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Discriminating facial expressions of emotion and its link with perceiving visual form in Parkinson's disease

Michelle Marneweck *, Geoff Hammond

School of Psychology, University of Western Australia, Australia

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ABSTRACT

We investigated the link between the ability to perceive facial expressions of emotion and the ability to perceive visual form in Parkinson's disease (PD). We assessed in individuals with PD and healthy controls the ability to discriminate graded intensities of facial expressions of anger from neutral expressions and the ability to discriminate radial frequency (RF) patterns with modulations in amplitude from a perfect circle. Those with PD were, as a group, impaired relative to controls in discriminating graded intensities of angry from neutral expressions and discriminating modulated amplitudes of RF patterns from perfect circles; these two abilities correlated positively and moderately to highly, even after removing the variance that was shared with disease progression and general cognitive functioning. The results indicate that the impaired ability to perceive visual form is likely to contribute to the impaired ability to perceive facial expressions of emotion in PD, and that both are related to the progression of the disease.

1. Introduction

Although traditionally conceptualized a disorder of movement, Parkinson's disease (PD) is associated with a range of non-motor symptoms, which include dysfunction in mood, sleep, cognition, and vision [54]. Many have questioned whether persons with PD are also impaired their ability to perceive facial expressions of emotion. The findings from individual studies have been mixed; some studies have reported impaired perception of facial expressions of emotion in PD [5–7,9,10,12–16,22,32,34,35,38,44,47,50,51,58,59,68] whereas others have found no such impairment [2,18,20,31,45,53,60,63,65]. Despite mixed findings from individual studies, a recent meta-analysis by Gray and Tickle-Degnen [30] concluded that those with PD were impaired in perceiving facial expressions of emotion and that this impairment was unrelated to the ability to perceive visual form. The studies reviewed measured this latter ability with the Benton Face Recognition Test (BFRT; [11]) or a similar test, all of which are traditionally viewed as measures of face recognition. The BFRT has been shown to be sensitive only to large impairments in facial identity recognition [21]. There have been reports that those with PD are impaired in perceiving facial information other than emotion [19,47,50]. Narme et al. [50] and Marneweck et al. [47] used psychophysical measures of extracting non-emotional facial information that might have been more sensitive to differences between PD and control groups. Furthermore, both Narme et al. [50] and Marneweck et al. [47] showed a positive correlation between the abilities to extract emotional and non-emotional information from faces [47,50]. Both the ability to perceive emotional and non-emotional information from faces might be affected by a more general impairment of the ability to perceive visual form. A range of low-level visual functions is known to be impaired in PD ([4], for a review); these impairments are likely to affect visual form perception that requires encoding of local orientation information prior to integrating separate features into global shapes and separating them from their backgrounds [41]. Therefore, a link between low-level visual function and perception of emotional expressions in PD might be expected. Contrary to this hypothesis, Hipp et al. [33] found no correlation between measures of low-level visual function (contrast sensitivity and color discrimination) and perception of facial expressions of emotion in PD; however, these analyses were conducted with a sample of patients at an early stage of PD with little variation between patients in disease severity (UPDRS motor score $M = 8$, $SD = 4$). The potential link between low-level visual function and emotional expression perception requires further testing with patients at a range of stages of PD. Furthermore, the potential link between the ability to perceive visual form, which is likely affected by impaired low-level visual function, and the ability to perceive facial expressions of emotion in PD is yet to be tested.

In previous work we found large impairments in those with PD in discriminating emotional expressions of graded intensity from neutral expressions and discriminating variations in intensity of the same

Abbreviations: PD, Parkinson's disease; BFRT, Benton Face Recognition Test; 2IFC, two-interval forced choice; RF, radial frequency; MoCA, Montreal Cognitive Assessment; GDS, Geriatric Depression Scale; MDS-UPDRS, Movement Disorders Society-sponsored revision of the Unified Parkinson's Disease Rating Scale; LED, daily levodopa dose equivalent.

* Corresponding author at: School of Psychology (M304), University of Western Australia, Crawley, WA 6009, Australia. Tel.: +61 8 6488 1415.
E-mail address: michelle.marneweck@uwa.edu.au (M. Marneweck).

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emotional expressions of four commonly expressed emotions, anger, disgust, happiness, and sadness [47]. These psychophysical measures used a two-interval forced-choice (2IFC) procedure, with, on each trial, successive presentation of stimuli with brief stimulus durations and a brief interstimulus interval. Given previous reports of impairment in PD in working memory [39] and in the processing time of visually presented information [36], it is possible that the sequential stimuli in the 2IFC procedure and the brief stimulus durations exaggerated the impairment in PD.

The aims of the current experiment were two-fold. First, we explored the link between perception of visual form and perception of facial expression of emotion in PD. To investigate perception of visual form, we measured the ability to discriminate radial frequency (RF) patterns of varying modulations in amplitude from a perfect circle. RF patterns, first created by Wilkinson et al. [67], are a family of smooth closed shapes that differ from each other and each from a perfect circle in a well-defined way: different patterns can be created by modulating the amplitude (affecting the sharpness or depth of the lobe), radial frequency (the number of lobes) and the orientation (the direction of the lobe). To investigate the link between the abilities to perceive visual form and facial expressions of emotion in PD, we correlated measures of discriminating RF3 patterns from perfect circles with measures of discriminating graded intensities of angry from neutral expressions. As a second aim, we investigated whether impairment in PD in discriminating angry from neutral facial expression was present when measured with longer stimulus durations in a 2IFC procedure (to reduce any effects of slower visual processing times) and with a single-stimulus yes–no procedure (to reduce the working memory demands imposed by sequential stimuli).

