THE DEVELOPMENT OF AFFECTIVE DECISION-MAKING

by

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The Development of Affective Decision Making

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Abstract

The current study examined the development of affective decision-making (ADM) in preschool-age children. Forty 3- and 4-year-olds were administered a simplified version of Bechara et al.'s (1994) gambling task. The task consisted of two decks of cards, one of which provided higher wins on every trial but was disadvantageous overall (i.e., it provided even higher losses), and one of which provided lower wins on every trial but was advantageous overall. During the last 25 trials (out of 50), 3-year-olds made more disadvantageous choices (65.4%) than 4-year-olds (40.7%), and 3-year-olds made more such choices than would be expected by chance, whereas 4-year-olds made fewer. This age-related change in performance is discussed in relation to the growth of ventromedial prefrontal cortex during the 3- to 4-year-old period.
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The Development of Affective Decision-Making

The preschool age period is characterized by substantial growth in prefrontal cortex (e.g., Luria, 1966) and related circuits (e.g., Thompson et al., 2000), as well as by rapid changes in executive function (EF; see Zelazo & Mueller, in press, for a review). The construct of EF is a complex one that captures a wide range of partially overlapping abilities, but it generally refers to the psychological processes involved in the conscious control of thought and action. However, there is still considerable debate concerning how best to characterize these processes. For example, Zelazo and Mueller (in press) recently suggested that a distinction can be made between the relatively “hot” affective aspects of EF associated with orbitofrontal cortex and the more purely cognitive, “cool” aspects associated with dorsolateral prefrontal cortex (cf. Metcalfe & Mischel, 1999).

Most research on EF and its development has focused on cool aspects of EF, but recently there has been interest in hot EF as well—particularly in the neuropsychological literature on adults. For example, Bechara, Damasio, and colleagues have conducted a series of studies on one kind of hot EF that might be referred to as affective decision making (ADM). In an initial study, Bechara, Damasio, Damasio, and Anderson (1994) found that patients with damage to ventromedial prefrontal cortex performed poorly relative to healthy controls on a gambling task in which participants are presented with four decks of cards, labeled A, B, C, and D, that vary in their reward and penalty contingency schedules. Although each card from decks A and B consistently results in a higher gain than each card from the other decks ($100 in decks A and B, and $50 in decks C and D), the variable (and unpredictable) losses associated with each card from A and B are much bigger on average than the ones from C and D ($1250 average in decks A and B.
for every 10 cards. and $250 average in decks C and D for every ten cards). Thus, over time. decks A and B are disadvantageous whereas decks C and D are advantageous.

Before the game starts. participants are given $2000 play-money and asked to make as much money as possible and lose as little as possible. They are also told that the experimenter will stop the game at some point. but they are not told when (in fact. the game ends after 100 turns). Because the penalty schedules are not predictable. this task is believed to simulate real life decision-making with personal consequences (Bechara et al.. 1997). In a subsequent study. Bechara et al. (1997) measured skin conductance responses (SCRs) in ventromedial patients and healthy controls who were performing the task. As in the initial study. the authors found that both controls and ventromedial patients preferred decks A and B at the outset. However. after about 10 to 20 card turns. the controls began to show anticipatory SCRs every time a card was picked from the disadvantageous decks A or B. even though verbal reports indicated that they did not know which decks were more advantageous at this point. After about 50 card turns. verbal reports from the healthy controls indicated that these participants had a “hunch” as to which decks were riskier (A and B): by about the 80th card turn. the healthy participants expressed verbal knowledge as to why decks A and B were riskier. Very contrasting results were found for the ventromedial patients. The patients did not generate anticipatory SCRs at all. and they continued choosing cards mostly from decks A and B even after they were able to indicate verbally which decks were more risky.

At a more basic level. Damasio. Tranel. and Damasio (1990) found that ventromedial patients did not exhibit SCRs when exposed to emotionally charged visual stimuli (e.g. photographs of social disaster. mutilation. and nudity) whereas healthy
controls did. When questioned about their reaction to the pictures, the ventromedial patients said that they knew they were supposed to feel an emotion (e.g. sad for social disaster) but that they did not feel anything. Healthy controls, on the other hand, reported feeling emotional reactions to the pictures. Both ventromedial patients and controls, however, generated SCRs to an unconditioned aversive stimulus (e.g. a loud noise). The authors suggested that social stimuli normally elicit an integration of both autonomic and cortical processes, but that this integration was disrupted in ventromedial patients (see also Bechara et al., 1994, 1997, 1998, 1999; Damasio, 1994; Damasio et al., 1990; Tremblay & Schultz, 1999).

