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Visual exploration of emotional facial expressions in Parkinson's disease

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ABSTRACT

Parkinson's disease (PD) is associated with impairments in facial emotion recognition as well as visual and executive dysfunction. We investigated whether facial emotion categorization impairments in PD are attributable to visual scanning abnormalities by recording the eye movements of 16 non-demented PD and 20 healthy control (HC) participants during an emotion recognition task. We examined the influence of several factors that can affect visual scanning, including oculomotor, basic visual, and cognitive abilities (executive function). Increases in the number and duration of fixations in the top regions of surprise facial expressions were related to increases in recognition accuracy for this emotion in PD participants with left-sided motor-symptom onset. Compared to HC men, HC women spent less time fixating on fearful expressions. PD participants displayed oculomotor abnormalities (antisaccades), but these were unrelated to scanning patterns. Performance on visual measures (acuity, contrast sensitivity) correlated with scanning patterns in the PD group only. Poorer executive function was associated with longer fixation times in PD and with a greater number of fixations in HC. Our findings indicate a specific relation between facial emotion categorization impairments and scanning of facial expressions in PD. Furthermore, PD and HC participants' scanning behaviors during an emotion categorization task were driven by different perceptual processes and cognitive strategies. Our results underscore the need to consider differences in perceptual and cognitive abilities in studies of visual scanning, particularly when examining this ability in patient populations for which both vision and cognition are impaired.

1. Introduction

Individuals with Parkinson's disease (PD) display impairments in the ability to recognize emotions from facial expressions (Clark, Neargarder, & Cronin-Golomb, 2008; Dujardin et al., 2004; Jacobs, Shuren, Bowers, & Heilman, 1995; Kan, Kawamura, Hasegawa, Mochizuki, & Nakamura, 2002; Lawrence, Goerendt, & Brooks, 2007; Sprengelmeyer et al., 2003), but the reason for this deficit is as yet unclear. Investigations of visual scanning behaviors in neuropsychiatric patients (Adolphs et al., 2005; Ogrocki, Hills, & Strauss, 2000), and healthy older adults (Wong, Cronin-Golomb, & Neargarder, 2005) suggest that abnormalities in visual scanning of facial images may contribute to impairments in emotion recognition abilities, raising the question of whether emotion recognition impairments in PD may arise from abnormalities in visual scanning.

The neuropathology of PD affects several structures that are implicated in eye movement control. PD is associated with a reduction in dopaminergic neurons in the substantia nigra pars compacta, leading to a dysfunction of fronto-striatal systems (Hornykiewicz & Kish, 1987; Parent, 1990; Taylor, Saint-Cyr, & Lang, 1986). Human and non-human primate research indicates that a specific area within the frontal lobes, the frontal eye field (FEF), is prominently involved in the larger cortical network that contributes to visual attention and oculomotor functioning (for review see Barton, 2001). The basal ganglia are also noted to play a key role in governing eye movements (for review see Hikosaka, Takikawa, & Kawagoe, 2000). Several studies have shown that abnormalities in visual scanning abilities are present in individuals with PD (Bares et al., 2003; Hood et al., 2007; Rascol et al., 1989; Vidailhet et al., 1994). Compared to healthy adults, individuals with PD display saccades that are slow, hypometric, and have increased response latencies (Hikosaka et al., 2000). PD patients also have difficulty controlling voluntary saccadic (i.e., antisaccades) (Hood et al., 2007) and smooth pursuit movements (Bares et al., 2003; Rascol et al., 1989).

Facial emotion recognition is a highly specific and complex process thought to involve several brain structures, including the amygdala, orbitofrontal cortex, dorsolateral prefrontal cortex, insula, basal ganglia, hippocampus and the anterior cingulate (Adolphs, 2002; Phillips, Drevets, Rauch, & Lane, 2003). In a previous study (Clark et al., 2008), we found that PD participants displayed specific impairments in facial emotion recognition relative to a non-emotional categorization task. It is generally argued

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that abnormalities in facial emotion recognition in PD arise from losses of dopaminergic neurons resulting in dysfunction of fronto-subcortical systems (e.g., Dujardin et al., 2004; Lawrence et al., 2007; Sprengelmeyer et al., 2003); however the specific perceptual or cognitive processes underlying facial emotion recognition abnormalities in PD are not fully understood. As suggested above, it is possible that visual scanning abnormalities may contribute to facial emotion categorization impairments observed in this patient population. The current study expands upon our previous research by examining emotion categorization abilities in PD in relation to their visual scanning behaviors. Based on findings that suggest a relation between visual scanning abnormalities and impairments in emotion recognition (Adolphs et al., 2005; Ogrocki et al., 2000; Wong et al., 2005), we reasoned that PD participants would display abnormalities in visual scanning of facial emotions that were related to impairments in emotion recognition abilities.

Reports that the amount and quality of emotion-specific information expressed in facial displays differs across regions of the face led us to examine the topographic location of fixations (top vs. bottom, right vs. left). In regard to top and bottom regions, normal adults show a preference to examine the eyes over other regions of the face (Adolphs et al., 2005; Walker-Smith, Gale, & Findlay, 1977). Expressions of anger, fear and sadness are reported to be best recognized from the top portions of the face, whereas disgust and happiness are more accurately recognized from the bottom portions; surprise facial expressions appear to be recognized equally well from the top and bottom regions (Calder, Young, Keane, & Dean, 2000). In regard to right and left sides, there is evidence to suggest that facial emotions are expressed more intensely by the left than the right hemiface in both human (Sackeim, Gur, & Saucy, 1978) and non-human primates (Fernandez-Carriba, Loeches, Morcillo, & Hopkins, 2002).

