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Decision making under risk and under ambiguity in Parkinson's disease

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ABSTRACT

In the present study we investigate decision making under ambiguity and decision making under risk in Parkinson's disease (PD) patients without cognitive impairment and in patients affected by Parkinson's disease dementia (PDD). In decisions under ambiguity, participants are not aware of the rules for gains and losses and have to learn about the utility of their selections through feedback. The two patient groups showed significant deficits and did not differ in the frequency of advantageous choices, though they had a markedly different cognitive profile. In decisions under risk, explicit information on the options' probabilities as well as on the associated gains and losses is given. PD patients and healthy controls performed at the same level, whereas PDD patients made significantly more risky and disadvantageous decisions. Results of the study suggest that both patient groups are impaired in decision making when learning by feedback and emotional processing is required, while only the PDD group shows difficulties when decision making is based on cognitive reasoning strategies.

1. Introduction

Choosing the best alternative among several options is essential in every-day life through the whole life span. While healthy old persons sometimes experience difficulties in making advantageous choices (e.g., Denburg, Tranel, & Bechara, 2005; Denburg, Tranel, Bechara, & Damasio, 2001; Fein, McGillivray, & Finn, 2007; Zamarian, Sinz, Bonatti, Gamboz, & Delazer, 2008), deficits seem to be more pronounced in patients affected by neurodegenerative diseases (e.g., Brand et al., 2004, 2005; Brand, Grabenhorst, Starcke, Vandekerckhove, & Markowitsch, 2007; Brand et al., in press; Delazer, Sinz, Zamarian, & Benke, 2007; Sinz, Zamarian, Benke, Wenning, & Delazer, 2008). Despite possible cognitive impairments, patients affected by Parkinson's disease (PD) have to face important and complex decisions, for example, opting for medical treatment (Griffith, Dymek, Atchison, Harrell, & Marson, 2005) or for financial arrangements. PD patients' cognitive deficits mainly concern executive functions affecting the ability to plan, organize and regulate goal-directed behaviour (Pillon, Dubois, Lhermitte, & Agid, 1986; Pillon, Dubois, Ploska, & Agid, 1991). Cognitive deficits progress to Parkinson's disease dementia (PDD) in about 40% of the cases and concern executive functions, attention, visuo-spatial processing as well as memory, while core language functions remain relatively well preserved (Emre, 2003; Emre et al., 2007).

Over the past years, neuroimaging (e.g., Cools, Lewis, Clark, Barker, & Robbins, 2007) and neuropsychological studies have directed increasing attention to the investigation of the cognitive and emotional aspects involved in decision making (e.g., Bechara, Damasio, Damasio, & Anderson, 1994; Manes et al., 2002). There is general agreement that decision making relies on several processing steps which are supported by specific brain areas and neurotransmitter systems. Experimental studies highlighted, among others, the structures supporting the representation of values, the anticipation of gains and losses, the experience of gains and losses, the weighting of different options as well as the framing and editing of a situation (for a review see Trepel, Fox, & Poldrack, 2005). Amygdala, orbitofrontal/ventromedial prefrontal cortex, cingulate cortex, dorsolateral prefrontal cortex as well as ventral and dorsal striatum are critically involved in decision making. It has been suggested that decisions in ambiguous and uncertain situations specifically activate the orbitofrontal cortex, the amygdala and the dorsomedial prefrontal cortex, regions critical for emotional processing and the integration of emotional and cognitive input. Differently, decisions with clearly defined risks would more strongly activate the dorsal striatum (Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005). Thus, a complex network of cerebral structures supports the selection of advantageous choices and the type of decision situation presumably influences the structures and processes involved. As Schultz et al. (2008) suggested, the brain generates specific signals for different forms of uncertainty.

Neuropsychological and neuroimaging studies (Cools et al., 2007) evidenced beneficial as well as detrimental effects of dopaminergic medication on cognition in PD, depending on the

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nature of the task and the basal levels of dopamine in underlying cortico-striatal circuits. Several studies have also highlighted the role of neurotransmitters in decision making and reward processing attributing a crucial role to the dopaminergic system (for reviews see Cools, 2006, 2008; Schultz, 2002). The dopaminergic system is critically involved in learning from feedback (e.g., Frank, Seeberger, & O'Reilly, 2004; Knowlton, Mangels, & Squire, 1996) as well as in reversal learning (Cools et al., 2007), and focal basal ganglia lesions have been shown to affect reward based learning (e.g., Bellebaum, Koch, Schwarz, & Daum, 2008). Neuropsychological studies suggest two distinct roles of the basal ganglia in decision making (Frank et al., 2004; Frank, Samanta, Moustafa, & Sherman, 2007). Dopaminergic medication had a negative effect on the patients' ability to learn from negative feedback (Frank et al., 2004), while stimulation of the nucleus subthalamicus led to increased impulsivity and speeded decisions in high-conflict situations (Frank et al., 2007), without affecting learning biases.

In a study specifically assessing decision making in PD patients "on" and "off" dopaminergic medication, Cools, Barker, Sahakian, and Robbins (2003) reported increased impulsivity and hasty betting behaviour in the "on" state, but no effect of dopaminergic medication on rational choices. In a further investigation assessing decision making in PD patients "on" and "off" medication (Czernecki et al., 2002), deficits were not modulated by L-DOPA treatment.