Damasio (1994) interprets these findings in the context of the Somatic Marker Hypothesis. The Somatic Marker Hypothesis states that physiological reactions, usually associated with learned rewarding or punishing events, are elicited in an "as if" fashion when the probability of their occurrence is likely. These physiological reactions are believed to bias decision-making behavior in an advantageous manner by marking the relevant cognitive process with a particular emotional value (Damasio, 1994). In other words, Damasio (1994) proposes that there is an affective mechanism involving ventromedial prefrontal cortex that can detect likely future consequences associated with certain courses of action (e.g. Bechara et al., 1994, 1997, 1998, 1999; Damasio, 1994). For example, anxiety may bias one's decisions under threatening circumstances and prove to be instrumental in decision-making. This hypothesis is consistent with the fact that ventromedial prefrontal cortex has rich projections to and from the limbic system (and other regions of prefrontal cortex; Damasio, 1994; Pandya & Yeterian, 1998), which make it well suited anatomically to integrate both emotional reactions and higher order
cognitive processes. Further evidence for the role of ventromedial prefrontal cortex in ADM comes from related work by Elliot (Elliot, Rees, & Dolan, 1999) and Rogers and colleagues (Rogers et al., 1999, 2000), who have, through the use of imaging technology, identified orbitofrontal cortex (which includes ventromedial prefrontal cortex) as crucial for guessing and decision-making behavior when the probabilistic contingencies are complex.

**Possible Independence of Hot and Cool Aspects of EF**

The gambling task is believed by some to be unique in that it specifically measures personal decision-making process independent of other aspects of EF (Damasio, 1994). Arguably, the ventromedial patients studied by Damasio, Bechara, and colleagues (e.g., Bechara et al., 1999) are not deficient in either emotional reactivity per se or higher order cortical processes per se. Instead, these patients may be deficient in the ability to integrate information from these two types of systems. Systematic comparisons of ventromedial patients to two other populations of brain damaged patients, amygdala and dorsolateral prefrontal cortex patients, offers partial support for this notion.

First, the performance of ventromedial patients was compared to that of patients who had sustained brain damage to the amygdala, an area of the brain believed to be crucial for basic emotional reactivity. Bechara et al. (1999) found that both patients with damage to the amygdala and patients with damage to ventromedial prefrontal cortex performed poorly on the gambling task. However, the authors argue that different mechanisms lead to failure in each population. The authors argue that the amygdala patients simply do not attach emotional value to punishing events, and thus cannot act advantageously to avoid punishment. In contrast, the ventromedial patients do respond to
punishment but cannot integrate present and future conflicting somatic states associated with particular stimuli (Bechara et al., 1999). In other words, the amygdala patients appear to lack emotional reactivity, whereas the ventromedial patients do not. The ventromedial patients, instead, appear to be unable to use emotional information to guide their actions effectively. The main evidence for this comes from the fact that the amygdala patients failed to develop conditioned SCRs after presentation of a slide previously paired with a loud noise, whereas the majority of ventromedial patients did generate conditioned SCRs (Bechara et al., 1999). Furthermore, the amygdala patients did not generate SCRs after punishing cards had been played (as opposed to anticipatory SCRs) while the ventromedial patients did (Bechara et al., 1999). Therefore, it does not seem to be the case that the ventromedial patients perform poorly on the gambling task simply because of a lack of emotional reactivity.

Second, the performance of ventromedial patients on the gambling task was compared to the performance of patients with damage to dorsolateral prefrontal cortex. The dorsolateral patients succeeded at the gambling task (more than 50% of cards selected from the advantageous decks) whereas the ventromedial patients did not (Bechara et al., 1998). However, the dorsolateral patients failed at a working memory task whereas the majority of ventromedial patients did not. This double dissociation provides some evidence that higher order processes associated with dorsolateral prefrontal cortex might not be essential for success on the gambling task.

However, it should be noted that the dissociation between working memory and decision-making was by no means clear cut. The dorsolateral patients actually performed at the low end of normal levels on the gambling task. In addition, some of the
ventromedial patients did fail the delay memory task, and more importantly, those who failed the delay task performed extremely poorly on the gambling task. Therefore, simpler components of EF such as working memory or response inhibition might be inextricably tied to good performance on the gambling task and to real life decision-making processes.

