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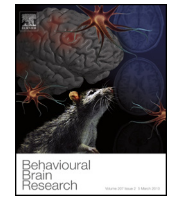

Research report

Impaired perception of human movements in Parkinson's disease

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HIGHLIGHTS

- Theories have linked motor execution and observation.
- Parkinson patients are impaired in motor execution.
- We hypothesized that Parkinson patients should be impaired in observation of human movements.
- Results confirm the hypothesis that Parkinson patients are impaired in biological motion perception.

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ABSTRACT

Interacting with other individuals in a social world requires fast and accurate perception of other individuals' identity, actions, or intentions. Humans are very efficient in these social tasks, as they can extract social information even if the actor is represented only by a handful of point-lights on an otherwise invisible body. Theories have argued that efficient visual perception of actions is based on intact motor system functioning. The motor system provides visuo-motor action representations shaped by the observer's own movements or motor repertoire. If the observer's motor repertoire is impaired, this should lead to impaired visuo-motor representations and ultimately to impaired visual perception of movements. Here we tested this hypothesis in a behavioral study with patients suffering from Parkinson's disease (PD). PD patients are typically impaired in movement execution. We tested these patients and a matched control group in a visual discrimination task on human movement perception. The results showed that PD patients were significantly impaired in the perception of human movements. This impairment was most prominent for transitive (object-related) movements. The results indicate that impaired movement execution critically influences movement perception. The results support the hypothesis that the motor system plays a causal role for the visual perception of human movements.

1. Introduction

Perceiving and interpreting the movements and actions of other individuals is an important aspect for human social interaction [1,2]. Thus, it is not surprising that humans are very accurate and efficient at recognizing other peoples' movements or gestures. It has been demonstrated already more than 40 years ago that observers can easily recognize the actions of other individuals even if the to-be-observed human body is depicted by only a handful light dots on an otherwise invisible body [3]. The sparse information of these so-called point-light displays has been shown to be sufficient to recognize gender, identity, or mood of the actor [4–6]. Despite many years of research and increasing knowledge about the perception of human movements, the neuronal mechanisms are still not fully understood. While there is mounting evidence that the superior temporal sulcus (STS) and lateral occipito-temporal cortex (LOTC) are critically involved in the process of perceiving human movements [7,8], also other cortical areas have been shown to play a role for the perception of human movements. For example, areas of the motor system, which are typically involved in the execution of movements, have been associated also with movement perception [9][e.g. 9]. In this regard, theories have postulated a link between movement perception and execution of movements [10]. These theories have been supported by behavioral studies demonstrating interference between visual perception of a movement and the observer's own movement or movement capabilities. For example, compared to stationary observers, walking observers were impaired in judging the walking speed of animated persons [11]. Similarly, it has been shown that self-generated movement

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of the observers modulates discrimination of body postures and movements [12,13]. Furthermore, observers' ability to judge the weight of a box lifted by another person depends on the weight of a box lifted by the observers [14]. Further evidence for a link between movement perception and execution of actions comes from fMRI studies reporting BOLD responses in the (pre)motor system during action perception [9,15,16]. In addition, EEG and MEG studies reported a suppression of alpha/mu- and beta-activity (8–30 Hz) in sensors over central and motor areas during action observation and imagination [17–20]. This suppression of alpha/beta-band activity was modulated by plausibility and the lateralization of the observed action [19,21,22].

In summary, several behavioral and imaging studies provide converging evidence for a link between action perception and execution. It has been suggested that such a link between action perception and execution reflects the sharing of body representations by the motor and visual system [10]. If the motor system is crucially involved in movement perception, dysfunctions in the shared visuo-motor representations in the motor system should lead to impaired perception of human movements. Indeed, studies have shown that observers with lesions in the human premotor or motor system are impaired in their ability to perceive human movements [23–25]. For example, it has been shown that patients with hemiplegia (a lesion at the motor system that affected the contralesional arm) are impaired in the perception of gestures performed by an arm contralateral to their impaired body site [24]. Another study has shown that paraplegia patients are severely impaired in the perception of human movements [25]. Also, patients with periventricular leukomalacia (PVL; a damage to the periventricular brain found in some prematurely born children) often show impaired motor abilities [26]. These patients also show impaired perception of human movements [27]. However, impaired perception did not correlate with the severity and even patients with early impaired movement production could perceive human movements to a certain degree [26]. Therefore, movement production does not seem to be a necessary prerequisite for movement perception. But impaired movement production seems to affect movement perception.

