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Measuring reversal learning: Introducing the Variable Iowa Gambling Task in a study of young and old normals

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We developed a modification of the Iowa Gambling Task (IGT) to test whether it is primarily a measure of reversal learning. Named the Variable IGT (VIGT), the design involves a contingency reversal midway through the task. Two versions of the task enabled us to study the effect of a stronger prepotent response on the ability to identify and adapt to contingency reversal. A significant reversal delay was observed among normal young players with a more dominating reward response. Although transitory, this delay is comparable to the characteristic behavioural impairment observed in patients with damage to the ventromedial prefrontal cortex (VM), addicts, psychopaths and individuals with other self-destructive disorders: They persist in a previously rewarding behaviour despite long-term heavy costs.

We also conducted the VIGT in a sample of healthy elderly adults. Results from this sample do not support VM-like or risk-aversive theories of ageing but are inconclusive regarding the frontal ageing hypothesis. Overall, our findings indicate that the VIGT is a sensitive and versatile measure of reversal learning and will serve as a useful instrument in future studies of affective decision making, addiction, and other self-destructive behaviour.

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The Iowa gambling task (IGT) was developed in order to study the affective decision-making processes underlying social and economic behaviour (Bechara, Damasio, & Damasio, 2000; Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Tranel, & Damasio, 2000; Bechara et al., 2001). The basic design involves selecting valued cards from one of four decks. Two of the decks have high immediate rewards on each draw but have an overall negative expected value (disadvantageous), while the other decks have lower immediate gains and an overall positive expected value (advantageous). The task is highly ambiguous in that subjects know nothing about the probability of future rewards and losses but can only infer future outcomes from previous selections. It is this inherent ambiguity which is supposed to enable the task to measure the emotive decision-making system of the brain (Bechara, 2004). Research interest in this area originated from the curious behavioural consequences of certain frontal brain injuries, most famously described with the case of Phineas Gage (Harlow, 1848, 1868). Subsequent to injury to the prefrontal cortex, some individuals experienced marked deficiencies in social and financial decision making, despite having intact intellectual abilities (Bechara et al., 1999, 2000, 2001). Their characteristic behaviour resembled that of addicts, psychopaths, and other self-destructive individuals: They persisted in choices which led to long-term negative consequences to their health, relationships and financial stability, what Bechara describes as ''myopia for the future'' (Bechara, 2004, p. 32).

Recognising the potential importance the study of frontal-damaged individuals offered to social and emotional decision-making research, Bechara and colleagues investigated whether the IGT could serve as a measure of the observed frontal brain deficit (Bechara, 2004; Bechara et al., 2000; Damasio, 1996). They accomplished this by studying the performance of individuals with lesions, primarily bilateral, of the ventromedial prefrontal cortex (VM) and compared their behaviour to normal controls. As expected, the VM patients illustrated their characteristic addictive-like impairment of perseveration in an initial rewarding response despite long-term losses.

It was from these gambling studies with VM patients that Bechara and colleagues proposed the somatic marker hypothesis (Bechara, 2004; Bechara, Damasio, Tranel, & Damasio, 2005; Damasio, 1996). The central idea of this hypothesis is that external reward/loss stimuli induce certain biophysical states, such as emotions and feelings, or the memory of these states, that then influence subsequent decision processes. Bechara (2004, p. 37) proposes that the ''body loop'' component of this system is activated in situations of ambiguity, where outcomes of choices are highly unpredictable. Such a system is arguably what underlies the lay notion of ''gut feelings''. It is the body loop component of the somatic marker hypothesis that Bechara and colleagues contend is being tested by the IGT and therefore is the defective system in VM patients.

Other researchers have challenged this account by arguing that the impairment of VM patients is one of reversal learning (Fellows & Farah, 2003; Maia &

McClelland, 2004; Rolls, Hornak, Wade, & McGrath, 1994; Tomb, Hauser, Deldin, & Caramazza, 2002). This hypothesis focuses on the brief advantageous period of the high-reward deck. Because losses do not occur immediately, a prepotent response is established in favour of the disadvantageous deck. Normative behaviour requires the inhibition of this prepotent response once it is identified that the contingencies of the decks have changed (i.e., experienced losses reveal that the deck with high immediate rewards is actually disadvantageous over many draws. Proponents of this interpretation of the IGT contend that the VM deficit is the inability to inhibit the prepotent response for the disadvantageous deck.

