# Gambling with the Minds of Children and the Lesioned: The Role the Ventromedial Prefrontal Cortex Plays in Decision Making

James I. Garijo-Garde

Psychology 131, Tufts University

## *Introduction*

Human decision making is considered an ability that separates us cognitively from most, if not all, other animals. A part of this decision making is balancing reward and punishment with risk. Healthy adult humans are fairly good at learning the risks associated with activities and understanding how to weigh these risks and pick a course of action. But, that is not to say all humans are endowed with this ability.

In 1994, a cognitive neuropsychology study provided a breakthrough method that pinpointed this exact type of human decision making to the ventromedial prefrontal cortex, and in 2004, a developmental psychology study looked at the conclusions of those researchers and attempted to discern new information relating to the development of balancing risk and reward or punishment in adolescents in order to reinforce the conclusions of cognitive neuropsychology and to gain new insights into how high-level human cognitive abilities develop over time. In examining the two studies, it becomes clear that the research two decades across support the same broader conclusion: the ventromedial prefrontal cortex is a brain region critical for decision making involving the assessment of rewards and punishments in the context of risk, and individuals for whom this area is underdeveloped or damaged are not as capable at making these decisions.

## *Background*

The ventromedial prefrontal cortex is a sector of the prefrontal cortex that, when damaged, results in a severe impairment in decision making (Bechara et al., 1994). Yet despite this, when the ventromedial prefrontal cortex is damaged, other functions associated with the prefrontal cortex, such as working memory, do not appear impaired, indicating the ventromedial prefrontal cortex seems to have a specific function unique to that space of the prefrontal cortex (Bechara et al., 1994).

While patients with brain damage to the prefrontal cortex suddenly find themselves unable to perform high-level cognitive functions, children are not yet aware of their deficits in these cognitive tasks. Many high-level cognitive functions – like working memory, set shifting, behavioral inhibition, decision making, and cognitive control of behavior – are deficient in children and adolescents, emerging in late infancy and developing gradually into adulthood (Hooper et al., 2004). While the brain reaches its full size between ages five and ten, synaptic pruning and myelination of axons have still not left the prefrontal cortex, believed to be the last developed area of the brain, ready for fully adult functioning in these children (Hooper et al., 2004). Many studies have reinforced this notion by showing different brain activation in the prefrontal cortex of children and adults, as well as deficits in child performance in working memory tasks (Hooper et al., 2004).

Yet despite this, brain imaging of the ventromedial prefrontal cortex and how it activates during decision making is not well-documented (Hooper et al., 2004). The reason for this lack of imaging is because the region is very close to the eyes and face muscles, which interfere with brain scans of the area (Hooper et al., 2004). Because of this, a task specifically reflecting use of the ventromedial prefrontal cortex is needed to conduct research into the brain area and its function. The first study this paper examines, written in 1994 by Bechara, Damasio, Damasio, and Anderson, seeks to establish such a measure with their Iowa Gambling Task. The Iowa Gambling Task was designed to compare the decision making of research participants with damage to or lesioning of the ventromedial prefrontal cortex with that of cognitively normal participants (Bechara et al., 1994). In the task, a participant is given a sum of fake money and continually selects cards from four decks, each with a monetary reward, and some with a monetary punishment (Bechara et al., 1994). Two of the decks appear more advantageous but have steep punishments that result in net losses, while two of the decks appear less advantageous but have less significant punishments that result in net gains (Bechara et al., 1994). The task is described in greater detail below, but the goal of the task is to show a correlation between poor performance picking cards and damage to the ventromedial prefrontal cortex (Bechara et al., 1994).

The Iowa Gambling Task is the current benchmark for behavioral research involving the ventromedial prefrontal cortex, having been used to show deficits in performance in ventromedial prefrontal cortex function in individuals with drug or alcohol dependencies as well as self-described risk takers (Hooper et al., 2004). In their 2004 study, Hooper, Luciana, Conklin, and Yarger reasoned that since adolescents have a reputation of being more likely to take risks, they may also exhibit performance on the Iowa Gambling Task below the levels achieved by healthy adults. But because they were unsure if lower performance on the Iowa Gambling Task could be a result of other deficits related to the continuing development of the prefrontal cortex, Hooper et al. tested their participants’ performance on working memory and inhibition tests and compared those results to performance on the Iowa Gambling Task (2004).

