Journal of the Neurological Sciences xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Journal of the Neurological Sciences

journal homepage: www.elsevier.com/locate/jns

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

ARTICLE INFO

Article history:
Received 13 February 2014
Received in revised form 30 July 2014
Accepted 11 August 2014
Available online xxxx

Keywords:
Parkinson's disease
Emotion perception
Facial expressions
Visual form perception
Radial frequency pattern
Visual function

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).

http://dx.doi.org/10.1016/j.jns.2014.08.014
0022-510X/

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 $R0$

Please cite this article as: Marneweck M, Hammond G, Discriminating facial expressions of emotion and its link with perceiving visual form in Parkinson's disease, J Neurol Sci (2014), http://dx.doi.org/10.1016/j.jns.2014.08.014

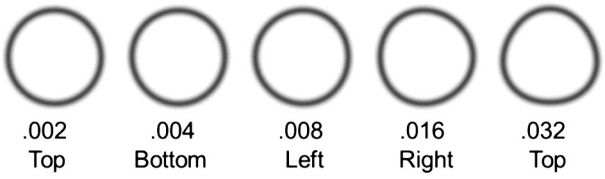

Fig. 1. RF3 patterns with specifications of variation in amplitude modulation (in proportion to the radius of the circle) and apex orientation.

is the unmodulated radius of the pattern, *A* is the maximum modulation amplitude expressed as the proportion of the radius of the unmodulated pattern, ∠ is the polar angle that defines a direction in the fronto-parallel plane relative to the center of the pattern, *phi* is a polar angle that allows the pattern to be rotated in the fronto-parallel plane, and *w* is the frequency of modulation. Five depths of amplitude modulation were created .002, .004, .008, .016, and .032 in proportion to the radius of the circle. There were four variations of each amplitude modulation such that the apex of the RF3 pattern appeared either at the top, left, right, or bottom of the pattern. The Weber contrast was set to −.7 to avoid visible persistence of the first stimulus which was present at higher contrast. The stimulus size, viewing distance, and interstimulus interval were identical to those in the 2IFC measure of emotion discrimination; the stimulus duration was set at 200 ms. One each trial, the perfect circle appeared in either the first or second interval and the RF3 pattern with one of five amplitude modulations appeared in the other interval. Participants indicated with a mouse-click whether the RF3 pattern appeared in the first or the second interval by clicking the left or right button, respectively. There were 10 randomized blocks of 20 trials, with each block containing the five variations of amplitude modulation each with four apex orientations, giving 200 trials in total.

2.3. Data analysis

Individual data obtained with the 2IFC psychophysical measures of discrimination of angry expressions and RF3 patterns were fitted with Cumulative Gaussian functions which generally fitted the individual data well; the median R^2 value was .94 for both discriminating angry from neutral expressions and for discriminating RF3 patterns from perfect circles. Absolute thresholds were taken as the stimulus level at which 75% correct performance was reached. For the emotion discrimination measure, there were two determinations for each participant, one for each of the two stimulus durations, giving 84 determinations in total. For the RF3 pattern discrimination measures, there was one determination for each participant giving 42 determinations in total. Thresholds could not be obtained for six of the 84 determinations for the emotion discrimination measure (two of which came from the same participant) and for one of the 42 determinations for the RF3 pattern discrimination measure, because the range of constant stimuli did not capture the complete psychometric function or because the fit to the individual data points was poor. One of the determinations in the emotion discrimination and RF3 pattern discrimination respectively for which thresholds could not be obtained came from one of the PD patients. For the emotion discrimination measure, seven thresholds (200 ms duration: $n = 3$; 1000 ms duration: $n = 4$) that were obtained from patients exceeded 100; these thresholds were set arbitrarily to 100, which is conceptually equivalent to a full-blown emotional expression. For the emotion discrimination measure with a yes–no procedure, we calculated d-prime as a measure of sensitivity for each of the three intensities of angry expressions. For both emotion discrimination measures, we conducted mixed ANOVAs (between subjects factor: group; within-subjects factor: stimulus duration). For the RF3 pattern discrimination measure, we conducted an independent samples *t*-test. To quantify group differences, we report measures of effect size (Hedges' *g*) on emotion discrimination measures (for each stimulus duration) and RF3 pattern discrimination measures. To quantify the relationship between emotion and RF3 pattern discrimination in PD, we report Pearson correlation coefficients with 95% confidence intervals. Instead of using absolute threshold scores in the correlations between 2IFC measures of RF3 pattern and emotion discrimination, which could not be obtained for all patients, we use mean percent correct scores across stimulus durations and stimulus levels; we exclude the lowest stimulus level at which most participants performed at chance. We similarly use the mean d-prime values across stimulus duration and stimulus level (excluding the lowest stimulus level) of the emotion discrimination measure with the yes–no procedure for its correlation with RF3 pattern discrimination. There was little or no correlation between measures of emotion discrimination and depressive symptoms and daily levodopa dose equivalent (LED), with 95% confidence intervals (CI's) overlapping zero; for brevity, these are reported in the Appendix A (Table A1).

