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Influence of promised rewards on conflict resolution in healthy participants and patients with Parkinson's disease

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ABSTRACT

The influence of promised rewards on conflict resolution processes is not clearly defined in the literature, and the underlying mechanisms are poorly understood. Some studies have shown no effect of reward, while others have demonstrated a beneficial influence. In addition, although the basal ganglia are known to play a critical role in the association between motivation and cognition, the influence of promised rewards on conflict resolution processes in Parkinson's disease (PD) has received little attention. In this context, we assessed the influence of promised rewards on both impulse activation and suppression in 36 healthy participants and 36 patients with PD, using a rewarded Simon task. Analysis of performances revealed that promised rewards worsened the overall congruence effect, but only in healthy participants. Although the incentive context did not modulate the congruence effect in patients, by using the activation-suppression model, we were able to show that promised rewards did influence impulse suppression in patients-but not in healthy participants. Suppressing inappropriate response activation in an incentive context appears to be harder in medically treated Parkinson's disease. This indicates that incentive motivation can modulate at least one cognitive process involved in cognitive action control in patients with medically treated PD. The activation-suppression model provides essential additional information concerning the influence of promised rewards on conflict resolution processes in a pathological population.

1. Introduction

Cognitive control is an important executive function commonly studied in contemporary neuropsychology in various neurological disorders, including Parkinson disease (PD) [1,2]. *Cognitive action control* refers to a subset of cognitive control processes that favor the production of goal-directed actions according to either internal objectives or environmental requirements. More specifically, cognitive action control allows for the expression of desired appropriate behavior, even if there is strong competition from an unintentional response triggered by irrelevant environmental information. Cognitive action control can be assessed in the laboratory with conflict tasks such as the Stroop task [3], the Eriksen task [4] or the Simon task [5]. The stimuli in the Stroop task and the Simon task usually carry both relevant and irrelevant features, which may activate either the same response or two different ones. In *congruent* situations, the relevant and irrelevant features of the stimulus both trigger the same response. By contrast, in *noncongruent* situations, the relevant and irrelevant features activate different responses, thereby creating conflict. Typically, compared with congruent situations, noncongruent ones induce slower and less accurate responses. The negative impact of conflict on response speed can be measured by the difference in reaction time for the correct responses in noncongruent minus congruent situations. This effect is known as the *congruence effect*. Dual-route models of information processing are now regarded as references for depicting the congruence effect in conflict tasks [6–8]. Different models have been proposed to conceptualize the cognitive control and have been used in various psychological domains [9]. However, dual-route models are considered to be more appropriate to describe the cognitive processes involved during online actions control, and especially during conflict resolution [10]. Dual-route models assume that the features of the stimuli trigger response tendencies via two distinct, parallel routes: an automatic, reflexive, route and a controlled one. The irrelevant feature of the stimulus activates a fast and automatic route, whereas the relevant feature activates a slower,

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controlled route. Furthermore, in conflict situations, selective response inhibition is required to suppress and overcome the irrelevant activation in favor of the relevant response. It is the cognitive cost of this process that is thought to induce the congruence effect.

According to the *activation-suppression model* [11–13], the selective inhibition of the irrelevant response tendency takes time to get going, and is therefore not immediately effective [14,15]. Accordingly, this model postulates that the efficiency of the top-down selective inhibition engaged to resolve conflict situations is greater for slow responses than for fast ones. Thus, in noncongruent situations, rapid responses are most vulnerable to inappropriate impulsive action selection captured by the irrelevant feature of the stimulus, resulting in fast, erroneous responses. Conversely, when responses are slower, selective inhibition has more time to build up and allows for the proper suppression of the automatic activation, facilitating the production of correct responses. Therefore, the congruence effect is lower for slow responses. Impulsive action selection can be revealed by the conditional accuracy function (CAF), which plots accuracy as a function of response speed. *Impulsive selection* is present when the fastest responses are the least accurate. Delta plots showing the relationship between the congruence effect and response speed, can be used to highlight response inhibition efficiency. *Effective selective inhibition* is observed when the congruence effect declines steeply for the slowest responses (for a review, see [10,16]).

According to motivation models in behavioral neurosciences, stimuli can motivated individuals by incentive expectancies (for review see [17]). The association of a hedonic reward to a neutral stimulus assigns an incentive value to the neutral stimulus. As a consequence, presentation of such a stimulus triggers expectation of the reward. Culturally, monetary coins have a powerful incentive value since they are strongly associated with hedonic processes. Accordingly, coins presentation may influence human behavior, including cognitive action control. However, relatively few studies have investigated the influence of promised rewards on the cognitive processes involved in the production of the desired action when a strong and undesired alternative is activated [18–21]. These studies have classically used rewarded conflict tasks, in which the promised rewards are displayed before the conflict situations (*reward anticipation*). A recent study featuring a rewarded Stroop-like task showed that the congruence effect was lower in rewarded than in nonrewarded situations, induced by response facilitation in both the congruent and noncongruent situations [20]. The authors therefore concluded that incentive motivation has a beneficial impact on cognitive action control. Other studies have failed to find any behavioral evidence of a significant influence of promised rewards on conflict resolution [18,21]. It should, however, be noted that these studies did not specifically investigate the influence of promised rewards on impulse selection and suppression. As a whole, therefore the influence of reward anticipation on cognitive action control is not yet fully understood.