**Development of ADM**

There is extensive research from varied contexts and domains showing that the ability to integrate conflicting pieces of information develops during the preschool age period (e.g. Zelazo & Jacques, 1996). For example, consider the Dimensional Change Card Sort (DCCS: Frye, Zelazo, & Palfai, 1995). In the DCCS, children are asked to sort picture cards according to prespecified embedded rules such as, IF playing the color game. THEN. IF. the picture is red THEN put it in location X. AND IF blue then in location Y. AND. IF playing the shape game. THEN. IF. picture is a rabbit THEN put it in location Y. AND IF a boat THEN in location X. The picture stimuli that is presented, however, can be sorted according to both dimensions (e.g. color and shape) and the correct sorting location conflicts for each particular stimulus (e.g. a red rabbit is correctly placed in location X if sorting by color, but should be placed in location Y if sorting by shape). It has been found that 5-year-olds but not 3-year-olds can switch sorting rules flexibly between the two different setting conditions (e.g. Zelazo, Frye, & Rapus, 1996). According to the Cognitive Complexity and Control (CCC) theory (e.g. Zelazo & Frye, 1997) children’s ability to use complex rule systems improves over the preschool age period. For example, 3-year-old children are able to use a single pair of rules, such as (a) IF playing the color game. THEN red here AND blue there. or. (b) IF playing the shape
game. THEN. rabbits here AND boats there. However. they cannot use a higher order rule (e.g. setting condition) to integrate the two conflicting pairs of rules that each stimulus card presents. Three-year-olds are even capable of reporting knowledge of the two conflicting pairs of rules individually. however when asked to sort according to those rules. they perseverate on the first acquired dimensional pair of rules (either the color sorting rules or the shape sorting rules) despite having just reported the correct sorting pair of rules (Zelazo et al.. 1996). Zelazo (1999) argues that the typical failure of cognitive flexibility in 3-year-olds is the result of a lack of sufficient recursive consciousness necessary for solving tasks at this level of complexity (i.e. tasks involving the use 2 incompatible pairs of rules). It might be the case that cognitive flexibility also plays a role. to some extent. in ADM. as some degree of hierarchical control might also be needed for that type of function.

Thompson et al. (1997) recently suggested that delay of gratification tasks also require the integration of conflicting pieces of information. These authors showed that older preschoolers. but not younger ones. when given the choice to receive a small reward now versus a bigger reward later. will choose to receive a bigger reward later (see also Metcalfe & Mischel. 1999). The older preschoolers will also more often choose to receive a small reward for each self and other later. as opposed to a big reward for self only now. To explain their results. Thompson et al.. (1997) suggested that the ability to hold or integrate two conflicting mental states in memory develops over the preschool period.

Because there is extensive evidence showing that ventromedial prefrontal cortex might play a crucial role on ADM. and because there is evidence that prefrontal cortex develops over the preschool period (see Zelazo & Mueller. in press. for a review). it
seems likely that ADM develops over the preschool period as well. Moreover, ADM as measured by Bechara et al.'s (1994) gambling task would seem to require the integration of conflicting pieces of task related information, and there is evidence showing that this type of integration develops considerably between the ages of 3 and 5 years (e.g. Zelazo, 1999). Furthermore, even though ADM has not been studied developmentally, it should be mentioned that there is some relevant early work on learning theory that has looked at probability learning and decision-making in preschoolers. This work has generally found that older preschoolers are better at making probability judgements than younger preschoolers (e.g. Kessen & Kessen, 1961).

The purpose of the present study was to create an age-appropriate decision-making task to measure ADM during the preschool period. This task consisted of a simplified version of the Bechara et al. (1994) gambling task, and was composed of two decks of cards instead of four: candy instead of money was used as the reward units; and happy and sad faces replaced the written text informing children of rewards and losses. On the basis of previous research on the development of EF, it was expected that 3-year-olds would choose more cards from the disadvantageous decks than the 4-year-olds. The creation of a task sensitive to developmental changes in ADM would serve as a basic first step towards future studies that would investigate more fully the underlying cognitive processes responsible for the development of advantageous affective decision-making.

Method

Participants

Forty-six preschool children were tested. Six of those tested were excluded from
the experiment either because of parental interference (2 children) or because they did not complete all of the predetermined trials in the task (4 children). The sample size was thus reduced to 40. Participants were 20 3-year-olds [M = 3(6); years(months), range = 3(1) to 3(11)] and 20 4-year-olds [M = 4(5), range = 4(0) to 4(10)] recruited from daycare centres in Toronto, Ontario and Shubenacadie, Nova Scotia. There were 20 males and 20 females: 8 males and 12 females in the 3-year-old group, and 12 males and 8 females in the 4-year-old group.

Apparatus

The apparatus for the decision-making task involved two counterbalanced sets of index cards (7 X 11 ½ inches). Each set was composed of two decks of 50 cards. Only one set was used for each experimental session. The background appearance of each card consisted of a design of either black vertical lines or black dots, and a main design involving a display of happy and sad faces (see Figure 1). The happy faces were black and were displayed on a white background on the top portion of the card, while the sad faces were white and were displayed on a black background on the bottom portion of each card. In addition, the bottom portion of each card was covered with a blue piece of Post-It® paper that the participant had to lift off in order to reveal that part of the card. The number of happy faces displayed on each card corresponded to the number of rewards associated with that particular card, while the number of sad faces indicated the number of rewards lost. Each set consisted of a deck of striped cards and a deck of dotted cards. One deck in each set was made to be disadvantageous and the other advantageous, and which deck was striped was counterbalanced between sets. Therefore, in one set, the
advantageous cards were the striped ones, whereas in the other set they were dotted. The rewards consisted of mini M&M® chocolate candies. The rewards won during the task were collected and displayed on a small glass graduated cylinder. The rewards that were lost were deposited back into a plastic container, which contained the source of rewards.
for that particular experimental session.