The methods and findings of these two studies are described below.

*Empirical Study: Insensitivity to future consequences following damage to human prefrontal cortex*

Background:

In 1994, Bechara, Damasio, Damasio, and Anderson wanted to create a task that reflected the real-life impairment in decision making that people with damage to the ventromedial prefrontal cortex exhibited. They were inspired by patient E.V.R., an individual with a lesion in his ventromedial prefrontal cortex (Bechara et al., 1994). E.V.R.'s general intellect and problem-solving skills were intact – he scored perfectly on the Wisconsin Card Sorting Test, paradigms requiring self ordering, cognitive estimates, and judgements of recency and frequency, and his solutions to social problems and ethical dilemmas are comparable to controls – but his decision making repeatedly leads to negative consequences in his real life (Bechara et al., 1994). Creating the Iowa Gambling Task, Bechara et al. sought to quantify the decision making deficits of E.V.R. and other participants with ventromedial prefrontal cortex damage (1994).

Participants:

4 men and 2 women with ventromedial prefrontal cortex damage, including E.V.R., were examined in this study (Bechara et al., 1994). Ages ranged from 43 to 84 years old (Bechara et al., 1994). About half the group had a college education, while for the other half, high school was the highest level of education achieved (Bechara et al., 1994). The control group, representing normal ventromedial prefrontal cortex function, consisted of 21 women and 23 men ranging in age from 20 to 79 years old (Bechara et al., 1994). Another "brain damage" control of participants with brain damage in areas other than the ventromedial prefrontal cortex were also used for this study (Bechara et al., 1994). These patients ranged in age from 20 to 71 years old

and consisted of 3 women and 6 men. Several of these participants had some form of memory defect (Bechara et al., 1994).

Procedure:

In designing the Iowa Gambling Task for their 1994 study, Bechara et al. created a simple card-based procedure. The participant sits in front of 4 decks of cards and is given $2,000 in fake money (Bechara et al., 1994). The researcher then instructs the participant that the game requires a long series of card selections from any of the four decks until they are instructed to stop (Bechara et al., 1994). After turning a card, subjects are given an amount of money that varies based on the card and the deck that card was in as a reward, but there is also a chance of penalty, which requires the participant to pay an amount of money (Bechara et al., 1994). The participants are instructed to maximize their profits (Bechara et al., 1994).

