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Research report

Object affordance and spatial-compatibility effects in Parkinson's disease

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ABSTRACT

Movement in Parkinson's disease (PD) is strongly influenced by sensory stimuli. Here, we investigated two features of visual stimuli known to affect response times in healthy individuals; the spatial location of an object (the spatial effect) and its action-relevance (the 'affordance' effect). Poliakoff et al. (2007) found that while PD patients show normal spatial effects, they do not show an additional affordance effect. Here we investigated whether these effects are driven by facilitation or inhibition, and whether the affordance effect emerges over a longer time-course in PD. Participants (24 PD and 24 controls) viewed either a lateralised door handle (affordance condition), a lateralised abstract stimulus (spatial condition), or a centrally presented baseline stimulus (baseline condition), and responded to a colour change in the stimulus occurring after 0 msec, 500 msec or 1000 msec. The colour change indicated whether to respond with the left or right hand, which were either spatially compatible or incompatible with the lateralised stimulus orientation in the affordance and spatial conditions. The baseline condition allowed us to assess whether compatibility effects were driven by facilitation of the compatible response or inhibition of the incompatible response. The results indicate that stimulus orientation elicited faster responses from the nearest hand. For controls, the affordance effect was stronger and driven by facilitation, whilst the spatial condition was driven by inhibition. In contrast, the affordance and spatial-compatibility effects did not differ between conditions in the PD group and both were driven by facilitation. This suggests that the PD group responded as if all stimuli were action-relevant, and may have implications for understanding the cueing of movement in PD.

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1. Introduction

Parkinson's disease (PD) is characterised by a slowness and poverty of movement caused by loss of the dopaminergic cells of the nigrostriatal pathway in the basal ganglia. PD patients

have particular difficulty with voluntary movements. This is attributed to underactivation of the supplementary motor area (SMA; Jahanshahi et al., 1995), which is closely linked to the basal ganglia and plays a key role in volitional movements (Nachev et al., 2008). However, sensory cueing can also be

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used to facilitate movement to almost normal levels, even when symptoms are severe (Glickstein and Stein, 1991). For example, auditory rhythmic cues such as marching music, and appropriately placed floor markers such as transverse lines, can help to alleviate gait impairments (see Rubinstein et al., 2002, for a review of cueing studies). Although much of the work on cueing of movement in PD has focussed on gait, external cueing has also been found to enhance upper-limb movements such as reaching movements (Majsak et al., 1998) and handwriting (Oliveira et al., 1997). These cues are thought to work by facilitating the timing of movements (Kritikos et al., 1995), and the selection of the appropriate action (Wylie et al., 2005). These externally evoked actions may bypass the underactive SMA in PD, relying more on lateral premotor areas (Jahanshahi et al., 1995). Given the potential therapeutic benefits of cueing for PD patients, it is important to establish the sorts of external stimuli that influence their movements. This paper follows up previous research (Poliakoff et al., 2007) that compared the effects of abstract spatial stimuli and action-relevant graspable objects.

In healthy participants, it is well established that spatial correspondence between stimulus and response leads to faster reaction times (RTs), even if the stimulus location is irrelevant to the task. Thus, participants making speeded responses to a stimulus dimension such as colour or shape are faster to respond with their right hand if the stimulus is also presented on the right. This is known as the ‘Simon effect’ (e.g., Simon and Small, 1969) or spatial-compatibility effect. Explanations generally evoke cognitive mechanisms, for example emphasising the conflict between automatic and intentional processes at the response selection stage (e.g., Wallace, 1971) or suggesting that stimulus location may elicit a shift of attention which generates a response code (Nicoletti and Umiltà, 1994; Rubichi et al., 1997). Several studies have addressed spatial compatibility in PD patients, with some showing apparently normal stimulus–response compatibility effects (Brown et al., 1993; Cope et al., 1996; Poliakoff et al., 2007) and others showing that unlike controls, there is no reduction in the effect in trials preceded by an incompatible trial (Praamstra and Plat, 2001; Fielding et al., 2005).

