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Decision-making in amnesia: Do advantageous decisions require conscious knowledge of previous behavioural choices?

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Abstract

Previous work has reported that in the Iowa gambling task (IGT) advantageous decisions may be taken before the advantageous strategy is known [Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science*, 275, 1293–1295]. In order to test whether explicit memory is essential for the acquisition of a behavioural preference for advantageous choices, we measured behavioural performance and skin conductance responses (SCRs) in five patients with dense amnesia following damage to the basal forebrain and orbitofrontal cortex, six amnesic patients with damage to the medial temporal lobe or the diencephalon, and eight control subjects performing the IGT. Across 100 trials healthy participants acquired a preference for advantageous choices and generated large SCRs to high levels of punishment. In addition, their anticipatory SCRs to disadvantageous choices were larger than to advantageous choices. However, this dissociation occurred much later than the behavioural preference for advantageous alternatives. In contrast, though exhibiting discriminatory autonomic SCRs to different levels of punishment, 9 of 11 amnesic patients performed at chance and did not show differential anticipatory SCRs to advantageous and disadvantageous choices. Further, the magnitude of anticipatory SCRs did not correlate with behavioural performance. These results suggest that the acquisition of a behavioural preference – be it for advantageous or disadvantageous choices – depends on the memory of previous reinforcements encountered in the task, a capacity requiring intact explicit memory.

Keywords: Amnesia; Decision-making; Explicit memory; Implicit memory; Reinforcement; Somatic marker

1. Introduction

Decision-making is commonly perceived as a highly rational and conscious process during which arguments in favour or against a behavioural choice are compared. Evidence for this view is our ability to make decisions that are unpleasant momentarily, but in the long term may be advantageous. However, the assumption that decision-making is always conscious and independent of emotional factors has recently been challenged. In their somatic-marker hypothesis, Damasio (1994, 1998) and Damasio, Tranel, and Damasio (1991) propose that rational cognitive processes involved in decision-making are assisted by emotion-related signals ('somatic markers'). According to the theory, somatic markers may be present before full conscious knowledge of the 'goodness' of a choice is available and they may bias decisions away from a potentially disadvantageous choice whether we are consciously aware of them or not. The hypothesis further proposes that the critical region for the acquisition of somatic markers is the ventromedial prefrontal cortex (PFC).

Support for these assumptions comes from studies with the 'Iowa gambling task' (IGT, see Bechara, Damasio, Damasio, & Anderson, 1994). In this task participants are shown four decks of cards and asked to select cards from these decks. On each trial they win some money, but on some trials they are punished and loose money. Unbeknownst to them, the immediate gain on decks C and D is small, but the possible loss is even smaller,

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resulting in the long run in a small benefit. On decks A and B the gain is large, but the possible loss is even larger, which in the long run results in a net loss. Healthy participants begin the IGT with selecting cards from all four decks, but quickly learn to prefer the advantageous decks. In addition, they show larger anticipatory skin conductance responses (SCRs) prior to selecting a card from the disadvantageous compared to the advantageous decks, which is in line with the notion that somatic markers assist the decision-making process in the IGT. Further, several studies have found that patients with ventromedial PFC damage make more disadvantageous than advantageous choices in the IGT (Bechara, Damasio, Tranel, & Damasio, 1997; Bechara, Tranel, & Damasio, 2000; Fellows & Farah, 2005; but see Manes et al., 2002), a finding taken as evidence for an insensitivity of these patients to future consequences of current actions (Bechara, Tranel, Damasio, & Damasio, 1996).