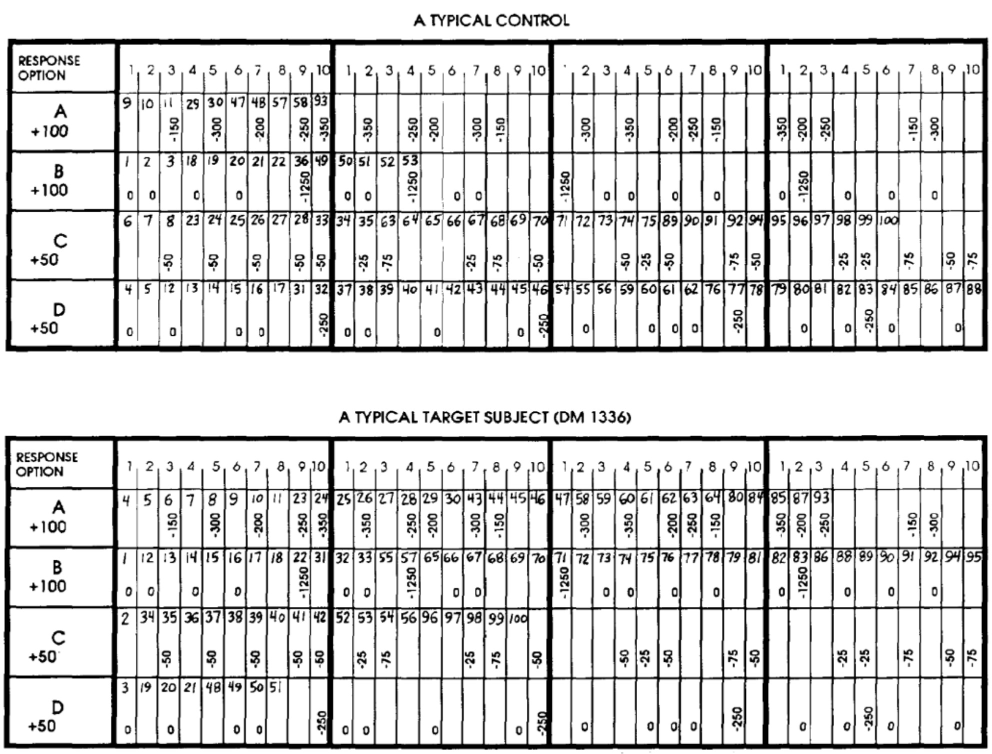


Fig. 1. *The top score card represents that of a typical control subject, and the bottom one that of a typical target subject. The hand-written numbers represent the profiles of card selections from the first to the 100th card. Control subjects select more from decks C and D, whereas target subjects select more from decks A and B.*

The four decks are each designated with a letter identification. The card reward and punishment values associated with each deck are shown in the figure above from Bechara et al.'s original 1994 publication. The figure also shows the breakdown of the order and number of cards picked by a typical control and a typical target subject (Bechara et al., 1994). Decks A and B pay out $100 a card, but penalties lead to net losses if you only play these decks (Bechara et al., 1994). In contrast, decks C and D pay out $50 a card but incur net gains in the long run (Bechara et al., 1994). Decks A and C had more frequent but lower magnitude punishments, while decks B and D had higher magnitude, lower frequency punishments (Bechara et al., 1994).

Results:

Bechara et al. found a significant difference in the number of advantageous and disadvantageous cards drawn by E.V.R. and other patients with ventromedial prefrontal cortex damage (1994). Variance calculations comparing the number of cards chosen from each deck by the normal controls and the target subjects demonstrated a significant interaction of group (controls vs. target subjects) with choice (A, B, C, D) ($F(3, 147) = 42.9$, $p < .00l$) (Bechara et al., 1994). Newman-Keuls *t*-tests revealed that the number of cards selected by normal controls from decks A or B (disadvantageous decks resulting in net loss) were significantly less than the number of cards selected by target subjects from the same decks (*p*s < .001), while the number of cards selected by controls from decks C or D (advantageous decks resulting in net gain) were significantly higher than the numbers selected by the target group (*p*s < .001) (Bechara et al., 1994). Within groups, comparison of subjects from different ages, gender, and education level yielded no statistical significance (Bechara et al., 1994).

In completion of the task, the typical control participant first selected cards from each of the decks, sampling the cards, before settling on the disadvantageous decks at first and then eventually switching to the advantageous decks, perhaps with occasional returns to the disadvantageous decks because of the higher payout (Bechara et al., 1994). In contrast, E.V.R. behaves like a normal participant at first, sampling all the decks and settling on the disadvantageous decks at first, but although he does make several selections from the advantageous decks, he returns frequently and systematically to the disadvantageous decks (Bechara et al., 1994). The other target subjects are reported as behaving similarly (Bechara et al., 1994).

The performance of the non-target brain damaged individuals was not significantly different from the normal controls (Bechara et al., 1994). Bechara et al. ran a one-way ANOVA on the difference in the total numbers of card selections from the advantageous decks minus the total numbers of selections from the disadvantageous decks obtained from normal and brain-damaged controls, which did not reveal a significant difference between the two groups ($F(1, 52) = 0.1$, $p > .1$), but the difference between the normal and the target subjects was again significant ($F(1, 50) = 74.8$, $p < .001$) (1994). Figure 3 from the original publication, included to the right, summarizes these results well.