Fellows and Farah (2005) tested this hypothesis by shuffling the decks and thereby removing the initial rewarding sequence of the IGT's disadvantageous decks. Although the overall expected value of the decks was equivalent to the IGT, VM patients no longer showed a decision-making deficit. This finding suggests that the establishment of a prepotent response is a key feature of the IGT and is necessary for the involvement of the decision-making system that is apparently defective in VM patients.

To investigate this further, we tested a modified version of the IGT: The Variable IGT (VIGT). The VIGT has a longer prepotent interval in which the immediate high reward deck is also the overall advantageous deck (higher expected value) for the first 60 selections. The deck contingencies are then reversed for the remaining 60 selections: The deck that was advantageous becomes disadvantageous and vice versa. We refer to this as the long prepotent (LP) version of the VIGT. We compared the LP version to a short prepotent (SP) design in which the first 60 selections follow the traditional IGT. Our objective in employing this task was to determine if reversal learning under ambiguity is the primary decision-making process being measured by IGT and whether the impairment in VM patients might be a pathological form of a normative reversal delay resulting from dominant prepotent responses. If the latter is true, we anticipated that switching to the advantageous deck would require significantly more draws among the LP players than the SP players.

This study does not address whether the reversal learning system is distinct from the somatic marker process proposed by Bechara and colleagues (2000), nor does it determine if IGT is primarily a measure of one of these systems. As Bechara et al. (2005) indicate in their response to challenges of the somatic marker hypothesis, the two hypotheses may not be incompatible. Given that a reversal requires some ''stop signal'', a somatic marker could serve as such an indicator (2005, p. 159).

We conducted the VIGT with a group of young and elderly individuals. The older group was studied in order to add to the growing literature on decision making in the elderly. A frontal age hypothesis has been proposed and supported by an IGT investigation among a subset of older adults (Denburg, Tranel, & Bechara, 2005; West, 1996). This theory posits that selective degeneration of the prefrontal cortex is one of the earliest consequences of normative ageing, an idea which is supported by neurobiological and neuropsychological research that has shown early comparative declines in the cellular and functional integrity of the prefrontal region. One of the main hypotheses to emerge from this model of the ageing brain is the prediction that elderly individuals will have weakened inhibitory control and will, in particular, have greater difficulty in suppressing prepotent responses when compared to a younger cohort (Dempster, 1992). Because the frontal ageing hypothesis argues that compromises to the prefrontal cortex occur earlier than other age-related cognitive declines, increased perseveration would be expected to occur among older adults who appear to have generally robust cognitive function. We wanted to investigate if this hypothesis would be supported by performance on the VIGT. If the ageing process leads to a VM-like prefrontal deficit, we anticipated that the older adults would select more disadvantageously on the SP version of the VIGT and that delay in reversal on the LP version would be greater among the older players than any observed delay in the young sample.

METHOD

Participants

We recruited 26 elderly individuals from the control population of the Alzheimer's Disease Research Center (ADRC) at the University of Southern California. Each year these individuals undergo an extensive battery of neuropsychological tests which evaluate their memory and general cognitive functioning. These individuals were eligible to participate in our study because of their neurological status: They have no history of dementia or mental illness and have normal or above normal scores on the ADRC's test battery.

Of our elderly participants, 73% were female. The average age of the participants was 80.5 years ($SD = 6.9$) and the average years of education was 16.6 ($SD = 3.5$).

For our young sample, we recruited 65 students from the University of California at Los Angeles through the California Social Science Laboratory recruitment system. The sample was 60% female with an average age of 21.9 years ($SD = 3.9$). The average number of years of education was 14.3 ($SD = 1.7$).

Prior to participant recruitment, our research project had been approved by the Committee for the Protection of Human Subjects at Caltech and the Institutional Review Boards at USC and UCLA.

Design and procedure

Participants were shown two cards from decks (constructed from standard playing cards) labelled with a square or diamond. Unlike the IGT, we use two rather than four decks, seeing no experimental advantage to the additional decks.

Subjects were told they would select cards to earn cash. Actual cash was awarded and earnings were kept by participants. They were told that their goal was to earn as much money as possible. A total of 120 cards were drawn, though the exact number of draws was not disclosed to participants. Cards were presented in a specific order, one card at a time, and no information was given about the values of future cards. On each selection, the participant chose one of two cards. Over the course of the task participants were told that they could switch between decks in whatever fashion they thought would most increase their earnings.

We divided the task into two 60-selection blocks. In the first block, one deck was an advantageous deck; the other was disadvantageous. The advantageous deck had a net gain of $2.50 for every 10 cards, the disadvantageous deck a net loss of $2.50. In the second block, the pay-out types reversed: The advantageous became disadvantageous and vice versa. The individual gains of the deck, +1.00 or +0.50, remained the same throughout the task. This ensured that participants would only learn about the change through the experience of losses rather than from a cue in the experimental design.