**Procedure**

The experimental session took place in a quiet room, and each child that participated was tested individually. Written informed consent was obtained from all parents or authorized representatives of the children who participated.

After a short warm-up play session with the child (about 5 minutes), the experimenter introduced the task to the child as a fun card game involving candy. The child was then asked to sit down at the designated table. The two decks of cards were placed face down in front of the child, and the graduated cylinder (used to collect the rewards) was placed between the two decks of cards. The experimenter sat on the side of the table closest to the child to either the child's right or left side, and the container holding the candies was placed in front of the experimenter.

The child was then introduced to the rules of the games (see Appendix for the protocol). The child was told that whatever candy he or she won, he or she would put inside the graduated cylinder in front of him or her, and that he or she was not allowed to eat any of the candy until the end of the game. The child was also told that he or she should try to win as much candy as possible before the end of the game. The child was then given a demonstration of how the cards worked (3 cards were selected from each deck) after which the child was told that they could choose whatever card they wanted every time, and that they could choose as many cards as they wanted before the experimenter announced that it was the end of the game (which, unbeknownst to the participant, was after 50 trials). Rewards were always administered before the losses. Every time that a card was turned, the experimenter announced the number of candies
won and placed them on top of the happy faces. after which they were placed inside the graduated cylinder. After this, the Post-It® piece of paper was lifted from the bottom of the card and the number of losses were announced, after which the appropriate number of candies were counted out of the graduated cylinder, placed on top of the sad faces, and then placed inside the container where the experimenter kept the candy. The losses were revealed only after the rewards were in order to minimize the complexity of the representative nature of the card, and to emphasize the immediacy of the reward information versus the loss information.

Unknown to the participant was the fact that one deck was disadvantageous and the other advantageous. In the disadvantageous deck, the participant won 2 candies every time that a card was turned over, but the number of losses per card could have been 0, 4, 5, or 6 candies (with a net average of 5 candies lost per 10 cards). In the advantageous deck, the participant only won 1 candy per card, but the number of losses could have been either 0 or 1 (with a net average of 5 candies gained per 10 cards). Therefore, although the number of rewards on any trial was greater in the disadvantageous deck, continuing to play from that deck resulted in a net loss of rewards. Continuing to play from the advantageous deck, on the other hand, resulted in a net gain of rewards. This contingency schedule is mathematically equivalent to the one used in the Bechara et al. (1994) gambling task (see Figure 2 for a full breakdown of the contingency schedule used).
Table 1 shows the response options for the punishment contingency schedule. The schedule was repeated for a total of 50 response options (trials).

Table 1. Punishment contingency schedule.

| Response Option | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|-----------------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
| “Bad” Deck (+2) | -4 | -6 | -4 | -5 | -6 | -6 | -5 | -4 | -6 | -4 |   |   |   |   |   |   |   |   |   |
| “Good” Deck (+1) | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |   |   |   |   |   |   |   |   |

Figure 2. Punishment contingency schedule. The schedule was repeated for a total of 50 response options (trials).

Results

The first half of the task (trials 1-25) allowed children an opportunity to sample from both decks. Trials 26-50 (the second half of the task) were considered for analysis. The dependent variable was percentage of disadvantageous choices made during the last half of the task (25 trials).

The mean percentage of disadvantageous choices made by 3-year-olds was 65.40% (SE = 5.43); and for 4-year-olds it was 40.74% (SE = 5.68); see Figure 3.

A two-way (Sex X Age) analysis of variance (ANOVA) revealed a significant main effect for age only. F(1, 36) = 9.839, p = .007, with 3-year-olds performing worse than 4-year-olds. The performance of 3-year-olds was significantly worse than chance (t = 3.095, p = .006), whereas 4-year-olds were marginally better than chance (t = -1.631, p =
There was not a significant main effect for sex, $F(1, 36) = 1.717, p = .198$, or for the interaction between sex and age, $F(1, 36) = 1.657, p = .206$.

Figure 3. Mean percentage (and standard error) of cards chosen from the disadvantageous deck during the children's version of the gambling task (trials 26-50) as a function of age.