3. Results

3.1. Discriminating anger from neutral expressions

Fig. 2 shows functions fitted to mean data points for PD and control groups for the 2IFC measure of discriminating angry from neutral expressions with 200 ms and 1000 ms stimulus durations. All functions increased monotonically with increasing differentiation of the expressive from the neutral face. The figure also shows that the PD group performed more poorly than the control group at both stimulus durations, and that an increase in stimulus duration made little or no difference to performance in either group. There was a significant main effect of group ($F(1, 35) = 12.64$, $p < .05$), but no main effect of stimulus duration ($F(1, 35) = 3.85$, $p > .05$), and no interaction between stimulus duration and group ($F(1, 35) = 1.36$, $p > .05$) on absolute thresholds. Table 2 shows that the mean absolute thresholds were higher for the PD group than the control group, with very large effect sizes for the group differences at both stimulus durations. The table also shows that there was greater variability in thresholds in the PD group than in the control group, and that some in the PD group had thresholds similar to some of the best-performing controls.

Fig. 3 shows mean d-prime values for both groups for each of the three intensity increments at each stimulus duration for emotion discrimination with the yes–no procedure. Sensitivity to expressions of anger increased with increasing intensity of the expression. The PD group showed lower sensitivity than the controls at both stimulus durations. As was the case for the 2IFC emotion discrimination measure, there was a significant main effect of group ($F(1, 40) = 19.94$, $p < .05$), with large effect sizes of the mean group differences across intensity increments for both stimulus durations (200 ms $g = 1.35$; 1000 ms $g = 1.00$). Although there was a significant effect of stimulus duration ($F(1, 40) = 25.40$, $p < .05$, $g = .48$), indicating a greater

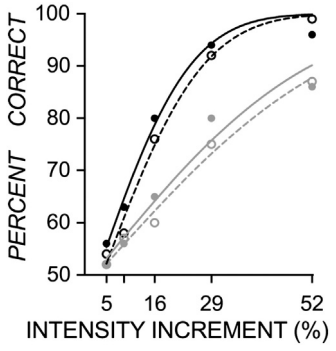

Fig. 2. Cumulative Gaussian functions fitted to mean percent correct scores for PD (gray) and control (black) groups when discriminating graded intensities of anger from neutral expressions with a 2IFC procedure. Dashed lines and unfilled circles show data for stimulus presentation durations of 200 ms and solid lines and filled circles show data for stimulus presentation durations of 1000 ms.

Please cite this article as: Marneweck M, Hammond G, Discriminating facial expressions of emotion and its link with perceiving visual form in Parkinson's disease, J Neurol Sci (2014), http://dx.doi.org/10.1016/j.jns.2014.08.014

Table 2
Mean estimates of absolute threshold (with standard deviation followed by range in parentheses), taken as the emotional intensity level at which 75% correct performance was reached, for the 2IFC measure of discriminating graded intensities of angry from neutral expressions for PD (200 ms, n = 21, 1000 ms, n = 22) and control (200 ms, n = 18; 1000 ms, n = 14) groups, with Hedges' *g* quantifying the difference between groups.

	Control	PD	*g*
200 ms duration	17 (6; 7–28)	38 (23; 10–100)	1.13[a]
1000 ms duration	16 (4; 9–24)	32 (21; 11–100)	1.00[a]

[a] Indicates statistical significance, $p < .05$.

sensitivity to angry expressions at the longer stimulus duration (which is shown in Fig. 3), there was no significant interaction between stimulus duration and group ($F(1, 40) = .05$, $p > .05$), indicating that the longer duration was no more beneficial for the PD group than the control group.