Additionally, while the performance of the control group improved one month later, further a day after that, and still more six

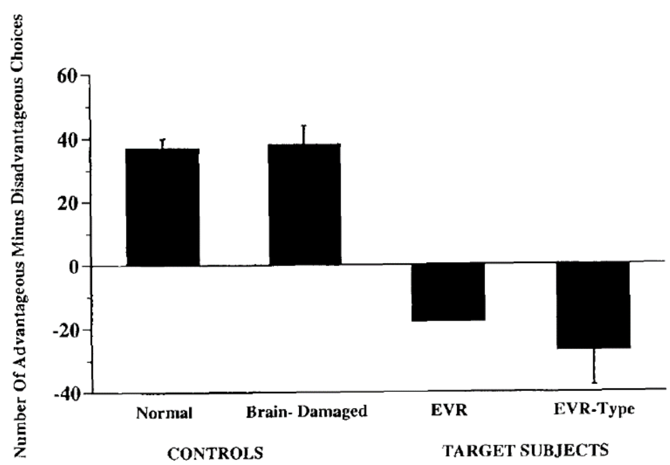


Fig. 3. *Total number of selections from the advantageous decks (C + D) minus the total numbers of selections from the disadvantageous decks (A + B) from a group of normal controls (n = 44), brain-damaged controls (n = 9), E.V.R., and E.V.R.-like subjects (n = 6). Bars represent means ± s.e.m. Positive scores reflect advantageous courses of action, and negative scores reflect disadvantageous courses of action.*

months later, E.V.R.'s performance and the performance of the target subjects remained impaired and did not improve over time (Bechara et al., 1994).

Unpublished results mentioned by Bechara et al. also reportedly indicated that E.V.R. and other patients with ventromedial prefrontal cortex lesions appeared more influenced by immediate punishment than delayed reward (1994).

### *Empirical Study: Adolescents' Performance on the Iowa Gambling Task: Implications for the Development of Decision Making and Ventromedial Prefrontal Cortex*

Background:

In their 2004 study, Hooper, Luciana, Conklin, and Yarger wanted to attempt to apply the Iowa Gambling Task, shown by lesion case studies like Bechara et al.'s in 1994 to be dependent on ventromedial prefrontal cortex function, to adolescents and children who do not yet have fully developed prefrontal cortexes. Noting that brain imaging of the ventromedial prefrontal cortex is difficult because of how close the area is to the eyes and face muscles, Hooper et al. felt this study could provide supporting evidence that this brain area was indeed responsible for assessment of risk at the hands of reward and punishment (2004). But, Hooper et al. also noted that children and adolescents have been previously shown to have other cognitive deficits in tasks tied to prefrontal cortex function, such as working memory and inhibition of impulse (2004). As a result of this, Hooper et al. gave the participants of their study additional tasks to measure these functions and cross-reference them with performance on the Iowa Gambling Task (2004). These included a Digit Span test to measure working memory and a go/no-go task to measure inhibition (Hooper et al., 2004). Working memory span and inhibitory control are both associated with the dorsolateral prefrontal cortex instead of the ventromedial prefrontal cortex (Hooper et al., 2004).

Hooper et al. hypothesized that the performance on the Iowa Gambling Task would improve with age, and that older age groups would outperform younger age groups, but that performance on the Iowa Gambling Task would correlate with performance on the Digit Span test and go/no-go task (Hooper et al., 2004).