Two versions of the task were constructed (Figure 1). Version short prepotent (SP) models IGT for the first block of selections: the +1.00 deck is the disadvantageous deck, the +0.50 deck is advantageous. This version is regarded as having a short prepotent phase since, as in IGT, losses within the disadvantageous deck do not occur immediately. Version long prepotent (LP) has a first block in which the +0.50 deck is disadvantageous and the +1.00 is advantageous (the order of cards in this block was identical to those used in the second block of Version SP). The labels of the versions reflect the duration of the established prepotent response, the period for which the initial preference for the deck with high immediate rewards is reinforced. For SP this period lasts for several selections from the high reward deck, while for LP this period lasts for the entirety of the first block of selections.

Risk types reversed at the beginning of the second block. After the 60th card was selected, the +1.00 disadvantageous deck became advantageous for version SP and the +1.00 advantageous deck became disadvantageous for version LP. The experimental presentation did not alter with this reversal, only the magnitude of losses changed. Participants could therefore only learn of the risk reversal by attending to the losses associated with the decks.

Statistical procedures

The conventional analysis of IGT looks at the total selections from the advantageous deck. A majority of selections (greater than 50%) from a given deck is regarded as a preference for that deck. Shapiro-Wilk normality tests were conducted on the sum of advantageous selections for each 60 selection block in

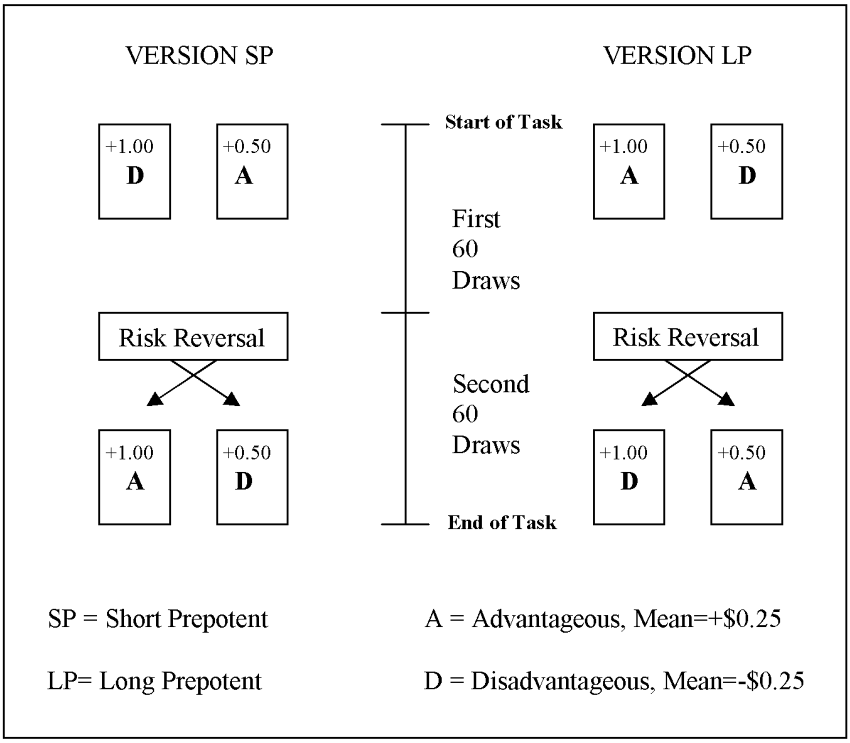

Figure 1. The Variable IGT (VIGT) presented a participant with two decks, one card at a time. Real cash was awarded. The monetary value of the card was unknown to the participant until it was selected and turned over. One deck had $1.00 gain on every card, the other had $0.50 gain. Cards in each deck occasionally had accompanying losses. The disadvantageous deck had an overall negative expected value (−$2.50 for every 10 cards). The advantageous deck had an overall positive expected value (+$2.50 for every 10 cards). As shown, version SP began with the +1.00 deck as disadvantageous, while LP began with the +1.00 deck as advantageous. The risk types switched after the 60th card was selected. The new risk types remained for another 60 draws. There was no change in the experimental presentation when the risk reversal occurred, only the magnitude of losses in the decks altered. Cards were presented in a specific order so that the blocks with the same risk types were identical between the two versions.

versions SP and LP. All but one group, the older version LP for the first block ($p = .009$), did not reject the null hypothesis of normality.