From the hypothesis of shared visuo-motor representations and the above mentioned studies on the relationship of impaired movement production and perception, it might also follow that people with impaired abilities to execute movements due to impairments in the motor system should also be impaired in the perception of human movements. Parkinson's disease (PD) offers an intriguing model to test this hypothesis and to test a general link between the motor and visual system for human movement perception in general. PD is typically associated with the triad of motor dysfunctions: akinesia, rigor, and tremor [28]. That is, patients suffering from PD are typically impaired in their movement execution. Given the interaction of observers' own movements and their perception of human movements, we hypothesized that patients with PD who are impaired in movement execution should also be impaired in the perception of human movements. In line with this hypothesis, a recent study found that PD patients are impaired in a temporal duration discrimination task on human movements and their scrambled counterparts compared to healthy control subjects, indicating altered processing of human and scrambled movements in PD [29]. Furthermore, PD is often associated with abnormal beta-band activity in the motor and basal ganglia system [30–32]. Since beta-oscillations in the motor system have been shown to play a role during perception of human movements, the abnormal beta oscillations in PD provide further support for our hypothesis of impaired perception of human movements in PD.

We tested this hypothesis in a behavioral study by presenting point-light animations of human movements [3] to a group of PD patients and a matched control group. If PD patients' impairments in motor execution and their abnormal beta-oscillations affect their abilities to perceive human movements, we expected that PD patients also show impaired perception of human movements. Such a finding would provide further evidence for a causal link between movement execution and perception and the interaction of visual and motor systems during movement perception.

Table 1
Characteristics of patient and control groups.

Gender	Patients	Controls
	17 (11 male)	17 (11 male)
Mean Age (±SEM)	60.5 ± 2.4	60.5 ± 2.6
Mean Years of Schooling (±SEM)	11.2 ± 0.4	11.2 ± 0.4

2. Methods

2.1. Participants

20 patients with Parkinson‘s disease and 23 healthy subjects participated in the experiment. All participants had normal or corrected to normal vision and no history of internal, psychiatric or neurological disorders other than Parkinson's disease. None of the patients had deep brain stimulation treatment. In order to be able to exclude participants suffering from dementia, we used the Mattis Dementia Rating Scale – 2 (MDRS-2) [33] with a cut-off score of 130 points. Three Parkinson‘s disease patients and six controls had to be excluded from the analysis due to low MDRS scores, inability to complete the testing session, a contested Parkinson's disease diagnosis, as well as symptoms indicative of neurological disorders and vision difficulties that first transpired after testing began. This resulted in a final sample of 17 patients and 17 age, gender and education matched controls (Table 1).

We measured patients‘ motor symptoms using the UPDRS scale and the Hoehn & Yahr (H&Y) scale [34]. We categorized one patient (6%) into H&Y-stage one, seven patients (41%) into H&Y-stage two and nine patients (53%) into H&Y-stage three.

UPDRS scores were rated by two independent raters. The inter-rater reliability correlation coefficient for UPDRS scores was highly significant ($r_s(15) = 0.86$, $p < 0.001$). Patients' mean UPDRS score was 31.88 ± 2.47 (averaged ratings of both raters).

Written informed consent according to the Declaration of Helsinki was obtained from all participants prior to testing. The study was approved by the local ethics committees of the medical department of the Heinrich Heine-University.

2.2. Procedure

Patients had been instructed not to take any dopaminergic medication 12 h prior to testing, which is a standard time period for medication withdrawal in so-called OFF medication states [e.g., 35–37]. All participants were tested separately and started the testing session with a computer-based motion perception task, followed by UPDRS and MDRS-2 tests (see below for details).

The motion perception task started with written instructions presented on the screen. Each trial started with a blank screen presented for 500 ms followed by presentation of the stimulus (Fig. 1A). Stimuli consisted of point-light animations of natural and different unnatural versions of moving humans, animals, or objects (Fig. 1B; see *Stimuli* for details). Stimuli were presented in blocks, with each block containing an equal number of natural and unnatural stimuli, presented in randomized order. The stimulus presentation length varied between 1.62–2.69 s (see *Stimuli* for details). After each stimulus presentation, response instructions were presented for up to 3 s on the screen. Participants had to decide if the stimulus depicted a natural or an unnatural motion by pressing buttons on a key-