Participants:

The sample used for this study consists of 145 total participants (79 girls, 66 boys) between the ages of 9 and 17 ($M$ = 12.89, $SD$ = 2.75) (Hooper et al., 2004). The participants were divided into three roughly equally sized groups by age: 9-10-year-olds, 11-13-year-olds, and 14-17-year-olds (Hooper et al., 2004). Age difference across these age groups was highly significant ($F(2, 142) = 590.10$, $p < .01$) (Hooper et al., 2004). The participating minors were mostly White (94%), right-handed (88%), tended to come from families with highly educated parents (years of education for mothers: $M$ = 16.15, $SD$ = 2.30; fathers: $M$ = 16.03, $SD$ = 2.79), and relatively high annual family incomes ($M$ = $89,111, $SD$ = $59,591) (Hooper et al., 2004). The participants also scored in the high average range of intellectual functioning on the Vocabulary (scaled score, $M$ = 12.81, $SD$ = 2.72) and Block Design (scaled score, $M$ = 12.85, $SD$ = 3.03) subtests of the third edition Wechsler Intelligence Scale for Children (WISC-III) or the third edition Wechsler Adult Intelligence Scale (WAIS-III), and also had above-average prorated full-scale IQs ($M$ = 116.56, $SD$ = 13.00) (Hooper et al., 2004).

Procedure:

The variant of the Iowa Gambling Task given to the participants was mostly the same as the version developed by Bechara et al. in 1994 except for a few key differences: Hooper et al. used a computerized version of the task, split the task into 5 blocks divided with breaks, and paid out real money with a starting amount of $5 instead of fake money with a starting amount of $2,000 (2004). The punishments and rewards were scaled accordingly (Hooper et al., 2004). Participants could keep their winnings at the end of the task (Hooper et al., 2004). Table 2 from Hooper et al.'s original 2004 publication, shown below, provides a more detailed breakdown of the decks, including which ones were advantageous and disadvantageous.

Table 2
*Comparison of Decks in the Iowa Gambling Task*

| Deck property | Deck 1 | Deck 2 | Deck 3 | Deck 4 |
|---|---|---|---|---|
| Win on each card selection | $0.25 | $0.25 | $0.10 or $0.15 | $0.10 or $0.15 |
| % of cards with losses | 50 | 10 | 50 | 10 |
| Range of losses | $0.35–$0.90 | $3.00–$3.25 | $0.05–$0.20 | $0.60–$0.65 |
| Net winnings after 20 selections | −$1.25 | −$1.25 | $1.25 | $1.25 |
| Classification | Disadvantageous, frequent punishment | Disadvantageous, infrequent punishment | Advantageous, frequent punishment | Advantageous, infrequent punishment |

The go/no-go task was also a computerized task (Hooper et al., 2004). For this task, participants were presented with a letter for 250 ms and had to press the spacebar in response to every letter except *X*, for which participants were told to withhold a response (Hooper et al., 2004). *X*'s occur 20% of the time while non-*X* letters occur 80% of the time (Hooper et al., 2004). Because of the lower frequency of withholding response, the task is designed to induce a need to inhibit responses when an *X* appears (Hooper et al., 2004).

The Digit Span test used was a subtest of the WISC-III (Hooper et al., 2004).

Results:

As described by Bechara et al. in 1994, participants in research involving the Iowa Gambling Test are expected to begin by sampling cards from each of the decks and move to the disadvantageous decks (decks 1 and 2 in Hooper et al.'s 2004 study) but then shift their choices towards the advantageous decks (decks 3 and 4) as the experiment progressed. Within each of the five blocks of 20 card selections, the number of advantageous cards selected relative to the number of disadvantageous cards selected was calculated and examined using a mixed-model ANOVA, with block (5 levels) as the within-subjects factor and age group (3 levels) and gender (2 levels) as between-subjects factors (Hooper et al., 2004). Because the assumption of sphericity was not met (Mauchly's $W = .75$, $p < .01$), the degrees of freedom for tests of within-subjects effects were conservatively adjusted using the Greenhouse-Geisser *F* test (Hooper et al., 2004). Between-subjects tests revealed a significant main effect of age group ($F(2, 139) = 4.98$, $p = .01$), but no significant main effect of gender or an Age Group × Gender interaction (Hooper et al., 2004). Tukey HSD post hoc tests indicated that the 14-17-year-olds made significantly more advantageous choices than the 9-10-year-olds ($p = .01$), but that the 11-13-year-olds did not differ from the other age groups (Hooper et al., 2004).