Within old and young groups we assessed whether players had a deck preference during a selection block using two-sided *t*-tests, testing if the total advantageous selections per block were equal to 30. Since we were also interested in preference trends between SP and LP players we assessed the main and interaction effects of version and interval for advantageous selections on the VIGT using analysis of variance. The interval variable refers to the six 20 card selection periods of the task. To examine the possible effect of age we included an age indicator variable into this model. No adjustments were made for multiple testing. All procedures were conducted with STATA Intercooled 8.2.

RESULTS

Young sample

Looking at the mean total advantageous selections for the young sample (all the selections from the deck with positive expected value), we found that for the first 60 selections both groups selected a majority of cards from the advantageous deck. The mean total was 34 (SD = 8.4) for the SP players and 42 (SD = 9.3) for the LP players. This preference for the advantageous deck was significant for both groups: SP: $t(32)=2.94$, $p < .01$; LP: $t(31) = 7.46$, $p < .001$.

After the 60th card was drawn, the risk of the deck types reversed for both versions, unbeknownst to the participants. The SP players appear to have identified the change, switching their preference to the advantageous deck that was formerly disadvantageous. They selected a mean total of 35 advantageous cards (SD = 12.2) during the second block of selections, showing a significant preference for the new advantageous deck: $t(32) = 2.17$, $p < .05$. While the SP players were able to recover their preference for the advantageous deck, the LP players were not. During the second block, LP players selected a mean total of 22 advantageous cards (SD = 15), which is a considerable divergence from their preference behaviour in the first block, $t(31) = -2.86$, $p < .01$.

To assess the difference in the trends of advantageous selections, we performed an ANOVA within the young sample. We tested for the main effects of version (SP or LP) and interval, where interval represented the subtotals of advantageous selections for every 20 selections of the task. We also tested the interaction of these two variables. As expected, a significant interaction effect was found for the version and interval variables. Unlike the SP players who increased their advantageous selections in a stepwise fashion, the LP players' emerging preference for this deck was less systematic and immediate: 2 (Version) $\times$ 6 (Interval) ANOVA: $F(5, 378) = 10.66$, $p < .001$. The SP players began selecting the majority of cards from the advantageous deck by the fifth interval of selections (second interval of second block), while the LP players never selected a majority from the advantageous deck, though their preference was moving towards the advantageous deck over the course of the second block (Table 1).

Prepotent dominance effects

Because of the findings between versions, we wanted to further investigate the relationship between a strong early preference on the task and delayed adaptation to the contingency reversal. To do this we classified each young participant

TABLE 1
Means (and standard deviations) of advantageous selections by 20 card intervals within the first and second block of the Variable Iowa Gambling Task (VIGT)

Group	*First block*			*Second block*		
	1–20	*21–40*	*41–60*	*61–80*	*81–100*	*101–120*
Young						
SP (n = 33)	9.1	11.3	13.8	9.5	11.6	13.5
	(3.5)	(4)	(4)	(5)	(5)	(4.5)
LP (n = 32)	11.9	14.8	15.6	6.3	6.9	9.2
	(3)	(5)	(4)	(5)	(6)	(6)
Aged						
SP (n = 14)	9.9	10.6	12	8.3	9.6	11.2
	(2)	(5)	(5)	(4)	(5)	(5)
LP (n = 12)	11.3	10	11.1	11.3	9.8	11.2
	(2.5)	(4)	(4)	(2.6)	(5)	(5.5)

Note: A mean of ten reflects an equal selection of advantageous and disadvantageous cards within the interval. SP is the short prepotent version and LP is the long prepotent version of the VIGT.

as exhibiting a ‘‘mild’’ or ‘‘strong’’ preference in the first block of 60 selections. Young players selected an average of 38.2 (*SD* = 9.7) advantageous cards in the first block. Players who selected fewer than 28 or greater than 48 advantageous cards were categorised as having a ‘‘strong preference’’. Thus, a player was considered to have a strong preference when he or she selected 1 standard deviation more or fewer advantageous cards from the average. Of the young players, 21 met this criterion; 14 were version LP players. To assess the delay in the players’ ability to re-establish their preference after the contingency reversal, we took the difference between the advantageous selections for cards 21–60 (first block) and 81–120 (second block). The first 20 cards for each block were excluded because this period was considered a learning period (i.e., the period required for normal populations to identify the advantageous deck on the IGT).