There is rich evidence that dopaminergic medication in PD increases the frequency of impulse control disorders (for a review see Voon, Potenza, & Thomsen, 2007), which are associated with excessive gambling in a subgroup of PD patients (e.g., Drapier et al., 2006; Grosset et al., 2006; Molina et al., 2000; Weintraub et al., 2006). Less attention has been paid to decision making in PD patients with apparently well preserved control mechanisms, who show no signs of pathological gambling (Brand et al., 2004; Busemeyer & Stout, 2002; Cools et al., 2003; Czernecki et al., 2002; Kobayakawa, Koyama, Mimura, & Kawamura, 2008; Mimura, Oeda, & Kawamura, 2006; Pagonabarraga et al., 2007; Perretta, Pari, & Beninger, 2005; Thiel et al., 2003). A series of neuropsychological studies has used the Iowa Gambling Task (IGT) to assess decision making abilities under ambiguity (Bechara et al., 1994; see also Bechara, 2004; Bechara, Damasio, & Damasio, 2000; for a review and discussion see Dunn, Dalgleish, & Lawrence, 2006). In this task, rules for gains and losses are implicit and participants have to learn from positive and negative feedback to make advantageous choices. As the task proceeds, participants gain insight into the task and the risks associated with different alternatives. Brand, Labudda, and Markowitsch (2006) proposed that the IGT measures different types of decisions – decisions under ambiguity in the first part of the task and decisions under risk when the rules have been figured out. In this view, the point in time when decisions shift from ambiguity to risk is individually different and depends on the participants' insight (see Brand et al., 2006).

Studies using the IGT yielded heterogeneous results in PD patients. While Busemeyer and Stout (2002) as well as Czernecki et al. (2002) reported largely preserved performance on the IGT, Kobayakawa et al. (2008) and Pagonabarraga et al. (2007) found disadvantageous, risky performance in PD patients. Kobayakawa et al. (2008) recorded skin conductance responses (SCRs) during performance on the IGT in order to measure emotional arousal. PD patients selected more disadvantageous decks and showed lower SCRs than controls after receiving feedback (gain or loss) and before making decisions. Kobayakawa et al. (2008) suggested that PD patients' bias toward disadvantageous choices may be accounted for by dysfunction of the amygdala, which is part of the limbic system and is known to be critically involved in risk processing and decision making (Bechara, Damasio, Damasio, & Lee, 1999; Cohen, Elger, & Weber, 2008). Thiel et al. (2003) assessed cerebral activation patterns in the IGT by FDG-PET. PD patients showed less activation of the right orbitofrontal cortex and deactivation of the right thalamus as compared with the control group. As Thiel et al. suggested, the non-motor loop linking the mesial orbitofrontal cortex and the anterior cingulate gyrus to the ventral striatum (Alexander & Crutcher, 1990; Alexander, Crutcher, & De Long, 1990; Alexander, De Long, & Strick, 1986; Middleton & Strick, 2000) would be dysfunctional in PD. Decision making in PD has also been investigated through tasks specifically assessing decisions under risk where probabilities, gains and losses are explicitly defined (Cools et al., 2003; Brand et al., 2004). In the study by Brand et al. (2004, 2006), PD patients' disadvantageous performance correlated with deficient executive functions as well as with impaired feedback processing.

In the present study, we evaluate two situations of decision making (decision under risk, decision under ambiguity) in PD patients without cognitive impairment, in PDD patients and in healthy controls. To the best of our knowledge, no study so far has compared decision making in PD and PDD. It is open for investigation whether patient groups perform differently on the IGT, a task which assesses decision making under initial ambiguity and relies on learning by feedback (Bechara et al., 1994; Bechara, Tranel, & Damasio, 2000). To decide advantageously, participants have to use the feedback they get after each of their choices and have to develop preferences for advantageous alternatives. The second task (Probability-Associated Gambling Task [PAG task]; Zamarian et al., 2008; see also Bonatti et al., 2008; Sinz et al., 2008) measures decision making under risk. In the PAG task participants have to decide whether to take a safe small amount of loss/win of 20 Euro ('fix sum' alternative) or to take the risk and gamble 100 Euro ('gamble' alternative). In this task, winning probabilities, gains and losses are exactly defined (see Section 2). However, probabilities change from trial to trial and participants have to flexibly adapt their choices. Few studies have been concerned with the relation between general cognitive status and decision making. Studies with patients affected by Alzheimer's disease suggest that a decline in general cognitive functioning may lead to increased difficulties in decision making, characterized by disadvanategeous choices and lack of consistent strategies (Delazer et al., 2007; Sinz et al., 2008). In PD, divergent findings have been reported. Pagonabarraga et al. (2007) found an inverse relation between global cognitive performance and IGT, with PD patients with the better global scores performing significantly worse on the IGT. Patients with better preserved cognitive abilities tended more strongly to risky choices and made more disadvantageous decisions. Other studies have found no relation between decision making deficits and global cognitive status in PD patients. As Kobayakawa et al. (2008) suggested, decision making in PD patients would be affected by the disease rather than by other cognitive deficits. If the global cognitive status plays a major role in decision making, healthy controls and PD patients should perform better than PDD. If PD is generally associated with a decline in decision making abilities, both patient groups should perform lower than healthy controls.

It is also conceivable that decisions under initial ambiguity (measured by the IGT) and decisions under risk (measured by the PAG task) are differentially affected in PD and PDD patients. Decisions in ambiguous and uncertain situations rely on learning by feedback, reversal learning and inhibition of risky choices. Thus, both groups – PD and PDD – may show difficulties in the IGT. In decisions under risk, where rules, gains and losses are exactly defined, cognitive strategies are crucial (Brand et al., 2006; Brand, Heinze, Labudda, & Markowitsch, 2008). While PDD patients very likely have difficulties in this task, PD patients without significant cognitive impairment may show better preserved performance.