Within-subjects tests revealed a significant main effect of block ($F(3.5, 481.4) = 23.69$, $p < .01$), and a significant Age Group × Block interaction ($F(6.9, 481.4) = 2.53$, $p = .02$) (Hooper et al., 2004). There was no significant Gender × Block ($F(3.5, 481.4) = 0.27$, *ns*) or Age Group × Gender × Block ($F(6.9, 481.4) = 1.61$, *ns*) interaction (Hooper et al., 2004). Follow-up one-way ANOVAs indicated that there were significant differences between age groups in Block 4 ($F(2, 142) = 5.56$, $p = .01$) and Block 5 ($F(2, 142) = 3.36$, $p = .04$) (Hooper et al., 2004). Tukey HSD post hoc tests showed that the 14-17-year-olds chose more advantageously in Block 4 than the 9-

10-year-olds (*p* < .01) and 11-13-year-olds (*p* = .05) (Hooper et al., 2004). In Block 5, the 14-17-year-olds chose more advantageous than the 9-10-year-olds (*p* < .04) but not the 11-13-year-olds (*p* > .05) (Hooper et al., 2004).

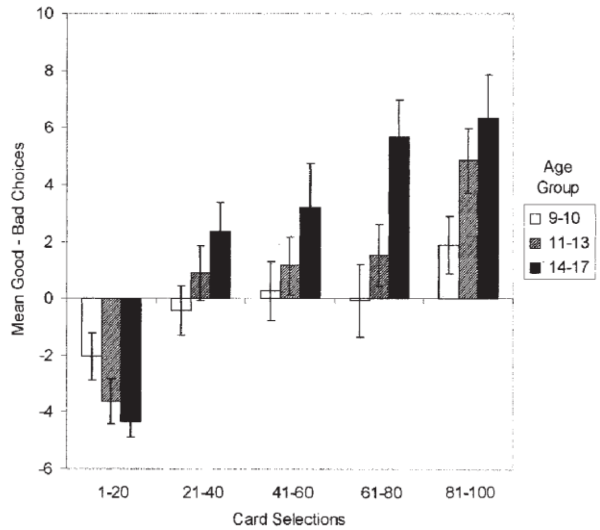


*Figure 1.* Mean (± *SE*) number of selections from advantageous – disadvantageous decks by healthy 9–10-year-olds (*n* = 49), 11–13-year-olds (*n* = 54), and 14–17-year-olds (*n* = 42) across blocks of 20 card selections in the Iowa Gambling Task.

In summary, Hooper et al. note that the 14-17-year-old group tended to switch preferences towards the more advantageous decks before the younger participants, and that female participants were more inclined to pick decks with infrequent punishments than male participants (2004). The mean advantageous ("good") and disadvantageous ("bad") choices by age group can be seen to the right in Figure 1 from Hooper et al.'s original 2004 publication.

In the go/no-go task, optimal performance involves both minimizing misses (not responding to a go trial) and avoiding false alarms (responding erroneously to a no-go trial) (Hooper et al., 2004). Summaries were calculated using signal-detection theory (Hooper et al., 2004). For each participant, the hit rate (number of correct responses to a go trial divided by the number of go trials) and the false alarm rate (number of no-go errors divided by the total number of no-go trials) were calculated and used to estimate $d'$, a measure of the overall discriminability between the go and no-go trials, assuming an equal variance Gaussian model (Hooper et al., 2004). A univariate ANOVA revealed significant main effects of age group ($F(2, 135) = 13.68$, $p < .01$) and gender ($F(1, 135) = 6.39$, $p = .01$) on $\hat{d}'$, but no significant Age Group × Gender interaction ($F(2, 135) = 1.98$, *ns*) (Hooper et al., 2004). On average, girls were better at the go/no-go task than boys (for girls, $M = 1.85$, $SD = 0.76$; for boys, $M = 1.50$, $SD = 0.81$) (Hooper et al., 2004). Tukey HSD post hoc tests were calculated to examine the main effect of age group (Hooper et al., 2004). They indicated that each age group significantly differed from the other age groups in their behavioral inhibition (as measured by $\hat{d}'$), with older adolescents better able to discriminate between go and no-go trials than younger adolescents (Hooper et al., 2004).