However, the mean performance for 3-year-old females was 73.58% ($SE = 7.05$) and for 3-year-old males it was 53.11% ($SE = 8.63$). A one-way ANOVA comparing the performance of 3-year-old females to 3-year-old males revealed a marginally significant
effect. \( F (1, 18) = 3.931, p = .063 \). with 3-year-old females performing worse than 3-year-old males. The mean performance of 4-year-old females was 40.85% (\( SE = 8.63 \)), and of 4-year-old males it was 40.67% (\( SE = 7.05 \)). A one-way ANOVA comparing the performance of 4-year-old males to 4-year-old females did not find a significant effect. \( F (1, 18) = 0.000, p = .988 \).

A linear regression function was also fitted to the data, with age in months as the predictor variable and percentage of disadvantageous choices (trials 26-50) as the response variable. Age in months was found to be a significant predictor of performance (\( R^2 = .155, B = -1.847, SE = .700, \text{Std. } B = -3.93, t = -2.639, p = .012 \)).

Discussion

ADM was assessed in preschool-age children using a simplified version of Bechara et al.'s (1994) gambling task. The results revealed that 3-year-olds chose a significantly greater number of cards from the disadvantageous decks than did the 4-year-olds. Moreover, 3-year-olds' performance was worse than chance, and the performance of 4-year-olds was marginally better than chance. These results support the hypothesis that ADM develops over the preschool period, and they can be interpreted in terms of the Somatic Marker Hypothesis (e.g. Damasio, 1994) and growth of ventromedial prefrontal cortex. However, alternative interpretations of the present results will also be presented and considered together with potential clinical applications.

Development of Ventromedial Prefrontal Cortex

Bechara, Damasio, and their colleagues propose that ventromedial prefrontal cortex serves the crucial role of integrating somatic states associated with future
consequences of behavior, together with knowledge of planned intentions and goals (Bechara et al., 1994; Damasio, 1994). Therefore, the age related improvement in decision-making ability observed in the present study might generally be the result, at least in part, of the growth of ventromedial prefrontal cortex. Prefrontal cortex develops over this age period (see Zelazo & Mueller, in press, for a review) and many cognitive abilities are believed to improve as a result of this growth. However, the growth of ventromedial prefrontal cortex in particular may play a larger role than the growth of other areas of prefrontal cortex in the development of decision-making ability, because, for example, patients with damage to ventromedial prefrontal cortex appear to be deficient in decision making ability (somewhat) independently of other more general frontal tasks (e.g. IQ measures: Bechara et al., 1994). Also, it has been found that some patients with damage to dorsolateral prefrontal cortex performed well on the gambling task (Bechara et al. 1998). Future neuroimaging studies with preschoolers might be able to investigate this idea further.

In addition, although the interaction between age and sex failed to reach significance, there was some suggestion that the 3-year-old females in the present sample performed worse than the 3-year-old males. Indeed, a one-way ANOVA comparing these groups revealed a marginally significant effect. It might be the case that there is a sex related difference in the rate of growth of prefrontal cortex, or perhaps specifically of ventromedial prefrontal cortex. This latter possibility needs to be considered carefully in light of evidence from Clark and Goldman-Rakic (1989) who found that in rhesus monkeys, males perform better than females in an object discrimination reversal task (a task believed to be sensitive to orbitofrontal cortex functioning), although the difference
in performance disappears with age. Moreover, young females who were given androgen performed similarly to the young males, and males who received orbital prefrontal cortex ablations performed similarly to the young females. Thus orbital prefrontal cortex appears to develop more slowly for female rhesus monkey, and this sex difference appears to be under the control of gonadal hormones.

Additionally, there is some evidence from Overman et al. (1997) that a similar biological mechanism may exist for humans. These authors tested toddlers and preschoolers on an object reversal learning task and found that prior to 30 months of age, boys were better than girls (there appeared to be a ceiling effect after 30 months). Therefore, there is a need for a more sensitive task of orbitofrontal development for older children. The level of complexity in the present child version of the gambling task is sufficiently high to render ceiling effects on performance a very unlikely possibility, and thus this task might be a more sensitive measure of orbitofrontal cortex development for preschoolers and young children. Future studies will attempt to address more deeply (and with additional statistical power) potential sex related differences in behavioral markers of orbital/ventromedial prefrontal cortical development.

