



Motor asymmetry and estimation of body-scaled aperture width in Parkinson's disease

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ABSTRACT

The present study examined how asymmetrical motor symptomatology helps predict the pattern of perceptual judgements of body-scaled aperture width in lateralised Parkinson's disease (PD). Eleven patients with PD predominantly affecting the left side of their body (LPD), 16 patients with PD predominantly affecting their right side (RPD), and 16 healthy controls made forced-choice judgements about whether or not they would fit without turning their shoulders through a life-sized schematic doorway shown on a large screen. Whereas control and LPD groups made accurate estimations of body-scaled aperture width, RPD patients significantly underestimated aperture width relative to their body, perceiving doorways on average that were 12% narrower than their bodies as wide enough to allow them to pass through without rotation. Across all patients, estimates of body-scaled aperture width correlated with ratio of right-to-left symptom severity. These perceptual errors may indicate a mismatch between the neural representation of external space and that of body size in PD.

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1. Introduction

Difficulties with spatial navigation are among the most distressing problems experienced by people with Parkinson's disease (PD). While these often reflect motor symptoms, such as rigidity, bradykinesia, and postural instability, many patients report that going through doorways, narrow corridors, and other confined spaces causes freezing or festinating gait, and/or leads to an increased likelihood of collisions, indicating a likely perceptual and/or attentional component to navigational problems (Lee & Harris, 1999; Rahman, Griffin, Quinn, & Jahanshahi, 2008; Schaafsma et al., 2003).

One explanation for mobility problems in confined spaces in PD is that attention is diverted from organising voluntary movements by objects in peripheral vision, such as the surrounds of doorways (McDowell & Harris, 1997). Consistent with this hypothesis, patients are more susceptible to visual distracters in peripheral vision (Deijen, Stoffers, Berendse, Wolters, & Theeuwes, 2006; Machado, Devine, & Wyatt, 2009). A general impairment in visual

attention is shown by the failure in PD to benefit from valid spatial cues, or to follow instructions not to look directly at stimuli presented in the periphery (Sampaio et al., 2011).

A second type of explanation for mobility problems is that changes to spatial vision and/or proprioception affects navigation in cluttered environments in PD (Lee, Harris, Atkinson, & Fowler, 2001a; Rahman et al., 2008). Disturbances to visuospatial processing are common in PD (Davidsdottir, Cronin-Golomb, & Lee, 2005; Lee & Harris, 1999; Lee, Harris, Atkinson, & Fowler, 2001b) especially in patients with symptoms predominantly on their left (LPD) rather than right (RPD) side, for example, in line bisection, optic flow perception, and tasks involving saccades to a target (Davidsdottir, Wagenaar, Young, & Cronin-Golomb, 2008; Starkstein, Leiguarda, Gershanik, & Berthier, 1987; Ventre, Zee, Papageorgiou, & Reich, 1992). In these studies, the LPD, but not the RPD, groups often show signs of directional neglect, suggesting a lateralised visuospatial or attentional deficit. Changes to proprioception in PD are also well known, although it is not clear how this is affected in asymmetric disease. In one study, Mongeon, Blanchet, and Messier (2009) reported that medicated RPD patients were less accurate when reaching to proprioceptively defined targets. Another recent study found constricted subjective self-referential conceptualization of space but only for LPD patients (Skidmore et al., 2009). Taken together then, such studies of perception in PD suggest that disrupted proprioceptive and visuospatial processing, most obvious in perceptual asymmetries in lateralised disease,

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may have roles in patients' difficulties in interacting with the local environment.

Asymmetries of motor impairment in PD, which appear to persist across the range of disease severity (Hoehn & Yahr, 1967), reflect asymmetric depletion of dopamine in the substantia nigra, as shown by single-photon emission tomography and positron emission tomography (Booij et al., 1997; Kaasinen et al., 2001). Further, marked asymmetry of dopaminergic activity in the putamen and caudate persists even in severe bilateral motor disability (Booij et al., 1997). This results in asymmetrical dysregulation of the striatum, leading to further asymmetrical dysfunction of multiple circuits involving the basal ganglia and cortical regions, including temporo-parietal regions important for visuospatial cognition (Clower, Dum, & Strick, 2005; Middleton & Strick, 2000). These asymmetries in dopaminergic regulation of the cortex are likely to be the neural substrate of the observed links between motor asymmetries and the greater impairment of spatial processing in LPD, since, for example, the right parietal lobe is known to be critical for processing spatial information (Fink et al., 2000).

