects were found to be significant. Follow-up to the Sex $\times$ 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, $t(38) = -1.33$, $p > .05$. Table 1 shows the marginal means for each age group corrected for sex.

3.2. Age and sex differences within different deck types

The four decks differed not only on whether they are 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 A). These two types of decks also differed on when the first loss occurred and the regularity of pattern for the loss. Given the unexpected Sex $\times$ Block 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

Table 1
Marginal means of the number of choices from the advantageous decks as a function of sex and age group

Age group	Block 1	Block 2
3-year-olds		
Males	9.79	9.36
Females	9.33	10.17
Total	9.56	9.76
4-year-olds		
Males	10.56	9.50
Females	9.75	11.13
Total	10.16	10.31
6-year-olds		
Males	9.88	10.38
Females	10.29	11.41
Total	10.09	10.89

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 × 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 × Sex × 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 × Block interaction approached significance, $F(1,22) = 3.67$, $p = .07$, with females outperforming males. 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.

3.3. 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
Females	1.17
Total	1.19
4-years-olds	
Males	2.06
Females	1.88
Total	1.97
6-years-olds	
Males	3.00
Females	3.06
Total	3.03

3.4. 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 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 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 deck.

3.5. 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, $z = 1.66$, $p < .1$.

4. Discussion

The primary goal of this study 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 our hypothesis. Further, an unexpected sex interaction was found in the direction opposite to what would be predicted from the literature. We will briefly discuss the developmental effects 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 gambling task overall, however, there was no significant Age by Block interaction as had originally been predicted. It is possible that our 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. (2001) reports 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 if we had added a third block, we may have shown a larger difference between the age groups.

To explore the choices from different decks in more detail, we conducted separate analysis on decks that had frequent losses and decks that had more infrequent losses. Although these analyses should be interpreted with great caution, they suggest an Age interaction effect for the infrequent decks. Follow up indicated only the 6-year-olds showed a significant Block effect, where children were choosing more from the advantageous deck in the second block. While our evidence is weak, it is in accord with other studies that have found age improvements on this task (Blair et al., 2001; Kerr & Zelazo, this issue; Overman, this issue). 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 behaviour.

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) indicates that 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) interpret 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) suggest 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.

The most intriguing finding in our study was the sex interaction effect. While a difference in sex 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.

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 (this issue). Despite having a larger number of losses per trial, they found evidence of male superiority for the 3-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.

4.1. Differences between present task and original gambling task

Despite our efforts to closely model the Iowa Gambling Task in our study, 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. Our instructions did not contain information about some decks being advantageous. Berry and Broadbent (1988) report that explicit instructions may lead to different modes of learning. Further, Schmitt, Brinkley, and 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, Colledge, Leonard, and Blair (2002) supports 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 our study may have encouraged a different mode of learning. 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 study were more anxious than the males.

A second difference between our task and the Iowa Gambling Task is the availability of feedback on overall performance in the game. While we 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 (this issue) 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 our study 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 our study.

The most significant difference, however, may have been the pattern of reward and loss contingencies. While the original gambling task had specific number of losses occurring over ten cards in a specific deck, ours occurred over 5 cards. Having losses occur over 5 cards rather than 10 may have led to a more regular pattern. In particular, our 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 A). 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 infrequent and frequent loss 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 study. 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 our losses 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 our version of the task. Our 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, our task cannot be considered to 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 our findings were solely due to the lack of "object reversal" component in our task, then one would expect no sex differences. The fact that females were outperforming males suggests that there may be another mechanism operating, whether covert or overt. If our task does index the integration of reward and loss contingencies over time, then our data indicate a female superiority in this ability, particularly when the pattern loss is more regular. One possible explanation for our findings is that there are two separate "systems" that influence decision-making over time. In the remainder of this section, we shall speculate on this possibility.

As discussed in the introduction, it is likely that the Iowa Gambling Task assesses a variety of skills. We discussed three of these skills. While our task does not appear to assess the ability to reverse associations, it can be argued that it assesses the other two skills. For instance, children must not only be able to make their choice based on imagined future scenarios, but they must also be able to integrate a variety of instances of conflicting rewards and losses in order to be able to decipher which choice is actually the best over time.

Tucker, Luu, and Pribram (1995) describe two major ways in which the frontal cortex is connected to the emotional limbic areas of the brain. The first pathway consists of the (orbital) ventral pathway linking the orbital PFC with the olfactory cortex of the limbic areas. The second, a dorsomedial pathway, 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. These two systems 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. In this system, reaction to stimuli is based on the accumulation of events over time rather than a single occurrence. This system would enable individuals to integrate reward and loss contingencies over time, one of the skills we hypothesize is necessary for our task. Tucker et al. note that while the dorsomedial system is poorly suited for unpredictable events, the (orbital) ventral system is ideally suited.

While the orbitofrontal cortex has been highlighted as an area important for decision-making, various neuroimaging studies indicate the importance of the anterior cingulate in decision-making (Bush et al., 2001; Carter et al., 1998; Elliot & Dolan, 1998; Gehring & Willoughby, 2002; Paulus, Hozack, Frank, & Brown, 2002). Both the orbitofrontal cortex and the anterior cingulate area has also been linked to the ability to generate SCRs in response to psychological stimuli (Tranel, 2000), indicating that both areas may be involved in the hypothesized covert biasing occurring in the early stages of decision-making. This suggests that these two brain regions and thus perhaps the two associated motivational systems are necessary for optimal performance on the task. Perhaps there is a sex difference in development of these two hypothesized systems.

