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BRIEF COMMUNICATION

Failure to Learn from Repeated Mistakes: Persistent Decision-Making Impairment as Measured by the Iowa Gambling Task in Patients with Ventromedial Prefrontal Cortex Lesions

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Abstract

Although frontal patients show impaired decision-making on the Iowa Gambling Task (IGT), there has been no follow-up study to date to determine whether there is recovery of function over time. We examined neurological participants' performance on repeated administrations of the IGT over the course of 6 years. We found that, while non-neurological participants showed considerable improvement due to practice effects on the IGT, patients with ventromedial prefrontal cortex (VMPFC) damage persisted in showing impaired performance on each retest. These results validate the clinical observations that VMPFC dysfunction does not appear to be subject to autonomous recovery over time in real-life. (*JINS*, 2012, *18*, 927–930)

Keywords: Decision making, Prefrontal cortex, Neuropsychological tests, Clinical psychology, Diagnosis, Reliability, Choice behavior

INTRODUCTION

The Iowa Gambling Task (IGT) was the first tool created to detect the elusive decision-making impairment of patients suffering from damage to the ventromedial prefrontal cortex (VMPFC). The IGT was perhaps successful in detecting the decision-making impairment of VMPFC patients because it mimics real-life decisions. The task is carried out in real-time, and it resembles real-world contingencies. It factors reward and punishment (i.e., winning and losing money) in such a way that it creates a conflict between an immediate, luring reward, and a probabilistic punishment. As in real-life, the task offers choices that may be risky, and there is no obvious explanation of each option's respective reward and loss schedule. Each choice is uncertain because a precise calculation or prediction of the outcome of a given choice is not possible. To succeed at the task, participants must learn which decks have a positive expected value or negative expected value.

The development of the IGT enabled researchers to detect these patients' decision-making impairment in the laboratory, measure it, and investigate its possible causes. This work has drawn attention to the potential value in studying the neural basis of decision-making, and in bringing this question to the laboratory through the use of structured decision-making tasks involving choices that mimic real-life situations in the way they factor uncertainty, reward, and punishment. As a result, a large body of subsequent research has used the IGT to study the decision-making impairment associated with many neurological and neuropsychiatric conditions (Bechara, 2010; Buelow & Suhr, 2009).

Here, we test the stability of decision-making ability over time in patients with VMPFC damage and normal participants. Past studies of the IGT indicate that non-neurological participants show improvement with retesting (Bechara, Damasio, & Damasio, 2000). This improvement is typical of

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frontal lobe tests (e.g., the Wisconsin Card Sorting Test) in that once the participant gradually discovers the rules of the task, the task becomes easy, and performance improves over time.

Although patients with a variety of other neurological impairments often recover significant function over time (e.g., Pascual-Leone, Amedi, Fregni, & Merabet, 2005; Stone, Patel, Greenwood, & Halligan, 1992; Wilson & Davidoff, 1993), clinical observations have often noted that VMPFC lesion patients do not recover their judgment and decision-making deficits over time, even when the damage is incurred very early on in life and the potential for recovery is optimal (Anderson, Bechara, Damasio, Tranel, & Damasio, 1999). However, empirical evidence that supports this clinical impression remains lacking. Thus the primary goal of this study is to directly address the question of whether patients with bilateral lesions of the VMPFC show improvement in decision-making ability over time.

METHODS

Participants

All non-neurological (hereafter referred to as "normal") participants were relatives or friends who accompanied the patients to the hospital. Patients with VMPFC lesions were selected from the Patient Registry of the University of Iowa's Division of Behavioral Neurology & Cognitive Neuroscience. Lesions were due to frontal meningioma in three participants, AcoA aneurysm and clip in five participants, a cyst in one participant, and a surgically removed pituitary tumor that invaded the orbital frontal cortex region in one participant. All VMPFC lesion patients had undergone basic neuropsychological and neuroanatomical characterization. All participants provided informed consent, which was approved by the appropriate human subject committees at the University of Iowa.

The selection criterion for normal participants was the absence of a history of mental retardation, learning disability, neurological disorder, psychiatric disorder, substance abuse, or any systemic disease capable of affecting the central nervous system. The criteria were also to exclude individuals with a history of head trauma (open head injuries or closed head trauma with loss of consciousness), as well as those who were currently on medications that affect the central nervous system (e.g., Prozac or antihistamines) that they should not discontinue. The selection of VMPFC lesion patients conformed to the above criteria for normal controls (except the neurological disease) with the following additional criteria: (1) a stable and chronic lesion (onset was at least 3 months before the experiment) and (2) bilateral involvement of the ventromedial cortices.