There are suggestions that the perceptual differences between LPD and RPD may be important in navigating through apertures, such as doorways, in natural cluttered environments. Thus, although both LPD and RPD frequently report bumping into the sides of doorways (Davidsdottir et al., 2005; Lee & Harris, 1999), RPD report bumping equally into the left and right sides of doorways, whereas LPD primarily report bumping into the left side of doorways (Davidsdottir et al., 2005). This suggests that collisions may have a different origin in the two groups, an idea tested by Lee et al. (2001a) who asked participants to judge whether they could fit through life-sized schematic doorways without rotating the body. Their LPD group required a doorway of about 1.5 times body width, and the RPD group one of 0.9 times (compared with the 1.1 times of the controls) before judging that they would fit through. The authors speculated that these differences in body-scaled aperture judgements arose because, in LPD, the (right hemisphere-based) visuospatial representation of external space is shrunk, whereas, in RPD, the (left hemisphere-based) representation of the body may be shrunk. This interpretation is broadly consistent with findings that LPD patients are impaired in mental manipulations of external objects, while RPD show deficits in mental manipulations of their own body relative to space (Amick, Schendan, Ganis, & Cronin-Golomb, 2006), and, more generally, with the hypothesis that whereas regions in the right hemisphere are necessary for object-centred transformations, there is a left-hemisphere advantage for viewer-centred transformations (Cronin-Golomb, 2010). There is also evidence that the magno-cellular visual pathway, which provides input to the right parietal lobe, is impaired in PD, in addition to any direct effects of the illness on parietal function (Silva et al., 2005).

An important but largely neglected question is that of exactly how asymmetries in motor impairment are related to changes in spatial perception, and so the nature of the underlying perceptual processes. Like most previous studies of visuospatial function in asymmetric disease, investigations of body-centred representations of visual space in PD have relied on patient classifications based on side of symptom onset or side of the body on which symptoms were worse at the time of testing (Lee et al., 2001b; Skidmore et al., 2009). Such a binary classification has the merit of simplicity, but patients typically exhibit bilateral motor impairments, and placing patients into left- or right-sided groups can result in a distinction that is not necessarily clinically applicable, and potentially discards up to half of their symptoms (Cooper et al., 2008). More specifically, such an approach fails to take into account the precise level of motor impairment on the most affected side (and by implication the extent of dopaminergic dysfunction in the con-

tralateral hemisphere) as well as the degree of asymmetry of motor impairment (the extent of dopaminergic dysfunction in one hemisphere relative to that in the other), factors which may be important in visuospatial processing in PD. For example, two recent studies have reported that the degree of right-sided symptoms in patients was specifically related to visuospatial performance (Cooper et al., 2008; Smith et al., 2010). Further, Foster, Black, Antenor-Dorsey, Perlmuter, and Hershey (2008) recently found that visuospatial memory impairment was related to the degree of asymmetry of motor signs in early PD, with worse performance in those with worse left-sided symptoms. The importance of the method of classifying patients was also apparent in the study by Cooper and colleagues, since when subsets of patients with predominantly right- and predominantly left-sided symptoms were compared, there were no significant differences in visuospatial performance between the groups. Together, then, these studies emphasise the need to consider the precise level of hemispheric impairment in lateralised PD in examinations of visuospatial processing (as well as the nature of the visuospatial task).

The purpose of the present study was to examine judgements of body-scaled aperture width in PD and healthy controls. The perceptual task used closely followed that of Lee and colleagues (2001a), in which seated participants judged whether or not the widest part of their body (taken to be the shoulders) would fit through a series of schematic doorways without turning. A battery of standard neuropsychological tests was also administered, including some with an attentional component. The study went beyond that of Lee et al. in using a different way of classifying the patients, and in varying the contrast and luminance of the doorway surrounds, and was designed to test three hypotheses:

- (1) The extent and direction of misjudgement of body-scaled aperture width would correlate with asymmetry of motor symptoms.
- (2) In patients, but not in controls, the misjudgements would be related to the perceptual salience of the aperture surrounds, and so to their ability to capture attention.
- (3) Attentional dysfunction, if indicated by the aperture judgement task, would be reflected in the other neuropsychological tests.

2. Method

2.1. Participants

Twenty-seven patients with idiopathic PD and 16 age-matched healthy controls participated. Participants were screened for dementia using the Mini-Mental State Examination (MMSE cut-off = 24, Folstein, Folstein, & McHugh, 1975) and for depression using the Beck Depression Inventory-II (BDI-II cut-off = 17, Beck, Steer, & Brown, 1996).² None had a history of head injury within the preceding 10 years, or of alcohol abuse, stroke, or epilepsy. The diagnosis of idiopathic PD was confirmed by a neurologist, who also allocated patients to a Hoehn and Yahr (1967) stage, and all patients met United Kingdom Parkinson's Disease Brain Bank Criteria for diagnosis of PD (Gibb & Lees, 1988). Ethical approval for the study was given by the Berkshire NHS Research Ethics Committee and by the University of Reading Research Ethics Committee. All participants gave their informed consent after a verbal and a written description of what their participation would involve.

2.1.1. Clinical assessment

All patients completed the 16-item Gait and Falls Questionnaire (GFG; Giladi et al., 2000), which included six items specifically constructed to assess freezing of gait (FOG). The Unified Parkinson's Disease Rating Scale Motor subscale was also used as a measure of current motor severity in PD patients and to classify patients into left- and right-sided PD groups (UPDRSm; Fahn, Elton, & Members of the UPDRS Development Committee, 1987). The UPDRS was administered by the neurologist blind to experimental results once after a minimum 10-h withdrawal from dopaminergic medication (mean withdrawal period was 13 h 29 min, standard deviation [SD] = 2 h 51 min) and then again 40–75 min after the usual PD medication (when the

² Scheduling limitations prevented one patient from completing the BDI-II.

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