3.2. Discriminating RF3 patterns from perfect circles

Fig. 4 shows functions fitted to mean data points for PD and control groups for the measure of discriminating RF3 patterns of varying amplitude modulations from perfect circles. Functions of both groups increased monotonically with increasing amplitude modulation, with the PD group performing more poorly than the controls. As was the case in the measure of emotion discrimination, absolute thresholds were higher and more variable in the PD group ($M = .031$, $SD = .025$) than in the control group ($M = .009$, $SD = .003$), with a large effect size for the significant group difference ($t(40) = 3.60$, $p < .05$, $g = 1.03$). Again, some with PD performed as well as some of the best-performing controls (PD *range*: .005, .075; Control *range*: .004, .017).

3.3. The link between perceiving emotional expressions and perceiving visual form

The correlations of discriminating RF3 patterns from circles with discriminating anger from neutral expressions with the 2IFC and yes–no procedures were significant, positive and moderate to large (2IFC $r = .86$; 95% CI: .70, .94, $p < .05$, and yes–no $r = .61$; 95% CI: .28, .81, $p < .05$). Table 3 shows that the progression of the disease, as measured by the motor score on the MDS-UPDRS, correlated moderately and negatively with the 2IFC measures of emotion and RF3 pattern discrimination; the correlation coefficient was smaller, with CI's just overlapping zero, between the MDS-UPDRS motor scores and the emotion discrimination measure with the yes–no procedure. The correlation between discriminating RF3 patterns and angry expressions remained significant, positive and moderate to large after removing the common variance shared with disease progression and general cognitive functioning (2IFC $r = .80$; 95% CI: .59, .91, $p < .05$; yes–no $r = .51$, 95% CI: .14, .76, $p < .05$). Therefore, after removing the common variance shared with disease progression and general cognitive functioning, RF3 pattern discrimination shared 64% and 26% of variance with emotion discrimination as measured by the 2IFC and yes–no procedures respectively.

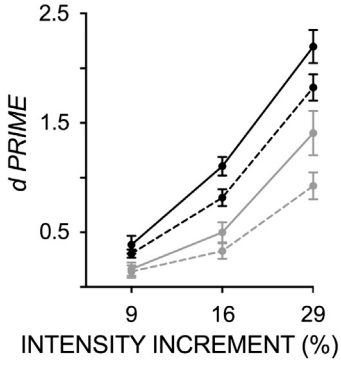

Fig. 3. Mean d-prime indices (+/− 1 standard error) for PD (gray) and control (black) groups when discriminating graded intensities of anger from neutral expressions using a yes–no procedure. Dashed lines show data for stimulus durations of 200 ms, and solid lines show data for stimulus durations of 1000 ms.

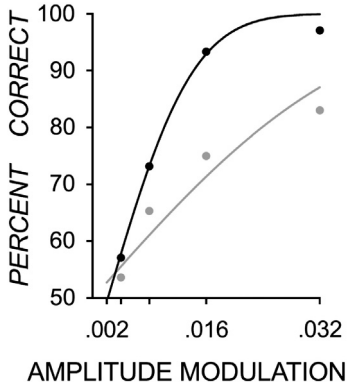

Fig. 4. Functions fitted to mean percent correct scores for PD (gray) and control (black) groups when discriminating RF3 patterns of varying amplitude modulations from perfect circles.

3.4. Potential effects of reported side of onset of PD symptoms, general cognitive functioning, and fatigue on discriminating angry from neutral expressions in PD

Absolute thresholds for the 2IFC emotion discrimination measure were higher, and more variable, in the group that reported PD symptom onset on the right side ($M = 39$, $SD = 24$) than that which reported PD symptom onset on the left side ($M = 25$, $SD = 10$), whereas d-prime values for the yes–no emotion discrimination measure were similar between these two groups (right-side symptom onset $M = .6$, $SD = .5$; left-side symptom onset $M = .5$, $SD = .3$). Group differences on both emotion discrimination measures were not statistically significant (2IFC $t(17) = -1.49$, $p > .05$, $g = .66$; yes–no $t(21) = -.42$, $p > .05$, $g = .17$) with small to moderate effect sizes. Furthermore, we found no significant correlation between side of PD symptom onset and emotion discrimination measures (2IFC $r = -.14$, 95% CI: −.51, .28, $p > .05$; yes–no $r = .09$, 95% CI: −.33, .48, $p > .05$). Together, this suggests little contribution of side of onset of PD symptoms to impaired discrimination of emotional expressions.