However, some conclusions from studies using the IGT have recently been questioned. One source of disagreement concerns the role of ventromedial PFC in decision-making. Some authors propose that a reversal-learning deficit may better explain the card-choosing behaviour of ventromedial PFC patients than an insensitivity to future outcomes, since patients must shift in responding away from the risky decks that initially seem rewarding, but are gradually associated with high punishment (Clark, Cools, & Robbins, 2004; Fellows & Farah, 2003; Maia & McClelland, 2004). The second problem concerns the role of awareness and its relation to anticipatory SCRs in the IGT. Bechara et al. (1997) found that only about 70% of those participants who exhibit normal learning on the IGT are able to comment accurately on the nature of the task and are fully aware of the differences between decks. Crucially, anticipatory SCRs in healthy subjects could be measured before participants had conscious knowledge about whether they were about to make a 'good' or a 'bad' choice. These findings were interpreted as evidence that somatic signals biasing decisions towards advantageous choices are present before participants know the advantageous strategy (Bechara et al., 1997). However, a problem with the interpretation of SCR data is that the nature of skin conductance responses does not permit direct conclusions about their significance: high SCRs may reflect positive or negative emotions as well as general arousal signals. A large anticipatory SCR may therefore be a correlate of the expectation of an immediate high loss rather than an indicator of long-term decisions (Tomb, Hauser, Deldin, & Caramazza, 2002). There is also disagreement concerning the question of what has to be considered as conceptual knowledge and how it could be established. Maia and McClelland (2004) note that open questioning such as used by Bechara et al. (1997) (e.g. 'Tell me all you know about what is going on in this game') may fail to reliably cue recall of all relevant knowledge. Using more detailed questions these authors found that card selecting behaviour of healthy participants is highly correlated with their immediate conscious knowledge about the task (Maia & McClelland, 2004). When they behave advantageously, participants show sufficient quantitative knowledge of the contingencies of the chosen cards, suggesting that performance in the IGT may be explained by consciously accessible knowledge rather than unconscious somatic signals. Nevertheless, the question remains whether conscious knowledge is a by-product of participants' involvement in the task, or whether it is a necessary component of successful performance.

In order to distinguish between these two possibilities and to further examine the role of somatic markers in the IGT, we tested eleven severely amnesic patients on the task. There are several reasons why performance of amnesic patients in the IGT is of particular interest. First, amnesic patients should be unable to acquire sufficient conceptual knowledge to guide their choices. Second, amnesic patients demonstrate intact learning in tasks that do not require conscious remembering (Cohen & Squire, 1980; Schacter, 1993; Shimamura, 1986), some of which are emotion-based (Hamann, Cahill, & Squire, 1997; Tranel & Damasio, 1993). A few tasks on which amnesic patients show preserved learning bare some resemblance to the IGT (Knowlton, Squire, & Gluck, 1994; Knowlton, Mangels, & Squire, 1996), and amnesics show intact autonomic responses to material they had previously been exposed to despite severely impaired conscious recollection (Bauer & Verfaellie, 1992; Tranel & Damasio, 1993). Thus, the performance of amnesic patients in the IGT allows conclusions about the role of conscious awareness in the task. A further question concerns the effect of damage to specific limbic regions on performance in the IGT. Amnesia may not only result from damage to the limbic system and the diencephalon, but also the basal forebrain and posterior orbitofrontal cortex, both adjacent to brain regions damaged in patients with a decision-making deficit in the IGT (Bechara et al., 1996). We therefore separated our amnesic patients into those who had damage to the basal forebrain and orbitofrontal cortex ('anterior' group) and those who had more posterior damage ('posterior' group).

2. Methods

2.1. Participants

Table 1 summarizes the demographic characteristics of the participants. All participants gave written informed consent. The study was approved by the local ethical committee of the University Hospital of Bern.

The criterion for involvement in the study was the presence of a severe, circumscribed and chronic memory impairment. The five patients of the 'anterior' group all had damage to the basal forebrain and orbitofrontal cortex, that is brain regions in the vicinity of ventromedial PFC. Patients 1, 2, 4 and 5 had brain damage following the bleeding from a ruptured aneurysm of the anterior communicating artery, and patient 3 had suffered from herpes encephalitis. Due to vasospasms, patient 5 additionally had lesions in the territory of the anterior and middle cerebral arteries. The 'posterior' group was more heterogeneous, both with respect to aetiology and lesion localisation. Patients 1 and 3 showed amnesia following an episode of hypoxia. Although MRI did not reveal any visible brain damage, both patients were included in the posterior group since hypoxia is known to cause primarily damage to the hippocampus or adjacent regions (Zola-Morgan, Squire, & Amaral, 1986). Patients 2 and 6 had damage to temporal structures due to encephalitis. After resection of a colloid cyst in the 3rd ventricle and a right fornix lesion patient 4 had suffered bilateral thalamic infarction. Finally, patient 5 became amnesic following bleeding from an aneurysm of the middle cerebral artery. Fig. 1 shows overlap maps of brain lesions drawn on standard templates using MRIcro (Rorden & Brett, 2000).

The control group consisted of eight healthy persons matched to the amnesic patients with regard to age and years of education (see Table 1). Patients were examined 1–14 years after the incident leading to amnesia. Table 2 summarizes