The number, gender, age, and years of education of normal participants and VMPFC lesion patients who participated in the study are presented in Table 1. There were no significant differences in age, gender, and education between the two groups. Participants were tested three times over the course of 6 years.

Materials

The general premise of the IGT is that participants must choose between decks of cards that yield high immediate rewards but larger probabilistic losses or decks that yield smaller immediate rewards with smaller probabilistic losses. The two decks with higher rewards and higher losses have a net value that is negative. Participants who favor these "disadvantageous" decks will lose money over the course of the game. Thus, the higher immediate rewards make these decks tempting, but they are ultimately poor choices. Conversely, the two decks that have smaller rewards and losses have an overall positive net value. The decks are presented on a computer screen and labeled A', B', C', and D'. Every time the participant picks a card from a deck, a message is displayed on the screen indicating the amount of money the participant has won or lost. Specifically, after selecting a deck with a reward, the following message is displayed: "Win $ X!". When the gain is followed by a loss/punishment, the following message is displayed: "Win $ X! but lose $ Y". Different audio feedbacks are also given for gains and losses. A green bar at the top of the screen displays the cumulative monetary reward. Once the money is added or subtracted from the cumulative reward, the face of the card disappears, and the participant can select another card.

Procedures

Participants were instructed to select one card at a time from any of the four decks visible on the screen. They were not told how much money could be won or lost, when the game would end, or the reward schedule of the decks. Finally, participants were asked to treat the play money in the game as if it were real money. The interval between Time 1 and Time 2 of testing was an average of one year. The interval between Time 2 and Time 3 of testing was an average of 5 years.

Table 1. Demographic data of participants

	Patients	Normal	
N	10	30	
Gender (male, female)	(5, 5)	(15, 15)	χ^2 (1) = 0.000, p = 1.000
Age (years; mean±SD)	53.5 ± 13.6	53.5 ± 14.0	t(38) = 0.007, p=0.995
Education (years; mean±SD)	13.1 ± 2.3	12.8 ± 2.0	t(38) = −0.431, p = 0.669

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Data were analyzed with the Statistical Package for the Social Sciences for Windows, Version, 17.0 (SPSS Inc., Chicago, IL). Demographic variables were compared between normals and patients using independent two sample *t* tests and χ^2 tests. We subdivided the 100 card selections into five blocks of 20 cards. For each block, we subtracted the number of selections from disadvantageous decks from the number of selections from advantageous decks, to derive a score for that block (e.g., (C'+D') – (A'+B')). A score above zero suggested that the participants were selecting cards advantageously, and a score below zero suggested disadvantageous selection. Repeated measures analysis of variance (ANOVA) tests (3 times × 5 blocks) were conducted to analyze the profile of the IGT performance. A total net score was also calculated by taking the sum of all five blocks in a testing session. To evaluate whether repeated testing with the IGT could distinguish patient performance from normal performance, we used a repeated measures ANCOVA with one between-subjects factor (normal *vs.* patient). To control for any demographic differences, we included age and education as covariates when comparing normal participants and patients.

RESULTS

Behavioral Performance in Normal Participants

Figure 1 presents the scores of all participants (normal and patients) across all five blocks, as well as total net scores.

Normal controls gradually switched their preferences toward the advantageous decks (C' and D') and away from the disadvantageous decks (A' and B') in each testing session, as reflected by increasingly positive scores across blocks (i.e., total number of cards selected from C'+D' minus number of cards selected from A'+B' in each block of 20 cards). Furthermore, in normal participants, the scores (by blocks or total) all improved as a function of repeated testing (see Figure 1A). A repeated measures ANOVA test (3 sessions × 5 blocks) revealed a significant difference in session (Greenhouse-Geisser adjusted $F(1.332, 38.641) = 126.62$; $p < .001$), block (Greenhouse-Geisser adjusted $F(2.767, 80.244) = 53.66$; $p < .001$), and the interaction between block and session (Greenhouse-Geisser adjusted $F(4.630, 134.276) = 2.68$; $p = .027$). Block effects were significantly more accentuated during the second and third testing sessions. Bonferroni *post hoc* tests using pairwise comparisons revealed a significant improvement in scores from Session 1 to Session 2 and from Session 2 to Session 3 (all $p < .05$).