Performance on both emotion discrimination measures (with 2IFC and yes–no procedures) was worse, and more variable, in the group with MoCA scores of 26 or below (2IFC $M = 41$, $SD = 29$; yes–no $M = .5$, $SD = .5$) than in the group with MoCA scores above 26 (2IFC $M = 30$, $SD = 8$; yes–no $M = .7$, $SD = .4$); these differences were not statistically significant (2IFC: $t(18) = 1.2$, $p > .05$, $g = .52$; yes–no: $t(22) = -.93$, $p > .05$, $g = .43$) with small to moderate effect sizes. Finally, we found no significant correlation between MoCA and emotion perception performance (2IFC $r = .28$, 95% CI: −.14, .61, $p > .05$; yes–no $r = .29$, 95% CI: −.13, .62, $p > .05$), all of which suggest little

Table 3
Correlation coefficients (with 95% confidence limits in parentheses) of progression of the disease, as measured by the motor score on the MDS-UPDRS, and measures of emotion discrimination with 2IFC and yes–no procedures and the measure of discriminating RF3 patterns (n = 24).

MDS-UPDRS motor score		
Emotion discrimination measure		
2IFC procedure	−.59[a]	(−.80, −.24)
Yes–no procedure	−.38	(−.68, .02)
RF3 pattern discrimination measure	−.59[a]	(−.80, −.25)

[a] Indicates statistical significance, $p < .05$.

contribution of general cognitive functioning to impaired perception of facial expressions of emotion in PD.

Since emotion discrimination measures were taken after the RF3 pattern discrimination measure, impairment in PD might have been due to fatigue. However, we found that mean performance by patients remained relatively stable between the first- and last-half of the trials for each of the emotion discrimination measures (2IFC first-half $M = 67$, $SD = 9$, last-half $M = 67$, $SD = 8$, $t(23) = -.46$, $p > .05$, $g = 0$; yes–no first-half $M = 59$, $SD = 7$, last-half $M = 60$, $SD = 5$, $t(23) = -.96$, $p > .05$, $g = .16$), which suggests little to no effect of fatigability.

4. Discussion

The results show large impairments in PD than control groups in discriminating graded intensities of angry from neutral expressions at brief and long stimulus durations on the 2IFC and yes–no procedures and in discriminating RF3 patterns of varying amplitude modulations from perfect circles, with positive and moderate to large correlations between these abilities, even after controlling for the progression of the disease and general cognitive functioning.

The positive and moderate to large correlations between the abilities to perceive facial expressions of emotion and visual form are incongruent with the conclusion from the Gray and Tickle-Degnen meta-analysis [30] that these abilities are unrelated. This conclusion was based on evidence from individual studies that the ability to perceive visual form, measured with the BFRT or a similar test, was intact in PD. The measures of visual form perception in these studies, however, were insensitive to differences between PD and control groups. Here we show impaired visual form perception in PD on a measure of discriminating RF3 patterns from perfect circles. RF patterns are considered a powerful tool to investigate the intermediate stages of visual form processing that underlie the transformation from low-level features, such as edge orientation, to high-level object representations such as faces ([41], for a review). The impairment in RF3 pattern discrimination in PD also adds to the current body of literature that shows impairment in a range of low-level visual functions [4].

The strength of the correlation between the ability to perceive emotional expressions and the ability to perceive visual form remained relatively unchanged after removing the common variance shared with the progression of the disease and general cognitive functioning. After removing this variance, there remained 64% shared variance between 2IFC measures of RF3 pattern discrimination and emotion discrimination, and 26% shared variance between measures of RF3 pattern discrimination and emotion discrimination with the yes–no procedure. The greater shared variance between the 2IFC procedures is presumably due to their common procedural elements. The 26% of shared variance between RF3 pattern discrimination and emotion discrimination with the yes–no procedure after removing the variance associated with disease progression indicates the extent of common variance between these measures that is not attributable to the similarity of the procedures.