Follow-up analyses were conducted and revealed that the age and gender effects were operating on different components of $\hat{d}'$ (Hooper et al., 2004). There was a significant effect of age group on the false alarm rate ($F(2, 139) = 25.98$, $p < .01$), but the main effect of age group on the hit rate was only significant at a trend level ($F(2, 139) = 2.73$, $p = .07$) (Hooper et al., 2004). There was a significant effect of gender on the hit rate, ($F(1, 139) = 6.06$, p = .02), but not on the false alarm rate ($F(1, 139) = 1.44$, *ns*) (Hooper et al., 2004). Post hoc tests revealed that the false alarm rate of each age group was significantly different from that of the others, with 9-10-year-olds having the highest false alarm rate and 14-17-year-olds having the lowest false alarm rate (Hooper et al., 2004). This all showed that girls were better overall at inhibitory control, while older groups were also improved over younger groups (Hooper et al., 2004).

The Digit Span test has two components: forward and backward, which were treated as within-subject variables when calculating the effects of age group on memory span (Hooper et al., 2004). A mixed-model ANOVA was computed with task (two levels) as the within subjects factor and age group (three levels) and gender (two levels) as between-subjects factors (Hooper et al., 2004). Between-subjects tests showed a significant main effect of age group ($F(2, 138) = 13.30$, $p < .01$) (Hooper et al., 2004). Follow-up Tukey HSD post hoc tests indicated that each age group was significantly different from both other age groups, showing a performance improvement as participants aged (Hooper et al., 2004). Within-subjects effects indicated that there was a significant main effect of task ($F(1, 138) = 143.06$, $p < .01$), with participants having a lower backward span score than forward span score across all age groups (Hooper et al., 2004). There was not a significant Age Group × Task or Age Group × Task × Gender interaction (Hooper et al., 2004). The Gender × Task interaction approached significance ($F(1, 138) = 3.70$, $p = .06$), with girls performing slightly (but not significantly) better than boys on the forward span (span for girls, $M = 6.32$, $SD = 1.20$; span for boys, $M = 6.12$, $SD = 1.27$) and boys performing slightly (but not significantly) better than girls on the backward span (span for girls, $M = 4.72$, $SD = 1.14$; span for boys, $M = 4.95$, $SD = 1.36$) (Hooper et al., 2004).

An alpha level of .05 was used throughout all calculations to judge whether findings were significant (Hooper et al., 2004). The overall performance across all tasks can be seen in Table 3 below (Hooper et al., 2004).

Table 3
*Performance Means (and Standard Deviations) on the Three Cognitive Tasks by Age Group*

| Task variable | 9–10 years | 11–13 years | 14–17 years |
|---|---|---|---|
| Gambling task | | | |
| Advantageous − disadvantageous choices | −0.41 (23.77) | 4.78 (20.34) | 13.19 (21.31) |
| Infrequent − frequent punishment choices | 14.65 (15.56) | 23.00 (17.68) | 23.81 (17.17) |
| Go/no-go task | | | |
| Go/no-go hit rate | 0.83 (0.15) | 0.88 (0.11) | 0.89 (0.12) |
| Go/no-go false alarm rate | 0.44 (0.14) | 0.34 (0.11) | 0.24 (0.13) |
| Go/no-go $d'$ | 1.30 (0.78) | 1.71 (0.71) | 2.13 (0.70) |
| Digit Span test | | | |
| Forward span | 5.63 (1.02) | 6.30 (1.24) | 6.83 (1.15) |
| Backward span | 4.42 (1.05) | 4.81 (1.27) | 5.31 (1.28) |