Normal participants showed improved total net scores (summed across all blocks) with each retesting. A repeated measures ANOVA on total net scores found a main effect of testing session (Greenhouse-Geisser adjusted $F(1.332, 38.631) = 126.62$, $p < .001$). Paired-samples *t* tests revealed that the total net score increased significantly from Time 1 to Time 2 ($t(29) = -8.068$; $p < .001$) and from Time 2 to Time 3 ($t(29) = -10.679$; $p < .001$).

Behavioral Performance in VMPFC Patients

Figure 1B shows that VMPFC patients mainly selected from disadvantageous decks when retested with the IGT. This is reflected by mostly negative scores in each individual block and the total net scores from all blocks. Although performance appears to improve somewhat as a function of repeated testing, this change was not significant: a repeated measures ANOVA (3 testing sessions × 5 blocks) did not indicate a significant difference in testing session, block, or the interaction between testing session and block (all $p > .05$). Patients did not show improved total net scores with each retesting. A repeated measures ANOVA on total net scores did not find a main effect of testing session ($p > .05$).

Impaired IGT Performance in Patients Relative to Normal Participants

A repeated measures ANCOVA test with between-subject factor of group (normal or VMPFC patient) and covariates of age and education was used for the three sessions of IGT testing. It revealed a significant session × group interaction effect (Greenhouse-Geisser adjusted $F(1.576, 56.733) = 8.470$; $p = .001$). This interaction reflects that

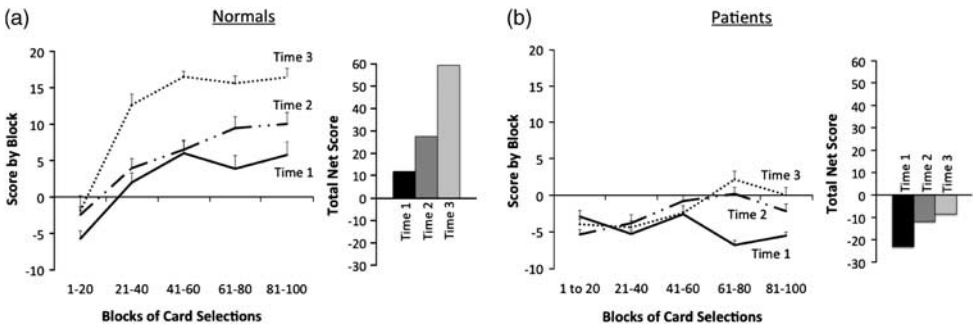

Fig. 1. (A,B) Line graphs show normal participant and patient scores ((C'+D')–(A'+B')) across five blocks of 20 cards at three times expressed as mean + *SE*. Bar graphs show the mean total net scores (sum of scores across all five blocks) on each task. Positive net scores reflect advantageous (non-impaired) performance, while negative net scores reflect disadvantageous (impaired) performance.

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normal participants showed improvement across the three testing sessions, while the patients' performance did not improve significantly with retesting. There was not a significant session, session × age, or session × education effect (all $p > .05$). As predicted, there was a significant between-subjects effect of group ($F(1,36) = 49.237$; $p < .001$), but not age or education (all $p > .05$), indicating that normal participants performed better than patients regardless of age or education. *Post hoc* analysis showed that normal participants outperformed the patients significantly on each testing session ($p < .001$).

DISCUSSION

The results of this study confirm our hypothesis that patients with bilateral lesions of the VMPFC do not show recovery of decision-making capabilities over time, and persist in making disadvantageous decisions as measured by the IGT, although one could make an argument for some minimal recovery at best. These results confirm clinical observations that the decision-making impairment of patients with VMPFC damage does not recover over time, even when the damage is acquired very early on in life (Anderson et al., 1999). Although recovery of function is often observed in several other domains, these findings support the notion that brain plasticity cannot compensate for the decision-making impairment associated with VMPFC damage.

The lack of improvement during retesting in VMPFC patients has significant implications, given the fact that disturbances of decision-making are among the most devastating consequences of focal brain damage. More so than impairments of language or movement, impaired decision-making leads to loss of independence and delays rehabilitation. Yet we lack a comprehensive survey of which lesions cause which specific defects, and when spontaneous recovery occurs. We do not know which specific regions are responsible for this plastic compensation, nor do we know its timing. This study enlarges our understanding of the recovery from impairments in decision-making caused by bilateral damage of the VMPFC.

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