If there was no delay in reversal learning, we expected the difference in advantageous selections to be near to zero. If more advantageous cards were selected in the second block, then the difference would be some negative number, while selection of fewer advantageous cards in the second block would result in a difference of some positive number. For the players with no/mild preference the mean difference was +5.6 (*SD* = 11.5), whereas the mean was +10.2 (*SD* = 19.9) for those with a strong preference. Both means are significantly greater than zero, which suggests that players’ preferences in the first block did not match that of the second block and there was generally less optimal performance in the second block than the first: No/Mild Preference: $t(43)=3.25$, $p < .01$; Strong Preference: $t(20) = 2.35$, $p < .05$. The higher mean among the strong preference players suggests a more dominant prepotent response results in greater delay in contingency identification and preference adaptation.

Aged sample

The preference behaviour of older individuals dramatically differs from previously studied samples (Table 1). Elderly players selected approximately equally from both decks for the majority of the first block. In the first block the SP players selected a mean total of 32.5 advantageous cards ($SD = 9.4$), and the LP players selected a mean total of 32 cards ($SD = 9.4$). There was no significant preference for either deck observed for the SP or LP players: SP: $t(13) = 0.99$, $p < .34$; LP: $t(11) = 0.89$, $p < .40$.

After the reversal we again assessed preference behaviour by the number of advantageous cards selected (selections from the formerly disadvantageous deck). The SP players had a mean total of 29 ($SD = 11.8$) advantageous selections; the LP group had a mean total of 32 ($SD = 10$). When these findings were tested to determine if they showed a statistically significant preference for one of the two decks, we found no such preference for either group: *SP*: $t(13) = -0.27$, $p < .80$; LP: $t(11) = 0.77$, $p < .46$. This result was corroborated by an ANOVA analysis of the variables version and interval. No significant main or interactive effects were found.

Markedly dissimilar to the young, older players did not show any consistent preference for the disadvantageous or advantageous deck. We confirmed this difference by an analysis of variance of advantageous selections for the six intervals of the VIGT, conducting a separate ANOVA for each version of the task. Evaluating the results of the two analyses, we found significant main effects of age and interval for SP players, but no interactive effect: Interval: $F(5, 270) = 4.71$, $p < .001$; Age: $F(1, 270) = 4.27$, $p < .05$. Among the LP players, there was a significant interaction for the variables age and interval, indicating that, while the young players gradually select more advantageous cards over the course of the first and second blocks, the older adults select an equal proportion of disadvantageous and advantageous cards throughout: 6 (Interval) $\times$ 2 (Age) ANOVA: $F(5, 252) = 6.42$, $p < .001$.

DISCUSSION

Recent contention over the interpretation of the IGT has focused on whether the task is a measure of the somatic marker system or reversal learning. This debate primarily rests on one design feature of the IGT. Though the decks with high individual rewards are disadvantageous in the long-run, losses do not occur immediately. This creates a short period in which an overall preference for the high immediately rewarding decks is reinforced. With an objective to further elucidate whether the IGT is a measure of response perseveration under ambiguity, we developed a novel IGT-based task in which there is a contingency reversal after 60 selections. During this first block of selections, the short prepotent version of the task has the traditional IGT design (using two decks instead of four), while the long prepotent version has the deck with the high individual rewards as the long-term advantageous deck. When tested with our young sample, we found that LP players selected fewer advantageous cards after the contingency reversal. Compared to the SP players, the LP group demonstrated a significant delay in their ability to identify and adapt to the contingency reversal. This finding supports the conclusion that the IGT is primarily a measure of reversal learning.

Fellows and Farah tested this idea with a different approach (2005). In a study with lesioned subjects who were specifically damaged in either the VM or the dorsolateral prefrontal cortex (DLPC), they presented an IGT task with shuffled decks (i.e., they removed the short prepotent period in the disadvantageous decks). When VM patients completed this modified IGT, their characteristic impairment disappeared. Taken with our findings, this result provides strong support that establishing a prepotent response is essential for engaging the decision-making system that is impaired in VM patients. This finding could additionally account for the normal performance of VM patients on other reversal learning tasks, like the Wisconsin Card Sorting Task (WCST; Anderson, Damasio, Jones, & Tranel, 1991). When the task lacks ambiguity in rewards and losses or fails to establish a predominant reward response, normative reversal behaviour may not require the emotive decision-making system presumed to be defective in VM patients.

Two other results from our investigation offer more evidence of a correlation between the dominance of an established rewarding behaviour and future reversal ability. Among the young sample, we categorised players by the strength of their preference for a given deck during the first block of selections. This was done to isolate players with a more dominating prepotent response. We then compared the reversal behaviour among the different preference types by subtracting the total advantageous selections on the second block from the first block (excluding the 20 card learning period). Both groups had a difference significantly greater than zero, indicating that neither group of players' initial preferences exactly matched their preference in the second block. For players with a strong preference, however, the mean difference was much greater, supporting the conclusion that a more dominant prepotent response impedes later reversal learning ability.