2. Materials and methods

2.1. Participants

Forty-two participants (PD $n = 24$; Control $n = 18$) were tested. Table 1 shows the demographic and clinical characteristics of each group; groups were on aggregate well matched for age, sex, and scores on measures of general cognitive functioning (Montreal Cognitive Assessment, MoCA; [52]) and depressive symptoms (Geriatric Depression Scale, GDS, [57]). Although some participants from both groups (PD group: $n = 7$; Control group: $n = 3$) scored below the traditional cut-off (26) for mild cognitive impairment on the MoCA, these participants were not excluded as there is a growing consensus that the traditional cut-off is too high for older adults [26,27,37,40,43,56,64]. Studies have consistently shown that MoCA performance declines with healthy aging, and that the traditional cut-off score might 'overpathologize' cognitively intact older adults. A cut-off score of 20 for mild cognitive impairment in older adults has been proposed by Larner [37], Waldron-Perrine and Axelrod [27], and Godefroy et al. [64]. All control participants from this study scored above this cut-off score. Patients were diagnosed by a neurologist and recruited from the Edith Cowan University Parkinson's Centre research database and from previous research participation. Control participants were recruited from the local community and from previous research participation. The Institutional Ethics Committee approved the experimental procedures and all participants gave written informed consent.

Table 1
Demographic and clinical characteristics of participant groups.

Characteristics	CONTROL	PD
Age in years	70 (53–80)	68 (58–82)
Males (Females)	12 (6)	16 (8)
Education years	16 (11–20)	14 (9–19)
MoCA	27 (22–30)	27 (19–29)
GDS	1 (0–4)	1 (0–10)
Years diagnosed	–	8 (2–22)
MDS-UPDRS-III	–	40 (19–57)
Hoehn–Yahr stage	–	2 (1–2)
LED	–	1057 (0–2662)
Reported side of symptom onset	–	9 (14)

All values (except number of males and females) are expressed as median (minimum–maximum range); MoCA = Montreal Cognitive Assessment, score ranges from 0 (most severe) to 30, a score ≥ 26 reflects normal cognitive functioning; GDS = Geriatric Depression Scale, score ranges from 0 to 15 (most severe), a score of 6 or more is suggestive of depression that should warrant thorough assessment; MDS-UPDRS-III = motor scale of Unified Parkinson's Disease Rating Scale, score ranges from 0 to 132 (most severe disease state); LED = daily levodopa dose equivalent [61]; reported side of symptom onset gives the number of reported left side onset (right side onset), with 1 participant reporting onset of symptoms on both sides.

2.2. Stimuli and procedures

Participants completed in one session that lasted between 1.5 and 2 h psychophysical measures of (1) discriminating graded intensities of angry from neutral expressions in a 2IFC procedure and in a yes–no procedure with the Method of Constant Stimuli, and (2) psychophysical measures of discriminating RF patterns with varying amplitude modulations from perfect circles using a 2IFC procedure with the Method of Constant Stimuli; the RF pattern discrimination measure was always given prior to the emotion discrimination measures. Patients were initially assessed for severity of motor symptoms using the Movement Disorders Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPRDS, [28]). Patients completed the testing session approximately 2 h before their next antiparkinson medication.

For the measure of emotion discrimination, we selected four models expressing full-blown anger from the NimStim Face Stimulus Set [62]; we graded these expressions in emotional intensity by morphing full-blown expressions of each model with their neutral expression (see [46] for details). Given that our previous findings showed a similar level of impairment in PD for each of the four emotions (anger, disgust, happiness, and sadness), we only tested anger. Each face showing an angry or a neutral expression was set in a rectangular white background that was 6.8 cm high and 5.4 cm wide subtending visual angles of 6.6° and 5.2° at a viewing distance of 59 cm. The order of the 2IFC procedure and a yes–no procedure of the emotion discrimination measure was counterbalanced. On each trial of the 2IFC procedure, two faces of the same model appeared successively on a computer screen at a duration of 200 ms or 1000 ms with a 200-ms blank interstimulus interval. The face with the neutral expression appeared randomly in either the first or the second interval and the face expressing one of five levels of intensity of anger (set at 5, 9, 16, 29, and 52% of the full-blown expression) appeared in the other interval. On each trial participants signaled the interval containing the angry face by clicking either the left or right button on a mouse to indicate the first or second interval respectively. There were 10 randomized blocks of 40 trials (with a break after the fifth block), with each block containing five intensities of anger each expressed by each of the four models at two stimulus durations, giving 400 trials in total. For the emotion discrimination measure with the yes–no procedure, each trial showed one face either with a neutral expression or with an expression of anger at one of three emotional intensities (9%, 16%, 29%); each face was presented at a duration of 200 ms or 1000 ms. Participants indicated with mouse-click whether the face was emotional by clicking the left mouse button or neutral by clicking the right mouse button. There were ten randomized blocks of 48 trials (with a break given after the fifth block) with each block containing three neutral expressions and three intensities of anger by each of four models at two stimulus durations, giving 480 trials in total.

For the measure of discriminating RF patterns with varying amplitude modulations from perfect circles (with a 2IFC procedure with the Method of Constant Stimuli), RF patterns were created by application of a sinusoidal modulation to the radius of a perfect circle, with three cycles of modulation around the full 2π radians, producing an RF3 pattern (see Fig. 1). The distance from the center to a specific point in the modulated pattern, r', is given by: $(R0 * (1 + A * \sin(w * \angle + phi))$, where $R0$