Available online at www.sciencedirect.com

SciVerse ScienceDirect

Journal homepage: www.elsevier.com/locate/cortex

Research report

Implicit olfactory processing attenuates motor disturbances in idiopathic Parkinson's disease

Valentina Parma [a], Maria Bulgheroni [a], Tomaso Scaravilli [b], Roberto Tirindelli [c] and Umberto Castiello [a,*]

[a] Dipartimento di Psicologia Generale, Università di Padova, Padova, Italy
[b] Unità Operativa di Neurologia Ospedale dell'Angelo- USL12, Mestre, Italy
[c] Dipartimento di Neuroscienze, Università di Parma, Parma, Italy

ARTICLE INFO

Article history:
Received 12 January 2012
Reviewed 18 March 2012
Revised 5 April 2012
Accepted 17 May 2012
Action editor H. Branch Coslett
Published online 5 June 2012

Keywords:
Kinematics
Olfaction
Parkinson's disease
Reach-to-grasp
Implicit processing

ABSTRACT

Many reports in the literature indicate that idiopathic Parkinson's disease (IPD) patients have substantial olfactory dysfunctions even before motor symptoms become evident. It has not yet been clarified, however, if some form of implicit olfactory processing is preserved in this population. An olfactory visuomotor priming paradigm, which detects implicit olfactory processing in neurologically healthy participants, was utilized to investigate motor control in relation to olfactory signals in a group of IPD patients. Two control groups were also considered: 12 vascular Parkinson's disease (VPD) in whom normal olfactory abilities are typically reported and 12 neurologically healthy participants. All of the participants were asked to perform reach-to-grasp movements toward large or small targets following olfactory cues delivered by a computer-controlled olfactometer. The odor was either 'size' congruent with the target (e.g., strawberry or apple, respectively) or incongruent (e.g., apple or strawberry, respectively). A bend sensor glove (CyberGlove) was used to measure the hand kinematics. Facilitation effects were noted in all the groups with regard to movement time. If a congruent rather than an incongruent odor was delivered, the movement time of the reach-to-grasp was shortened and facilitation effects in maximum grip amplitude were noted in both the IPD and the VPD groups. The maximum grip amplitude was smaller when no odor, as compared to a congruent odor, was delivered. The present results suggest that implicit olfactory processing affects motor control in IPD patients favoring less severe bradykinesia and hand movement hypometria. Once confirmed, these findings could be useful when rehabilitation strategies are being hypothesized for these patients.

1. Introduction

Parkinson's disease (PD) is principally characterized by motor disturbances which are often the reason these patients seek their physicians' attention. These disturbances reflect, at least in part, a pathological loss of dopaminergic neurons in the ventral midbrain and nerve terminal degeneration in the striatum (Bernheimer et al., 1973). The greater the neuronal

* Corresponding author. Dipartimento di Psicologia Generale, Università di Padova, Via Venezia 8, 35131 Padova, Italy.
E-mail address: umberto.castiello@unipd.it (U. Castiello).
0010-9452/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.cortex.2012.05.017

loss in the substantia nigra, the lower the concentration of dopamine in the striatum, and the more severe symptoms are in these patients. Typically, by the time PD is clinically diagnosed, a significant loss of dopaminergic neurons has already occurred.

Although a progressive loss of nigral neurons is considered an essential neuropathological feature, recent findings in the literature seem to suggest that PD is characterized by a variety of symptoms which go beyond motor disturbances (Braak et al., 2003, 2004; Chaudhuri et al., 2006; Ziemssen and Reichmann, 2007). A great deal of attention has been paid to PD-related non-motor symptoms such as sensory disorders, autonomic dysfunctions, mood and sleep disorders, cognitive deficits and hyposmia which appear to be perceptible even before motor parkinsonism becomes explicit (Braak et al., 2003, 2004; Wolters and Braak, 2006).

Olfactory dysfunction is a non-motor symptom that has long been described in patients with PD (Doty, 2003). A significant decrease in odor detection, discrimination, and identification has, in fact, frequently been reported in PD patients with respect to neurologically healthy controls (Ansari and Johnson, 1975; Korten and Meulstee, 1980; Quinn et al., 1987; Hawkes et al., 1997, 1999; Double et al., 2003).