Meaningful interpretation of visual forms, including emotional facial expressions, is a multistage process [41], any of which might be impaired in PD, thereby contributing to impaired perception of emotional facial expressions. Perceiving visual form initially requires accurate encoding of local orientation information, and then integrating separate features into global forms and segregating them from their backgrounds [42,67,69]. RF pattern discrimination is thought to tap intermediate stages of visual form processing [41], where separate features are pooled into global forms. Therefore, the present findings suggest that the disruption present at intermediate stages of visual form processing in PD contributes to impaired perception of facial expressions of emotion. The link found by Narme et al. [50] between configural face processing and perception of emotional expressions in PD similarly supports a role of disruption at the intermediate visual form processing stage in impaired emotional expression perception. Many cortical regions have been implicated in intermediate visual form processing, including V4, the fusiform face area, inferotemporal cortex, and lateral occipital cortex [23,24,55,66]. Processing in some or all of these regions might be disrupted in PD, thereby contributing to impaired perception of visual forms including facial expressions of emotion. It is possible that disrupted processing at these intermediate visual-form processing regions is partly due to poor input from more peripheral visual processing, which is known to be impaired in PD [4]. Findings from Hipp et al. [33] are not in line with the possible role of peripheral visual processing in emotional expression perception; however, their sample of patients was not representative, because the patients were only at an early stage of PD with little variation in disease severity. Therefore, the role of poor input from peripheral visual processing in impaired emotional expression perception in PD cannot yet be ruled out. It is also possible that disrupted processing at some intermediate visual-form processing regions, particularly fusiform face and inferotemporal regions, is partly due to their interconnections with the denervated basal ganglia in PD [3,25,49]. In summary, peripheral and intermediate stages of visual form processing might be disrupted in PD, thereby contributing to impaired emotional expression perception. Disrupted processing at the intermediate visual-form processing regions in PD might be partly a consequence of poor input from peripheral stages and of impaired processing in the basal ganglia's interconnections with these regions.

After taking into account the variance that is shared with the impaired ability to perceive visual form, there still remains variance that is unaccounted for in emotion discrimination with the 2IFC and yes–no procedures respectively. Thus the impaired ability to perceive emotional expressions in PD is not entirely explained by the impaired ability to perceive visual form. Our previous work [47] showed a link between voluntary control of facial musculature and the ability to perceive emotional expressions in PD. This link is consistent with an embodied simulationist account of emotion perception (see [29], for a review) that motor systems that are engaged by voluntary control of facial musculature and simulation of observed facial expressions are disrupted in PD, thereby impairing both voluntary control of facial musculature and perception of facial expression of emotion. Together these findings support the likelihood of a multifactorial contribution to impaired perception of facial expressions of emotion in PD.

The impairment in PD in discriminating graded intensities of angry from neutral expressions replicates previous findings by our group [47]. Previously, we showed that those with PD were impaired in discriminating emotion from neutral expressions with emotional intensity increments sampled from a narrower range (5 to 35% of the full-blown expression) than we used here (5 to 52% of the full-blown expression). We show that the relative impairment in PD is present with higher intensities of the expression. Although we have shown that general cognitive functioning contributes little to impaired perception of emotional expressions in PD, consistent with our previous research [47], we cannot determine the role of specific cognitive declines in perception of emotional expressions. Nevertheless, there was also a similar level of impairment in PD on a measure of emotion discrimination with a single-stimulus yes–no procedure, which unlike the 2IFC procedure, does not require the ability to hold information from the first stimulus while processing that of the second stimulus; this suggests that the impairment in PD in emotion discrimination as reported here and previously on the measure with the 2IFC procedure was not exaggerated by working memory demands. The impairment in PD was also present with longer stimulus durations on both emotion discrimination measures, which indicates that brief stimulus durations did not exaggerate the impairment in emotion discrimination in PD. Although longer stimulus durations were no more beneficial for PD than control groups, performance across groups generally improved with increasing stimulus duration on the yes–no procedure but not on the 2IFC procedure; sensitivity was greater in both groups at the longer stimulus duration in the

Please cite this article as: Marneweck M, Hammond G, Discriminating facial expressions of emotion and its link with perceiving visual form in Parkinson's disease, J Neurol Sci (2014), http://dx.doi.org/10.1016/j.jns.2014.08.014

yes–no procedure but not in the 2IFC procedure. One of the key differences between the 2IFC and yes–no procedures is that the 2IFC procedure allows a visual comparison of the emotional and neutral expression. The yes–no procedure requires recollection of an emotional and neutral expression without having the familiarity that is given by visual comparison. Nevertheless, the level of impairment in PD is similar at brief and longer durations in both 2IFC and yes–no procedures. This indicates that the impairment in PD in discrimination of facial expressions of emotion as measured here was not exaggerated by slower visual processing times or working memory demands required by sequential stimuli.

