Neuroscience and Biobehavioral Reviews 37 (2013) 2836–2846

Contents lists available at ScienceDirect

Neuroscience and Biobehavioral Reviews

journal homepage: www.elsevier.com/locate/neubiorev

Review

What are people with Parkinson's disease really impaired on when it comes to making decisions? A meta-analysis of the evidence

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ARTICLE INFO

Article history:
Received 10 May 2013
Received in revised form 2 October 2013
Accepted 9 October 2013

Keywords:
Decision-making
Parkinson's disease
Feedback
Dopaminergic medication
Effort-based decision-making
Value-based decision-making
Risky decision-making
Decision-making under uncertainty
Basal ganglia

ABSTRACT

Parkinson's disease (PD) is associated with motor and cognitive impairment caused by dopamine dysregulation in the basal ganglia. Amongst a host of cognitive deficits, evidence suggests that decision-making is impaired in patients with PD, but the exact scope of this impairment is still unclear. The aim of this review was to establish which experimental manipulations commonly associated with studies involving decision-making tasks were most likely to generate impairments in performance in PD patients. This allowed us to address the question of the exact scope of the decision-making deficits in PD and to hypothesize about the role of the basal ganglia in decision-making processes. We conducted a meta-analysis of available literature, which revealed that the two key predictors of impairment in PD were the feedback structure of the decision-making task and the medication status of patients while performing the tasks. Rather than a global impairment in decision-making ability, these findings suggest that deficiencies in choice-behaviour in patients with PD stem from dysfunctions at the outcome evaluation stage of the decision-making process.

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http://dx.doi.org/10.1016/j.neubiorev.2013.10.005

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1. Introduction

Parkinson's disease (PD) is a neurodegenerative disorder primarily associated with degeneration of dopamine-producing neurons in the substantia nigra pars compacta. This degeneration affects the functioning of the other basal ganglia nuclei, particularly the putamen, which results in the primary motor symptoms of bradykinesia (slowness of movement), akinesia (poverty of action), tremor and rigidity. Other symptoms of PD, not related to motor functioning, include certain psychiatric disorders (such as depression, apathy, anxiety, hallucinations and delusions) and deficits in cognitive functioning. It is these cognitive deficits, and more specifically deficits in decision-making, which are the focus of this review. In the main, we discuss if the impairments in decision-making observed in PD suggest a general deficit affecting all stages of the decision-making process, or whether this deficit is limited to a specific stage. We attempt to address this question in view of the available experimental evidence and discuss the implications for the role of the basal ganglia in decision-making.

1.1. General cognitive dysfunction in Parkinson's disease

Traditionally, the view has been that the basal ganglia are purely motor structures that are important for selection and execution of movement. Their role in cognitive functioning has been recognized more recently because of the intimate connectivity of the basal ganglia with areas of the frontal cortex which are involved in executive functions (e.g. Alexander et al., 1986; Middleton and Strick, 1994) (for a review see Middleton and Strick, 2000). Cognitive impairments observed in people with PD, in whom the basal ganglia are affected, provide further support for the importance of the basal ganglia for cognitive functioning.

Cognitive dysfunction in PD can range from mild cognitive impairment (MCI), found in the early stages of illness, to dementia in patients in advanced stages of the disorder (Dirnberger and Jahanshahi, 2013; Dubois et al., 2007; Emre et al., 2010; Kehagia et al., 2010; Litvan et al., 2012) and impact on important abilities, such as decision-making (Brand et al., 2004; Mimura et al., 2006; Pagonabarraga et al., 2007). Executive dysfunction in PD is characterized by deficits in internal control of attention, set-shifting, planning, reduced ability to perform two tasks concurrently, deficits in inhibitory control, and conflict resolution (Dirnberger and Jahanshahi, 2013). Impairment of executive function in Parkinson's disease is thought to be associated with the dysfunction of the associative fronto-striatal loop between the caudate nucleus and the dorsolateral prefrontal cortex (e.g. Cools et al., 2002; Marie et al., 1999).

Dopaminergic medication has been shown to be effective in alleviating many of the motor symptoms associated with PD. However, it can have variable effects on cognitive function, either improving, or in some cases impairing performance on specific tests. For instance, with dopaminergic medication, performance on many tests mediated by the motor or associative circuit improves, whereas performance on tests mediated by the limbic (ventral striatum-anterior cingulate) or orbitofrontal (caudate-orbitofrontal cortex) circuits tends to worsen (Cools, 2001; Gotham et al., 1988; Jahanshahi et al., 2010; Swainson et al., 2000). More specifically, dopaminergic medication successfully alleviates some working memory, cognitive sequencing and task switching impairments in PD (MacDonald and Monchi, 2011). At the same time this medication has been linked to impairments in conditional associative learning, probabilistic reversal learning, and incremental learning with feedback (e.g. Cools, 2001; Cools et al., 2003, 2007; Gotham et al., 1988; Jahanshahi et al., 2010). To account for this puzzling set of findings, the 'dopamine overdose' hypothesis (Gotham et al., 1988; Cools et al., 2003) proposes that while dopaminergic medication has beneficial effects in the areas of the brain most affected in the early stages of the disease, such as the dorsal striatum, it causes overdosing in the parts less affected, such as the ventral striatum.

1.2. Specific cognitive dysfunction in Parkinson's disease: decision-making

In addition to the variable effects of dopaminergic medication on tests of cognitive functioning, another major source of variability in PD patients' performance is the indices of performance themselves, namely the tests. Studies of decision-making ability in PD are a case in point (Osman, 2011). For instance, some experiments using tasks designed to mimic risky decision-making (e.g. Iowa Gambling Task (IGT)) revealed impairments in decision-making in PD (e.g. Brand et al., 2004; Kobayakawa et al., 2008; Mimura et al., 2006). Studies utilizing tasks designed to mimic everyday decision-making (e.g. Dynamic decision-making tasks (DDM)), on the other hand, observed no such deficits (e.g. Osman et al., 2008; Witt et al., 2006). Consequently, inconsistent results presented in the literature on decision-making in PD may stem from methodological issues: given that the tests of decision-making differ considerably, results from various studies may not be comparable. Without careful evaluation, this can lead to a distorted picture of the actual decision-making impairments in PD.

1.3. Objectives and structure of the review

Our aim is to comprehensively review the pattern of findings that emerge from studies investigating PD patients' performance on different decision-making tasks. Our goal is to identify the exact nature of the deficits and the influence of task characteristics and medication status on decision-making performance in PD. The first part of the review introduces the tasks that are commonly used to study decision-making in PD, and discusses the specific experimental manipulations that are associated with impairments, including medication status. Next, the general findings of a meta-analysis of 38 studies investigating decision-making impairments in PD are presented. The results of the meta-analysis are evaluated and discussed in the concluding section of this article with a particular focus on the implications of these findings for the role of the basal ganglia in decision-making.

2. Decision-making stages and tasks

Evidence has shown that decision-making relies on several processing steps which are supported by different brain areas and neurotransmitter systems (Delazer et al., 2009; Kable and Glimcher, 2009; Rangel et al., 2008). Decision-making is typically conceptualized as a process that involves the representation and assignment of