Damasio and his colleagues specifically argue, in the somatic marker hypothesis, that ventromedial prefrontal cortex might be responsible for the re-enactment of somatic states associated with future consequences of behavior when anticipating similar events, or when presented with related stimuli (Bechara et al., 1994, 1997, 1999; Damasio, 1994). This group of authors found that, contrary to healthy controls, patients with damage to ventromedial prefrontal cortex did not exhibit anticipatory SCRs when
choosing cards from disadvantageous decks (Bechara et al., 1997). Therefore, these patients appear unable to develop or use the information that such somatic states are proposed to provide in normal decision-making behavior. Future studies should therefore assess the role that somatic states (e.g. as measured by electrodermal activity) play in the development of decision-making behavior. Such a study could measure electrodermal activity in preschoolers while they play the present child version of the gambling task. Because it was found that 3-year-old children make a greater percentage of disadvantageous choices than the 4-year-old children do, and because it has been proposed that physiological reactions associated with likely future gains or losses mark and guide one’s choices (Damasio, 1994), it might be the case that the younger preschoolers will fail to develop anticipatory SCRs whereas the older preschoolers will. Perhaps 3-year-olds do not physiologically anticipate future events involving rewards and losses as well as older preschoolers do. Alternatively, if there is no age group difference between the anticipatory SCRs, and 3-year-old children still choose a greater percentage of disadvantageous cards than the 4-year-old children do, then it is possible that even though somatic markers are present in both groups of children, the 3-year-old children for some reason do not use them to guide their action choices whereas the 4-year-old children do.

In sum, it seems reasonable to propose that development of ventromedial prefrontal cortex plays a role in the observed age-related changes in ADM, and future studies should address this possibility further. However, other psychological explanations, which may or may not depend on the development of ventromedial prefrontal cortex, should also be considered. Such explanations might help clarify further
the possible cognitive mechanisms underlying the development of ADM.

**Other Possible Explanations of Age-related Changes in ADM**

It must be kept in mind that the poor performance of the 3-year-olds in the present task can be attributed to a number of different variables in the decision-making process. For example, losses in the disadvantageous deck were more variable than in the advantageous deck. That is, in the advantageous deck, the possible losses per card were 0 or 1, whereas in the disadvantageous deck they were 0, 4, 5, or 6. Therefore, the 3-year-olds might have preferred the disadvantageous deck because of its variability. Future studies should investigate whether or not the variability of the losses plays a role in determining deck preference.

Another factor that might have contributed to the 3-year-olds' performance on the present task has to do with how well children at this age can learn from variable reward and loss contingency information. Early research on learning has looked at the ability of preschoolers to guess probabilities. For example, Kessen and Kessen (1961) presented 3- and 4-year-olds with a deck of black and red cards. Children were assigned to one of four groups, each differing on the type of deck received in terms of the ratio of black to red cards. The children were asked to guess the color of each card and were given direct feedback regarding whether or not they guessed correctly. Children were then presented with a new deck of black and red cards that either differed or did not differ from the first deck of cards in the ratio of black to red cards. Kessen and Kessen (1961) found that 3-year-olds, but not 4-year-olds, perseverated on their responses by continuing to make predictions based on the ratio of the first deck of cards that was presented. Furthermore.
3-year-olds were more likely than 4-year-olds to repeat a prediction (i.e. black card) despite receiving negative feedback. Four-year-olds, on the other hand, tended to switch more often on their predictions when receiving negative feedback (Kessen & Kessen, 1961). Future research should assess children's tendencies to stay or shift as a function of feedback received on each trial in the gambling task (i.e. win only; win and lose, etc.). This research might provide useful information regarding children's sensitivity to win and loss contingencies, as well as their ability to benefit from this information.

It might be the case that the 3-year-olds performed poorly on the present task because they approached the task unidimensionally. For example, 3-year-olds (and not 4-year-olds) might have simply ignored the losses and just concentrated on the wins. Doing so would clearly result in choosing more cards from the disadvantageous deck because the wins per card in that deck were higher than in the advantageous deck. Siegler (1996) specifically lists the task characteristics that appear to elicit, in young children, the preference to approach a task unidimensionally. Namely, such tasks are: (a) unfamiliar, (b) require a quantitative comparison, (c) require a discrete choice between 2 or 3 alternatives, and (d) include a single perceptually or conceptually dominant dimension that can lead children toward specific incorrect answers. The present child version of the gambling task seems to fit all of these characteristics. Therefore, it does seem plausible that the youngest participants tested might have performed poorly on the present task because they focused on the single (perhaps more salient) dimension of wins, as opposed to both wins and losses. If 3-year-olds are indeed approaching the gambling task unidimensionally, future studies will have to investigate why this is the case in terms of underlying cognitive processes. For example, future studies could manipulate the
winning and losing contingency schedule in several ways to assess 3- and 4-year-olds' ability to attend to and use more than one of the relevant dimensions presented in the gambling task (i.e. wins, losses, present, and future).