In an attempt to investigate whether working memory or inhibitory memory performance correlated with performance on the Iowa Gambling task, Hooper et al. computed partial correlations between the task measures, controlling for age (2004). Both the net infrequent punishment choices and the backward digit span were correlated at a trend level ($p < .10$) with net advantageous choices on the Iowa Gambling Task, and go/no-go hit rate was significantly correlated with the net infrequent punishment choices on the Iowa Gambling Task (Hooper et al., 2004). But, because of the association between backward digit span and prorated full-scale IQ, it was unclear whether the modest association between Iowa Gambling Task performance and backward digit span was due to the variance associated with the overall cognitive abilities or to specific variance associated with working memory (Hooper et al., 2004). To address this uncertainty, Hooper et al. performed hierarchical linear regressions to predict net advantageous choices on the Iowa Gambling Task (2004). Age accounted for a significant proportion of the variance in each model, but none of the other variables produced a significant increase in the predictive power of the model, leading Hooper et al. to conclude in rejection of part of the hypothesis that it can't be discerned that scores on measures of global cognition, working memory, or behavioral inhibition significantly contribute to performance on the Iowa Gambling Task during adolescence (2004).

## *Discussion*

Together, the results of these two studies paint a fairly clear picture on the function of the ventromedial prefrontal cortex. Bechara et al.'s 1994 study makes a clear connection between real-life deficits and the performance of participants with ventromedial prefrontal cortex damage on the Iowa Gambling Task. Bechara et al. speculate that lesions to the ventromedial prefrontal cortex may leave these patients too sensitive to reward, so punishment is insufficiently noted; insufficiently sensitive to punishment while reward sensitivity is normal; or generally insensitive to future consequences, positive or negative, leaving behavior motivated purely by immediate prospects (1994). Bechara et al. mention that other studies point to the idea that patients like E.V.R. seem to be able to access the requisite knowledge to develop options of actions in scenarios, but seem to be unable to properly select the best option (1994). But while their study seems convincing in its qualifications of function of the ventrome, Bechara et al. acknowledge that these findings could still be the result of problems relating to working memory and suggest that further research be conducted into the matter since they cannot definitively prove that working memory is not the root cause of these deficits (1994).

One decade later, Hooper et al.'s child development study paints a picture that supports and strengthens the findings of Bechara et al. (2004). There was a clear improvement in performance on the Iowa Gambling Task across older age groups, which is best explained by the different levels at which the prefrontal cortexes, including the ventromedial section, are developed at these ages (Hooper et al., 2004). And further still, the researchers note that the oldest adolescents tested – 17-year-olds – still performed significantly lower than the accepted adult normal level, indicating that the ventromedial prefrontal cortexes of 17-year-olds may still not be developed to the point of adult-level decision making ability (Hooper et al., 2004). Hooper et al. also note that the 14-17-year-olds only began to differentiate themselves from the other groups in the fourth and fifth blocks of the task, while normal adults typically begin to develop an effective strategy in the third block (2004). The relative independence of performance on the Iowa Gambling Task and the other tasks (no significant correlation) seems to further cement the notion that the ventromedial prefrontal cortex has unique function that is specific to its own sector of the prefrontal cortex, fitting nicely with Bechara et al.'s observed results from 1994 that individuals with damage to only the ventromedial prefrontal cortex only show impairment in decision making and not other high-level tasks like working memory (Hooper et al., 2004).

While Hooper et al. acknowledge that performance differences could be related to procedural differences in their version of the task from Bechara et al.'s standard, or that poor performance in the younger participants could be the result of arbitrary card selection, the young children still showed some signs of eventual improvement and were noticeably upset when penalized, and the changes in procedure do not seem to show glaring invitations of significantly poorer performance across the board (2004).

Together, these two studies depict a clear implication that the ventromedial prefrontal cortex has unique functioning that has very noticeable, measurable effects in both laboratory and real-life decision making. This type of knowledge is instrumental for better understanding a brain area that cannot be easily scanned, and the results of these two papers will likely fuel many more studies localizing high-level tasks to specific sections of the prefrontal cortex and the human brain as a whole.

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