Structures such as olfactory bulbs, olfactory tracts, and/or the anterior olfactory nuclei appear to be affected early during disease development (Tissingh et al., 2001; Del Tredici et al., 2002; Braak et al., 2003, 2004). Although olfactory deficits could be related to dopaminergic loss, Huisman et al. (2004) used tyrosine hydroxylase immunohistochemistry to show that the number of dopaminergic cells within the olfactory bulbs of PD patients was doubled with respect to that generally found in neurologically healthy subjects. This finding led to the hypothesis that increased levels of dopamine within the olfactory glomeruli might determine an inhibitory transmission in the olfactory bulb. Possibly responsible for this condition in PD, the inhibitory process described might explain why hyposmia in these patients is not levodopa-responsive (Huisman et al., 2004).

Although it is well established that the majority of patients with idiopathic Parkinson's disease (IPD) have a defective sense of smell, a large number of investigations have utilized olfactory tests which require an explicit report of odor features (e.g., Doty et al., 1988; Daum et al., 2000; Haehner et al., 2009). Such explicit report implies specific forms of odor memory involving the generation of a name or the odor identification for the participant to respond (Olsson et al., 2002). This aspect is particularly relevant in PD, given that studies addressing odor recognition memory performance seem to suggest that such function in PD patients is impaired (Corwin et al., 1985; Zucco et al., 1991; Kesslak et al., 1988; Mesholam et al., 1998). At a neural level, this finding seems to be supported by studies reporting that olfactory perception may preferentially recruit the hippocampus, possibly reflecting its role in the working memory element of odor-related tasks (Kareken et al., 2003; Bohnen et al., 2008a, 2008b).

In everyday life, nevertheless, odors are rarely encountered in isolation and generally exist in a contextual relationship with other details. In most cases odors are learned unintentionally and unconsciously (Issanchou et al., 2002; Wilson and Stevenson, 2006). As a result, it is difficult to describe odors in terms of specific constituents, and attention is generally focused on individuals' reactions to odor-related events rather than on the identity or the names of odors per se (Engen, 1987; de Wijk and Cain, 1994). Not surprisingly, while people seem to have more difficulty in naming objects via smell than via sight (Cain et al., 1995), they nevertheless negotiate the world of odors quite successfully. While means of encoding odors other than language seem to be utilized, both explicit and implicit processing could be involved in forging the rather complex relationship between odors, their sources, and behaviors connected to them.

Until now, no studies have attempted to assess if any kind of implicit odor processing occurs in PD patients, but recent findings concerning the role played by olfactory stimuli in shaping motor behavior can provide some insight into the direction research should take (Castiello et al., 2006; Tubaldi et al., 2008a, 2008b). Experiments were devised by some investigators to study reach-to-grasp movements performed in the presence or absence of an orthonasal olfactory task-irrelevant stimulus. In some of the experiments the olfactory stimulus evoked an object that was smaller or larger than the visual target utilized. The maximum distance between the index finger and the thumb (i.e., maximum grip amplitude) was found to be affected in different ways depending on the stimulus. If the olfactory stimulus evoked an object that was smaller than the visual target, the maximum grip amplitude was smaller than the one associated to a no-odor clue, but if it evoked an object that was larger than the visual target utilized, the maximum grip amplitude was larger than that associated to a no-odor clue. Moreover, when the 'size' of the odor stimulus and the size of the visual target corresponded, facilitation effects were noted: movement time was, in fact, shorter compared to situations in which the visual target did not correspond to the olfactory stimulus or when there was no olfactory clue. Taken together, these findings seem to indicate that although an olfactory stimulus is irrelevant as far as task performance is concerned, it is nevertheless implicitly elaborated in motor terms to facilitate – or interfere with – the motor plan prepared for the visual target.

Based on the hypothesis that if some sort of implicit olfactory processing still takes place in PD patients this would be reflected in their motor behavior, we designed a reach-to-grasp experiment (e.g., Müller and Stelmach, 1992; Castiello et al., 1993; Saling et al., 1996; Gordon et al., 1997; Tresilian et al., 1997; Gordon, 1998) and added an olfactory stimulus. This population has commonly been found to be slower and to reach smaller peak amplitudes than age-matched control participants but, in other respects, task performance appears to be similar in the two groups. At the same time, studies concerning the influence of olfactory stimuli on reach-to-grasp movements in neurologically healthy individuals have reported alterations in the same specific movement's parameters found in the PD patients (Castiello et al., 2006; Tubaldi et al., 2008a, 2008b).

IPD patients were thus asked to carry out reach-to-grasp movements in the direction of visual targets of different sizes in the absence or presence of preliminary olfactory stimuli that were size congruent or incongruent with the visual targets. The performance of these patients was compared with that in VPD patients with no specific olfactory