Beyond this regional specificity, researchers examining visual scanning patterns in healthy adults have proposed that scanning behaviors are governed by two general factors, including the cognitive processes of the viewer (top-down processes) and the image properties of the stimuli (e.g., low-level stimulus properties) (for review see Henderson, 2003). Visual scanning is strongly influenced by the nature of the task. For example, scanning patterns can differ substantially depending on whether the viewer is engaged in free viewing, memorizing aspects of the image, or examining the emotional connection between individuals in the image (Henderson, Weeks, & Hollingworth, 1999; Land & Hayhoe, 2001; Yarbus, 1967). Such data have been interpreted to suggest that visual scanning is strongly controlled by top-down cognitive processes. Other studies have shown that visual scanning behaviors are partially controlled by low-level stimulus properties of the image such as spatial frequency content, edge density, line curvature and local contrast (Krieger, Rentschler, Hauske, Schill, & Zetzsche, 2000; Mannan, Ruddock, & Wooding, 1996; Mannan, Ruddock, & Wooding, 1997; Parkhurst & Niebur, 2003; Reinagel & Zador, 1999).

Taking these findings into consideration, we investigated visual scanning patterns in relation to facial emotion categorization in PD (Experiment 1). We were particularly interested in examining scanning patterns in relation to the locations of fixations on facial expressions (top vs. bottom, right vs. left). We then assessed visual scanning patterns of emotional facial expressions in relation to three potential contributing factors: basic oculomotor abilities (Experiment 2), visual and visuoperceptual abilities (Experiment 3) and executive functioning abilities (Experiment 4). Because these abilities are known to be disrupted in PD (contrast sensitivity: Amick, Cronin-Golomb, & Gilmore, 2003; oculomotor: Hood et al., 2007; executive function: Zgaljardic, Borod, Foldi, & Mattis, 2003), we considered the possible moderating influences each of these abilities might exert on visual scanning behaviors when viewing emotional facial expressions. This evaluation helped to differentiate between the influences of abnormalities in perceptual and cognitive processes on visual scanning behaviors in PD.

2. General method

2.1. Participants

Participants included 16 individuals with idiopathic PD without dementia (8 men, 8 women) and 20 healthy control (HC) participants (10 men, 10 women) (Table 1). The groups did not differ with respect to age (t [34] = .46, p = .65; range: PD = 46–72; HC = 45–72) or education (t [34] = .56, p = .58; range: PD = 12–20; HC = 13–19). We recruited PD participants from the Parkinson's Disease Clinic at the Boston Medical Center and through local PD support groups. Participants in the HC group were recruited from the community. All were right-handed except for 1 PD participant. The research was approved by Boston University's Institutional Review Board. All individuals gave their informed consent.

Participants were required to be in good overall health and native speakers of English. They had no history of any of the following: uncorrected abnormal vision or hearing; psychiatric illness (including pre-existing diagnosis of depression or anxiety); use of psychoactive medications besides antidepressants and anxiolytics in the PD group; neurological illness other than PD, intracranial surgery, alcoholism, drug abuse, or eye disease.

PD participants were staged by their neurologist according to a measure of motor disability (Hoehn & Yahr, 2001). All were in stages II–III (mild to moderate bilateral disability) at the time of testing. Seven PD participants reported a right body side onset of motor symptoms (RPD: 3 men, 4 women) and nine reported a left-side symptom onset (LPD: 5 men, 4 women). Neither the RPD and LPD patients nor the male and female PD patients differed in

Table 1
Participant characteristics.

Variable	HC (M/F = 10/10)		PD (M/F = 8/8)		RPD (M/F = 3/4)		LPD (M/F = 5/4)	
	M	SD	M	SD	M	SD	M	SD
Age (years)	59.7	6.7	58.6	7.2	59.9	7.4	57.7	7.4
Education (years)	16.7	1.5	16.3	2.6	17.0	2.8	15.8	2.4
Disease duration (years)	n/a	n/a	6.0	3.1	6.1	3.1	5.9	3.2
Hoehn & Yahr score (median & range)	n/a	n/a	2.0	2.0–3.0	2.0	2.0–3.0	2.0	2.0–2.5
Dementia Rating Scale (/144)	n/a	n/a	142.9	1.0	143.4	0.8	142.6	1.0
Mini-Mental State Exam (/30)	28.9	1.0	28.5	1.4	28.6	1.0	28.4	1.7
Beck Depression Inventory (/63)	4.1[a]	4.6	9.2[a]	5.4	9.9	4.2	8.7	6.3
Beck Anxiety Inventory (/63)	3.6[a]	4.5	10.9[a]	8.4	11.0	6.2	10.8	10.1

Note: HC = healthy control; PD = Parkinson's disease; RPD = right body side of motor onset Parkinson's disease; LPD = left body side of motor onset Parkinson's disease; M/F = male–female ratio; M = mean (or median where noted). Within rows, means with the same superscript are significantly different at $p \leq .01$.