Findings in the elderly sample might also be taken as an illustration that, in the absence of a prepotent response, detection and adaptation to a reward contingency change is unimpeded. Unlike the young sample, there was no apparent reversal learning impairment among the older players for either version of the task. This behaviour may be a direct consequence of the older adults' lack of an initial preference. Without a prepotent response, the emotive decision-making system directing reversal learning under ambiguity in the young remains inoperative in the older sample, making the evaluation of this system impracticable.

Other factors may have contributed to the contrasting behaviour in the old and young players. Differences in their motivation may be significant. For example, equivalent monetary rewards might have less value to older adults than young adults, resulting in divergent preference behaviour. Given that the young and old samples were recruited through research organisations, in which they are ongoing volunteers, we believe we selected samples of individuals who are highly motivated to participate and to follow the objectives outlined in the study.

We acknowledge that a deficiency in working memory could contribute to a contingency valuation deficiency, as observed in DLPC-damaged patients (Bechara, Damasio, Tranel, Anderson, 1998). The older participants undergo annual neuropsychological testing through the ADRC, testing which heavily focuses on memory functioning. All of these individuals have consistently performed normal or above normal on these tests. Moreover, the literature on gambling task studies indicates that the development of preferences depends more on the strength and frequency of emotional responses to reward and loss rather than recall of the numerical sequence of rewards and losses. For these reasons, we believe impairment in working memory cannot account for the performance of the older adults.

The discovery of a dopaminergic deficiency (reduced D_2-like receptors) in the frontal cortex of elderly women supports an age-associated explanation of the VIGT performance via valuation insensitivity (Kaasinen et al., 2002). The existence of such an impairment is further bolstered by Carstensen, Pasupathi, Mayr, and Nesselroade's (2000) socioemotional selectivity theory which argues that an insensitivity to emotionally negative stimuli results from normative ageing. If the older participants were insensitive to the monetary values of cards, this could explain why strong preferences were not observed. We note, however, that this idea contradicts observations made during our experiments. At the conclusion of the task, the interviewer asked subjects to describe their selection strategy. Many of the older adults indicated that they were trying to avoid any losses. When they discovered that they could not, they decided that there was no real difference between the decks. Although anecdotal, these observations nonetheless give more support to a comparative valuation deficiency rather than a global insensitivity to loss.

It is also conceivable that life experiences play a role. Having grown up during the Great Depression, the aged individuals might have acquired unique ways of assessing economic rewards and losses. Whatever the explanation, the older adults we investigated behave like no other population previously studied: They do not demonstrate a deck preference on either version of the task. This evidence goes against two of the main theories of risk decision making in the elderly. One folk idea of ageing is that risk-aversion increases in later life. If elderly adults are risk-averse, we would expect to see more selections from the advantageous decks, avoiding heavy losses, rather than a seemingly random selection strategy. A contrary view is the ‘‘frontal lobe hypothesis of ageing’’ which argues that the prefrontal brain degrades with age, possibly leading to a VM-like deficit among elderly adults (West, 1996, p. 272). Denburg et al. (2005) present evidence for a VM-deficit in a subset of the elderly. We do not observe such a deficit among our elderly sample, though it should be noted that the small number of elderly participants prevented us from determining if a subset of the older adults had a VM-like deficit. The VIGT used two decks rather than the IGT’s four-deck design, which further limits our ability to compare the elderly sample’s performance on this task with performance of aged samples on the IGT. Moreover, our elderly sample might not be directly comparable to Denburg et al.’s since their subjects were recruited from the general population, while our older adults came from an Alzheimer’s research group in which they have undergone rigorous neuropsychological examination. Despite the non-appearance of a VM-like impairment, the aged sample’s apparent insensitivity to reward and loss may still involve a frontal brain deficit. Although the small sample of elderly participants precludes any strong conclusions about their performance, the findings reiterate the need and value of further study of the decision-making behaviour of older adults.