Another important cognitive component that appears to be important for success in the present task is the ability to integrate one's knowledge and action. In other words, it might not be sufficient to attend to and know task relevant information: rather, a certain degree of cognitive flexibility might be needed to use this knowledge in a functional manner. Specifically, the dissociation between knowledge and action (abulic dissociation, Zelazo et al., 1996) that the patients exhibited in the study by Bechara et al., (1997) might also be present in the 3-year-olds tested under the present task. Near the end of the gambling task, the ventromedial patients studied by Bechara et al. (1997) reported that they should have chosen more cards from the advantageous decks. as those cards were better in the long run, yet they continued to choose from the disadvantageous decks. Similarly, it might be possible that the young preschoolers tested in the present decision-making task. may also show dissociation between knowledge and action. This possibility seems plausible in light of evidence from Zelazo et al. (1996) showing that young preschoolers typically show such abulic dissociations in situations that to them are cognitively complex. For example, 3-year-olds might possess the knowledge that if they choose cards from the advantageous deck they might not lose as much in the end. but this knowledge may conflict with the immediately available knowledge that the rewards in the disadvantageous deck are higher. The two conflicting pieces of information might be difficult for 3-year-olds to integrate. perhaps because of a more general difficulty using higher order rules (e.g., Zelazo & Frye, 1997). To test this hypothesized dissociation
between knowledge and action, a group of preschoolers could be asked if they know which deck is better during the task. The young preschoolers might then show a dissociation between the knowledge reported regarding which cards are better, and the actual cards chosen during the task. Alternatively, they might never report knowledge of which deck is better, and a better method to assess if such dissociation is present might be to tell them explicitly which deck is better before they start playing. The task performance of this group could be compared to that of a control group that does not receive any information regarding the nature of the decks. The 3-year-olds in the experimental group might continue to choose more cards from the disadvantageous deck, in spite of being told explicitly which deck is better. If such a dissociation were present, then the reason for it would have to be further investigated. Cognitive flexibility and the role of reflective consciousness might play a role in explaining such a dissociation.

Alternatively, or in conjunction with cognitive flexibility, the ability to inhibit prepotent tendencies to choose cards from the high paying (but disadvantageous) deck might also be crucial for successful performance, and might account for abulic dissociations, if present. Lack of inhibition in this context would correspond to knowing what one is trying to do, but being unable to resist a tendency to respond incorrectly. The role of response inhibition in the decision-making process should therefore also be considered, especially in light of the finding that ventromedial prefrontal cortex may serve the crucial role of response inhibition (e.g. Roberts. 1998: Robbins. 1998: Dias et al.. 1996. 1997: Tremblay & Schultz. 1999: Rolls et al.. 1994: Levine et al.. 1999).

Plasticity of Function and Clinical Applications
The behavior of the ventromedial patients studied by Damasio and colleagues (e.g., Damasio, 1994) shares similarities with the behavior of psychopathic individuals who in turn have sometimes been labeled as disinhibited. Indeed, several measures aimed at assessing the types of self-defeating behaviors encountered in the everyday lives of people high in psychopathy parallel the documented performance of ventromedial patients on the gambling task (Newman et al., 1987). However, the findings in this area have been contradictory (e.g., Schmitt et al., 1999). On the one hand, recent research by LaPierre et al. (1995) found that a group of psychopathic individuals performed worse on tasks believed to be ventromedial in nature (e.g. go-no-go discrimination task) than on other tasks considered to be more frontodorsolateral in nature (e.g. Wisconsin Card Sorting Task). Furthermore, Newman et al. (1987) found that psychopathic individuals continued playing longer than controls in a card game where the probability of punishment increased with every block of ten cards. On the other hand, however, Schmitt et al. (1999) recently assessed the performance of psychopathic individuals on the Bechara et al. (1994) gambling task and found that degree of psychopathy did not predict performance on the gambling task (although anxiety level did). Therefore, the link between ventromedial prefrontal cortex and psychopathy is not clear cut. However, the possibility exists that psychopathic individuals may crucially differ from ventromedial patients in that each population follows different developmental pathways.

Some recent studies of brain damage in early childhood suggest that different developmental trajectories may help explain the greater incidence of criminal and aggressive behaviors in psychopathic individuals than in adult ventromedial patients (e.g. Anderson et al., 1999; Price et al., 1990). For example, Anderson et al. (1999) studied
two individuals who sustained prefrontal damage including the ventromedial area before the age of 16 months. In contrast to patients of adult ventromedial damage, both of the sampled patients showed significant impairments in moral reasoning and perspective taking (see anecdotes reported in the article). Clinical evidence also revealed a history of acts of violence and criminal activity. Early prefrontal brain damage in the ventromedial area could have thus resulted in an abnormal development of social and moral rules in these patients. These findings seem to suggest that the violence and criminality commonly associated with psychopathic personalities (but not ventromedial patients) could be the result of atypical development, which may have been caused by early brain dysfunction in prefrontal cortices (Anderson et al., 1999).

In a similar vein, Gorenstein and Newman (1980) believe that psychopathy, antisocial and impulsive personality, and even alcoholism are all separate manifestations of the same underlying dysfunction, which can perhaps be understood as a dysfunction of prefrontal cortex. If the ability to make personal life decisions is indeed present in these disorders, understanding the developmental process required for making personal life decisions may have far reaching implications.