In a recent review of the literature on decision-making, Krawczyk (2002) notes that both the orbitofrontal network and the anterior cingulate are important in mediating decision-making. Particularly, the anterior cingulate is thought important in sorting out conflicting options. Further, he notes that research indicates the anterior cingulate is important in both the early and later stages of decision-making. This may provide another explanation for the discrepant findings of sex differences between our study and that of Kerr and Zelazo (this issue). While children in our study were exposed to rewards and losses simultaneously, children in the Kerr and Zelazo study saw rewards first and then a few seconds later the losses. Exposure to rewards and losses simultaneously may have produced more conflict and led to a greater reliance on this system for our task. Similarly, having four deck choices rather than two may have led to greater conflict as well for younger children who have more limited working memory.

The ventromedial area includes portions of both the orbitofrontal cortex and anterior cingulate. Furthermore, the orbitofrontal cortex and the anterior cingulate are two of the areas reported to have been damaged in the patients taking part of the Bechara et al. study (Bechara et al., 1994; Manes et al., 1999). In fact, Manes et al. note the importance of exploring differences in decision-making in patients with large lesions versus those with more focal lesions to either the OFC or the dorsomedial areas. Indeed, research on the Iowa Gambling Task and modification of this task in adults has linked it to both OFC cortex and dorsomedial area of the prefrontal cortex (Manes et al., 2002; Rogers et al., 1999; Rubinsztein et al., 2001).

Certainly, there is longstanding evidence in the literature of sex differences in emotional development such as shame, empathy, and sympathy (Eisenberg et al., 1988; Lewis, Alessandri, & Sullivan, 1992; Robinson, Zahn-Waxler, & Emde, 1994; Zahn-Waxler, Robinson, & Emde, 1992). While there is evidence that the OFC and the ability to reverse associations develops earlier in males, evidence for a female advantage in the dorsomedial area and its associated abilities is not as clear. Research indicates that there are important developments in the anterior cingulate and abilities correlated with this area during childhood (Casey et al., 1997; Fernandez-Duque, Baird, & Posner, 2000 for review; Gerardi-Caulton, 2000). A longitudinal study by Kochanska, Murray, and Coy (1997) provide some support for a female advantage in one area of social development. In this study, Kochanska et al. explored inhibitory control as a contributor to moral development. Inhibitory control was defined as a special class of self-regulatory mechanisms linked to the development of the anterior attention system proposed by Posner and Rothbart (1998, 2001). The anterior cingulate cortex is hypothesized to be an important part of this system (Posner & Rothbart, 1998). Kochanska and her colleagues found sex differences in inhibitory control during the toddler and school age periods, with girls outperforming boys. Furthermore, Kindt, Brosschot, and Everaerd (1997) found sex differences in threat bias on the emotional Stroop task. Neuroimaging studies indicate that this task activates the affective division of the anterior cingulate in normal adults (Shin et al., 2001; Whalen et al., 1998). This research suggests that there are developmental sex differences in this network.

Other research indicates sex differences in the anterior cingulate in adulthood (Kaasinen, Nagren, Hietala, Farde, & O Rinne, 2001; Yucel et al., 2001). Pujol et al. (2002) found a sex difference in the right anterior cingulate, which was related to personality differences. Specifically, they found that females tended to have more asymmetry in the affective division of the anterior cingulate and that this pattern was associated with a higher score a Harm Avoidance personality scale. This fits with the interpretation that the females in our study may have been more anxious. Finally, the development of this area has been associated with maternal behavior (Devinsky & Luciano, 1993; Devinsky, Morrell, & Bogt, 1995; Lorberbaum et al., 2002).

4.2. Limitations and future directions

Research accumulated thus far provides evidence of an improvement in some aspects of decision-making with age. This supports the idea that brain networks underlying this process undergo functional maturation during childhood. It is important to note that while some areas of the brain may contribute more to decision-making, it is likely that the maturation of many areas of the brain contribute to improvement in decision-making. Given that the brain as a whole is undergoing maturation during childhood, it is impossible at this point to specify which areas are responsible for changes in decision-making. It may be that factors such as working memory or long term memory play an important role in the improvement of decision making over time. Future research using neuroimaging techniques could identify brain areas that are important for decision-making during childhood.

While our data are supportive of a female advantage in decision-making when the task requires integration of reward information over time, this study included only a small number of participants. Further research is needed to assess whether the findings from this study will generalize to other populations. In this respect, the female advantage in this task needs to be replicated. Also, more research is needed to assess whether other differences in task administration will affect performance on the Iowa Gambling Task and variations of this task.

Finally, it is important to note that varying the pattern of reward/loss may have an important impact on differences in decision making among children. In this respect, there are at least three important factors. 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 of occurrence of loss may be more relevant for sex differences. These two variables may influence predictability of loss. Unfortunately, in the present study, there was a confound between these three factors and so we can only hypothesize as to which is important. Further research systematically controlling these variables will help clarify this issue.

5. Uncited reference

Zahn-Waxler, Radke-Yarrow, Wagner, and Chapman (1992).

Appendix A. Reward/Loss contingencies for each deck type

	Disadvantageous decks		Advantageous decks	
	Deck A	Deck B	Deck C	Deck D
Card turn	+ 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

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