In addition to object location, the motor system can also be influenced by the action-relevant features contained within an object. In healthy humans, viewing action-relevant objects that invite a particular action, such as a cup with a handle, can activate sensorimotor brain areas (Grèzes and Decety, 2002) and influence manual response times (Tucker and Ellis, 1998; Tipper et al., 2006). For example, Tucker and Ellis (1998) demonstrated that when participants were classifying whether an object was upright or inverted, responses were faster if the object handle and response hand were on the same side of space (the ‘affordance effect’), suggesting that the sight of the handle primed action from the nearest hand. Tucker and Ellis (1998, 2001) proposed that action-relevant object-features (such as handles) are directly perceived and automatically activate a motor code, an idea with roots in Gibson’s original notion of direct perception (Gibson, 1979).

It has been suggested that common mechanisms may underlie affordance and spatial compatibility (e.g., Anderson et al., 2002). However, emerging evidence supports dissociation between spatial (Simon) and affordance compatibility

effects. Affordance compatibility has been demonstrated for non-spatial grasp-relevant features such as grip aperture (Ellis and Tucker, 2000; Grèzes et al., 2003a, 2003b) and wrist rotation (Ellis and Tucker, 2000), and in contrast to the spatial effect appears to rely on the formation of detailed object representation (Tipper et al., 2006). Of relevance to the current study, Symes et al. (2005) found additive effects of the spatial location and handle orientation of graspable objects, suggesting that a lateralized graspable object activates two codes, one pertaining to object location, and the other to type of grasp.

Our recent work with PD patients (Poliakoff et al., 2007) also assessed both spatial and affordance compatibility within a single design. We measured the influence of action-relevant stimuli (graspable door handles) on RTs, compared to abstract bar stimuli designed to elicit spatial-compatibility effects only. Both stimuli were oriented diagonally either to the left or right of the presentation screen. Crucially, the orientation of the stimulus was irrelevant to the task; participants made a bimanual choice response to the shape of each stimulus, responding with one hand to rounded stimuli, and with the other to square stimuli. The healthy controls were influenced by the irrelevant spatial location of the abstract stimuli, but showed a greater effect after viewing the graspable door handles, thus supporting the proposal for additive sources of compatibility (Symes et al., 2005). In contrast, whilst PD patients showed an equivalent effect of spatial compatibility, action-relevant door handles did not exert a stronger influence. This suggests that in PD external cues may exert their influence through spatial location alone, and that the additional influence of action-relevant stimuli on the motor system is disrupted.

However, recent evidence suggests that some visuomotor priming effects may be modulated in PD, rather than absent. Castiello et al. (2009) measured facilitation of a reach and grasp action after observation of a model making the same action in PD and control participants. For both groups, the initiation time and duration of the movement was improved after observation of the same action. Whilst the controls’ responses were facilitated whether observing a PD or control model performing the action, the PD group were only facilitated when watching a PD model. The fact that they did not exhibit the same benefit after observing a healthy control model, who produced a faster movement, was interpreted as showing that facilitation only occurs if the observer is able to recreate the kinematics of the observed action. The modulation of this visuomotor priming effect in PD may also be relevant to affordance effects in PD, since there is overlap in the brain areas mediating the observation of graspable objects and actions (e.g., Grèzes et al., 2003a, 2003b). Furthermore, our previous study suggests that both effects are similarly disrupted at the behavioural level in PD (Poliakoff et al., 2007).

The current study was designed to compare further characteristics of affordance and spatial compatibility and assess whether the effects are similarly dissociated in PD and healthy controls. This was achieved in two ways. First, we included a baseline condition with centrally presented stimuli. This was to determine whether the observed compatibility effects resulted from facilitation from compatible stimuli, or interference from incompatible stimuli. Although previous work

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