Furthermore, in the Newman et al. (1987) study, it was found that the performance of the psychopaths could be improved by incorporating a waiting period of 5-seconds before every response. Newman et al. (1987) proposed that the waiting period allowed the participants to benefit from the punishment information and reflect on it before responding. The concepts of risk-taking, impulsivity, and response inhibition are obviously interrelated, and future studies should address the contribution that such proposed processes play in the development of decision-making ability. For example, the
poor performance of 3-year-olds in the present task might be the result of impulsive and unpremeditated choices. Therefore, it might be possible that the 3-year-olds’ performance on the gambling task could be improved by simply requiring the children to wait a predetermined amount of time before making each card selection. The longer time delay might, according to Patterson and Newman (1993), allow the participants to reflect on the losses that occur (stage 3 of their proposed 4 stages involved in response modulation) and thus modulate their responses more effectively.

The findings presented by Newman et al. (1987) that psychopaths’ response modulation can be improved under experimental circumstances, raises the issue of the interaction between neural plasticity and experience, together with hope for clinical treatment. Just as the psychopaths’ performance was improved in Newman et al.’s (1987) study, it might be the case that other disorders characterized as disinhibited in nature can benefit from treatments involving such strategic interventions. Because it has been found that EF in general develops over the preschool age-period, it might be the case that such strategic interventions might be most effective for disorders of disinhibition that present themselves during this formative period (e.g. ADHD: Barkley, 1997). Indeed, Dowsett and Livesey (2000) present evidence that performance on a go-no-go task can be improved in 3-year-olds when children are provided with appropriate experience with related tasks designed to encourage reflection and the use of higher order rules. Therefore, it appears, not surprisingly, that the role of relevant experience is crucial in the development of proposed prefrontal abilities.

In conclusion, the present study serves the function of a first step toward the
understanding of the development of ADM. Future research will need to concentrate on teasing apart the specific mechanisms that are involved in making real-life decisions involving personal consequences. Specifically, the concerted interaction of lower order and higher order cognitive systems seems likely to be a key aspect to well functioning ADM. Much research has been conducted on the functioning of cool aspects of EF and its development, and some research has been conducted on hot EF. However, relatively little is known about the interaction of these two systems.
References


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Appendix

Protocol for the children’s gambling task.

“Do you like M&Ms? Well, we are going to play a game where you get to win M&M’s. Do you want one?” [give one M&M to child so that they know what they are playing for]. “Okay, in this game we get to put the M&M’s that you win in this tube here [graduated cylinder]. I’m going to give you 10 to play the game [deposit 10 M&M’s in cylinder counting out loud] and I’ll show you how the game works and how you can win some more.” [A training session is then given to the child, where he/she will be introduced to the game by demonstrating what happens when the first 3 cards from each deck are turned-3 from one deck first and then 3 from the other deck.] e.g.: “Okay, I’m going to show you how the game works. We have the stripe cards and the dot cards. Let’s see how the stripes work first. [flip card over] Look there’s 2 happy faces, that means that you win 2 M&M’s: [place 2 M&M’s on top of the happy faces counting out loud, and then in the cylinder] Okay, now we have to open this up and see if there’s any sad faces [the bottom part of the cards are covered with a blue sheet of Post-It paper: wins are given out first and then the losses are taken.] Oh there’s 4 sad faces, that means that you lose 4 M&M’s so we have to give 4 back [take 4 M&M’s from cylinder and place on top of sad faces counting out loud and then place back in the tupperware container.] We don’t like the sad faces do we? Because we lose M&M’s, but we like the happy faces right? Because we get to win M&M’s [confirm child’s understanding of what the happy & sad faces represent ];[The cards are in front of the child and the graduated cylinder is in between the 2 decks. The experimenter has a tupperware container filled with M&M’s. The order of stripes and
dots from left to right is randomly assigned from participant to participant as well as the
order of card sets: order 1- stripes are disadvantageous and dots are advantageous. &
order 2-stripes are advantageous and dots are disadvantageous].

[Afber the training part: “Okay, now we are ready to start playing the game.
You get to choose whichever card you want to play with every time. You can play
from the dots or the stripes or from both. You get to choose one card every time
and you can pick as many cards as you want until I say STOP and then the game
will be done. So, remember you want to make sure that you win as many M&M’s as
possible! Let’s see if we can fill this tube right up to the top with candy! Whatever
you have in the tube by the end of the game you can eat or take home with you.
Okay? Which card do you want to flip first.” [Continue until 50 cards have been
turned. Also, if the losses outnumber the number of candy in the cylinder [very rare], just
take back everything that is in the cylinder explaining that “we don’t even have that
many to give back so we’ll have to give back everything we have.” Leaving the
collection cylinder empty.]

-At the end of the game the child is rewarded with extra M&M’s for having done
“such a good job”.