Maia and McClelland (2004) argue that a reversal learning interpretation of the IGT is an alternative to the somatic marker hypothesis. Like Bechara and colleagues (2005), we see no reason why the two systems are not compatible. If the two hypotheses can be synthesised, more explication is required to explain why a proposed ‘‘stop signal’’ is defective for VM patients. If these patients have a sufficient emotive-based system to establish a preference for immediate rewards, why does the system fail when contingencies change? Findings from the various forms of the IGT point to a distinct system for the establishment of a prepotent reward response and for the reversal of previously rewarding behaviours when reward contingencies have changed. Primate and human neuroimaging studies of reversal learning tasks, specifically Go/No-Go and ID/ED tasks, implicate the amygdala, prefrontal orbitofrontal cortex and subgenual sector of the anterior cingulate cortex as the brain regions central to this cognitive function (Mitchell, Colledge, Leonard, & Blair, 2002; Owen, Roberts, Polkey, Sahakian, & Robbins, 1991; Rogers et al., 1999; Rolls et al., 1994). Further work should focus on the process by which the prepotent response engages this reversal system in situations of reward ambiguity, which distinct brain regions are involved and how these systems are integrated.

The implications of the findings in the young sample highlight several directions for further research. No other gambling or reversal learning task has produced such a transitory impairment in normal individuals. That we observe a reversal learning delay among the young LP players indicates that VIGT might serve as a more sensitive measure of reversal learning. VIGT is also a more versatile measure in that the prepotent period can be defined by the investigator and allow for the study of the relationship between the temporality of the prepotent response and subsequent reversal performance. Based on a comparable gambling task with a varying reward structure, Newman, Patterson, and Kosson (1987) demonstrated that disadvantageous perseveration of a prepotent response among prison psychopaths diminished when participants were required to wait a few seconds before making a card selection. As with our findings, this evidence suggests an important role for the duration of an experienced prepotent response on future contingency detection and behaviour reversal. Continued investigation in this area should evaluate the individual and interactive effects of the strength of a prepotent response (measured by the number of rewarding experiences/cards) and the duration of the response (the time involved with a given experience/selection) on reversal learning.

Since the IGT has been able to successfully measure the impairment of VM-damaged populations, it has become a tool in the study of other special populations, such as pathological gamblers, addicts, and psychopaths (Bechara, 2003; Bechara & Damasio, 2000; Cavedini, Riboldi, Keller, D'Annucci, & Bellodi, 2002; Losel & Schmucker, 2004). Like VM patients, these populations exhibit myopic financial and social decision making. For a brief period, the VIGT is able to induce this characteristic behaviour among normal individuals under the kind of reward ambiguity inherent to real-life social and financial decisions. Not only does this finding indicate that VIGT can serve as a powerful instrument in the study of self-destructive populations, but it also offers support for the view of addiction as an aberrant learning disorder (Grant, Contoreggi, & London, 2000; O'Brien, Childress, Ehrman, & Robbins, 1998; Ryan, 2002; Tiffany & Conklin, 2000). Further investigation into these findings will inform a wide range of scientific research including decision making under ambiguity, addiction, and ageing.

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REFERENCES

Anderson, S. W., Damasio, H., Jones, R. D., & Tranel, D. (1991). Wisconsin card sorting test performance as a measure of frontal lobe damage. *Journal of Clinical and Experimental Neuropsychology*, 3, 909–922.

Bechara, A. (2003). Risky business: Emotion, decision-making and addiction. *Journal of Gambling Studies*, *19*, 23–51.

Bechara, A. (2004). The role of emotion in decision-making: Evidence from neurological patients with orbitofrontal damage. *Brain and Cognition*, *55*, 30–40.

Bechara, A., & Damasio, H. (2000). Decision-making and addiction: I. Impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequences. *Neuropsychologia*, *40*, 1675–1689.

Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision-making, and the orbitofrontal cortex. *Cerebral Cortex*, *10*, 295–307.

Bechara, A., Damasio, H., Damasio, A. R., & Lee, G. P. (1999). Different contributions of the human amygdala and ventromedial prefrontal cortex to decision-making. *Journal of Neuroscience*, *19*, 5473–5481.

Bechara, A., Damasio, H., Tranel, D., & Anderson, S. W. (1998). Dissociation of working memory from decision making within the human prefrontal cortex. *Journal of Neuroscience*, *18*, 428–437.

Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (2005). The Iowa gambling task and the somatic marker hypothesis: Some questions and answers. *Trends in Cognitive Science*, *9*, 159–162.

Bechara, A., Dolan, S., Denburg, N., Hindes, A., Anderson, S. W., & Nathan, P. E. (2001). Decision-making deficiency, linked to a dysfunctional ventromedial prefrontal cortex, revealed in alcohol and stimulant abusers. *Neuropsychologia*, *39*, 376–389.

Bechara, A., Tranel, D., & Damasio, H. (2000). Characterization of the decision-making deficiency of patients with ventromedial prefrontal cortex lesions. *Brain*, *123*, 2189–2202.