Recent imaging studies in healthy participants have suggested that the basal ganglia and dopamine release could play a nodal role in the interaction between incentive motivation and cognitive action control [18–20]. In particular, Aarts et al. observed a relationship between dopamine synthesis capacity and behavioral performance in a motivated Stroop-like task [18]. Healthy participants with a high synthesis capacity in the left caudate nucleus exhibited a deleterious influence of promised rewards on cognitive action control (stronger congruence effect in high- vs. low-reward conditions). The authors suggested that in participants with a high dopamine synthesis capacity, the promise of a high rewards overdosed the dopamine system, leading to impaired cognitive action control. To date, there has only been one study of the influence of promised rewards on cognitive action control in conflict situations in PD, which represents a pathophysiological model of dysfunction in the basal ganglia and the dopamine system [19]. This study showed that rewarding the fastest responses-or punishing the slowest ones-in a Simon task had no effect on cognitive action control processes in patients with medically treated PD, contrary to controls. The authors suggested that dopaminergic treatment overdosed the ventral frontostriatal system which, in turn, prevented the incentive situation from modulating patients' cognitive action control.

In this context, the objective of the current study was to clarify the influence of promised rewards on the temporal aspects of information processing in conflict situations in both healthy participants and patients with medically treated PD. To this end, we used a Simon task in which incentive motivation was induced by monetary rewards.

2. Methods

2.1. Participants

Two groups of 36 participants took part in the study: a group of healthy controls (HC) (age range: 44–71 years; education range: 6–17 years) with no neurological or psychiatric history, recruited by advertisement, and a group of patients with idiopathic PD [22] (age range: 29–71 years; education range: 6–20 years) undergoing medical care at Rennes University Hospital, France. Participants' clinical and demographic data are detailed in Table 1. Dementia was excluded using the Mattis Dementia Rating Scale (MDRS, [23]), and psychiatric disorders using the French version of the Mini-International Neuropsychiatric Interview (MINI 500, [24]). Trained psychiatrists assessed depressive symptoms on the Montgomery and Asberg Depressive Rating Scale (MADRS, [25]). PD severity was measured on the Unified Parkinson's Disease Rating Scale (UPDRS), and the Hoehn and Yahr [26] and Schwab and England [27] scales. All the participants, HC and patients, were examined in the department of Neurology of the Rennes University Hospital, France. Both groups were matched for age, sex, education level and MDRS score. Patients performed the experimental task on their usual antiparkinsonian medication in order to decrease the bias from motor impairment. Medication included levodopa and dopamine agonists in 28 patients, and levodopa only in 7 patients. The experiment was approved by the local ethics committee of Rennes University Hospital, and conducted in accordance with the Declaration of Helsinki and current French legislation (Huriet Act).

2.2. Materials and procedure

The stimulus presentation was programmed using E-prime Professional version 2.0 running on a DELL LATTITUDE E550 computer. The experimental task comprised a baseline phase (32 trials) and an experimental one (five blocks of 72 trials, with a short pause between each block). Each phase was preceded by a familiarization phase (12 trials before the baseline phase, and six trials before the first block of the experimental phase). The baseline phase consisted of a standard Simon

Table 1
Clinical and demographic data (mean ± *SD*) and comparisons between HC and PD groups using the Mann-Whitney *U* test.

	HC group	PD group	*p* value
Men/women	18/18	18/18	
Age (years)	59.4 ± 6.3	56.6 ± 9.2	0.25
Education (years)	12.1 ± 3.8	11.1 ± 4.3	0.26
Disease duration (years)		11.4 ± 4.2	
UPDRS-III "on"		8.0 ± 5.8	
UPDRS-III "off"		28.3 ± 9.7	
Schwab and England (%) "on"		87.5 ± 8.6	
Schwab and England (%) "off"		71.2 ± 16.7	
Hoehn and Yahr "on"		0.9 ± 0.7	
Hoehn and Yahr "off"		2.3 ± 0.7	
LEDD (mg)		1204 ± 525	
Dopa agonist (mg)		431 ± 411	
Levodopa (mg)		773 ± 389	
MADRS	1.9 ± 2.4	4.8 ± 5.1	0.01
MDRS	139.8 ± 2.9	139.4 ± 3.9	0.93

Note. UPDRS = Unified Parkinson's Disease Rating Scale; MADRS = Montgomery and Asberg Depressive Rating Scale; LEDD = levodopa equivalent daily dose; MDRS = Mattis Dementia Rating Scale.