Carstensen, L. L., Pasupathi, M., Mayr, U., & Nesselroade, J.R. (2000). Emotional experience in everyday life across the adult life span. *Journal of Personality and Social Psychology*, *79*, 644–655.

Cavedini, P., Riboldi, G., Keller, R., D'Annucci, A., & Bellodi, L. (2002). Frontal lobe dysfunction in pathological gambling patients. *Society of Biological Psychiatry*, *51*, 334–341.

Damasio, A. R. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences*, *351*, 1413–1420.

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review*, *12*, 45–75.

Denburg, N. L., Tranel, D., & Bechara, A. (2005). The ability to decide advantageously declines prematurely in some normal older persons. *Neuropsychologia*, *43*, 1099–1106.

Fellows, L. K., & Farah, M. J. (2003). Ventromedial frontal cortex mediates affective shifting in humans: Evidence from a reversal learning paradigm. *Brain*, *126*, 1830–1837.

Fellows, L. K., & Farah, M. J. (2005). Different underlying impairments in decision-making following ventromedial and dorsolateral frontal lobe damage in humans. *Cerebral Cortex*, *15*, 1558–1563.

Grant, S., Contoreggi, C., & London, E. D. (2000). Drug abusers show impaired performance in a laboratory test of decision-making. *Neuropsychologia*, *38*, 1180–1187.

Harlow, J. M. (1848). Passage of an iron bar through the head. *Boston Medical and Surgical Journal*, *39*, 389–393.

Harlow, J. M. (1868). Recovery from the passage of an iron bar through the head. *Publications of the Massachusetts Medical Society*, *2*, 327–347.

Kaasinen, V., Kemppainen, N., Nagren, K., Helenius, H., Kurki, T., & Rinne, J. O. (2002). Age-related loss of extrastriatal dopamine D_2-like receptors in women. *Journal of Neurochemistry*, *81*, 1005–1010.

Losel, F., & Schmucker, M. (2004). Psychopathy, risk taking and attention: A differential test of the somatic marker hypothesis. *Journal of Abnormal Psychology*, *113*, 522–529.

Maia, T. V., & McClelland, J. L. (2004). A reexamination of the evidence for the somatic marker hypothesis: What participants really know in the Iowa gambling task. *Proceedings of the National Academy of Sciences*, *101*, 16075–16080.

Mitchell, D. G., Colledge, E., Leonard, A., & Blair, R. J. (2002). Risky decisions and response reversal: Is there evidence of orbitofrontal cortex dysfunction in psychopathic individuals? *Neuropsychologia*, *40*, 2013–2022.

Newman, J. P., Patterson, C. M., & Kosson, D. S. (1987). Response perseveration in psychopaths. *Journal of Abnormal Psychology*, *96*, 145–148.

O'Brien, C. P., Childress, A. R., Ehrman, R., & Robbins, S. J. (1998). Conditioning factors in drug abuse: can they explain compulsion? *Journal of Psychopharmacology*, *12*, 15–22.

Owen, A. M., Roberts, A. C., Polkey, C. E., Sahakian, B. J., & Robbins, T.W. (1991). Extra-dimensional versus intra-dimensional set shifting performance following frontal-lobe excisions, temporal-lobe excisions or amygdalo-hippocampectomy in man. *Neuropsychologia*, *29*, 993–1006.

Rogers, R. D., Owen, A. M., Middleton, H. C., Williams, E. J., Pickard, J. D., Sahakian, B. J., et al. (1999). Choosing between small, likely rewards and large, unlikely rewards activates inferior and orbital prefrontal cortex. *Journal of Neuroscience*, *20*, 9029–9038.

Rolls, E. T., Hornak, J., Wade, D., & McGrath, J. (1994). Emotion-related learning in patients with social and emotional changes associated with frontal lobe damage. *Journal of Neurology, Neurosurgery and Psychiatry*, *57*, 1518–1524.

Ryan, F. (2002). Attentional bias and alcohol dependence: A controlled study using the modified Stroop paradigm. *Addiction and Behavior*, *27*, 471–482.

Tiffany, S. T., & Conklin, C. A. (2000). A cognitive processing model of alcohol craving and compulsive alcohol use. *Addiction*, *95*, S145–S153.

Tomb, I., Hauser, M., Deldin, P., & Caramazza, A. (2002). Do somatic markers mediate decision on the gambling task? *Nature Neuroscience*, *5*, 1103–1104.

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Developmental Neuropsychology*, *13*, 87–96.