In summary, the work described here showed impaired discrimination of facial expressions of emotion with the progression of PD, as was measured with 2IFC and yes–no procedures at brief and longer stimulus durations. Disrupted processing at both peripheral- and intermediate visual-form processing stages might contribute to impaired discrimination of facial expressions of emotion in PD. Perceiving accurately the facial expressions of others' emotions contributes to social integration [1], which in turn is essential for mental [48] and physical well-being [17]. Therefore, the impaired ability to perceive facial expressions of emotion in PD is likely to be detrimental to the regulation of individual and social behavior. Finally, the ability to meaningfully interpret objects, requiring intact processes of visual perception and visual cognition [70], has been associated with visual hallucinations in PD, the latter of which have been proposed to stem in part from impaired visual processing of environmental stimuli [8].

Conflict of interest

There is no conflict of interest.

Acknowledgments

We are grateful to the people with Parkinson's disease and to those in the control group who have kindly given their time by committing to this study. We also acknowledge the contribution of the Edith Cowan University Parkinson's Centre and Parkinson's Western Australia for assisting with participant recruitment. Development of the MacBrain Face Stimulus Set was overseen by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development. Please contact Nim Tottenham at tott0006@tc.umn.edu for more information concerning the stimulus set. We would also like to give our sincerest thanks to Edwin Dickinson and David Badcock from the Vision Laboratory at the School of Psychology, University of Western Australia, for their assistance with the development of the RF pattern discrimination measure. We would also like to acknowledge the funding to the first author: Australian Postgraduate Award, Jean Rogerson Postgraduate Scholarship, University of Western Australia PhD Completion Scholarship, and a Parkinson's Western Australia Research Grant. Finally, we thank the anonymous reviewers for their thoughtful comments on the manuscript.

Appendix A

Table A1
Correlation coefficients (with 95% confidence intervals in parentheses) of measures of emotion discrimination with two-interval forced choice and yes–no procedures and measures of RF3 pattern discrimination with measures of depressive symptoms, as measured by the GDS, and levodopa dose equivalent (LED, [61]) in PD (n = 24).

	GDS	LED
Emotion discrimination measures		
Two-interval forced choice procedure	−.05 (−.44, .36)	.02 (−.39, .42)
Yes–no procedure	.06 (−.35, .45)	−.35 (−.65, .07)
RF3 pattern discrimination measure	−.12 (−.50, .30)	−.22 (−.57, .20)

*[a]Indicates statistical significance, $p < .05$.

References

[1] Addington J, Saeedi H, Addington D. Facial affect recognition: a mediator between cognitive and social functioning in psychosis? Schizophr Res 2006;85:142–50.
[2] Adolphs R, Schul R, Tranel D. Intact recognition of facial emotion in Parkinson's disease. Neuropsychology 1998;12(2):253–8.
[3] Alexander GE, DeLong MR, Strick PL. Parallel organization of functionally segregated circuits linking basal ganglia and cortex. Annu Rev Neurosci 1986;9:357–81.
[4] Archibald NK, Clarke MP, Mosimann UP, Burn DJ. The retina in Parkinson's disease. Brain 2009;132:1128–45.
[5] Ariatti A, Benuzzi F, Nichelli P. Recognition of emotions from visual and prosodic cues in Parkinson's disease. Neurol Sci 2008;29(4):219–27.
[6] Assogna F, Pontieri FE, Cravello L, Peppe A, Pierantozzi M, Stefani A, et al. Intensity-dependent facial emotion recognition and cognitive functions in Parkinson's disease. J Int Neuropsychol Soc 2010;16:867–76.
[7] Baggio HC, Segura B, Ibarretxe-Bilbao N, Valldeoriola F, Marti MJ, Compta Y, et al. Structural correlates of facial emotion recognition deficits in Parkinson's disease patients. Neuropsychologia 2012;50:2121–8.
[8] Barnes J, Boubert L, Harris J, Lee A, David AS. Reality monitoring and visual hallucinations in Parkinson's disease. Neuropsychologia 2003;41:565–74.
[9] Beatty WW, Goodkin DE, Weir WS, Staton RD. Affective judgments by patients with Parkinson's disease or chronic progressive multiple sclerosis. Bull Psychon Soc 1989;27:361–4.
[10] Bediou B, Brunelin J, d'Amato T, Fecteau S, Saoud M, Henaff M, et al. A comparison of facial emotion processing in neurological and psychiatric conditions. Front Psychol 2012;3:1–10.
[11] Benton AL, Sivan AB, Hamsher K, Varney NR, Spreen O. Contributions to neuropsychological assessment. New York: Oxford University Press; 1994 [1994].
[12] Blonder LX, Gur RE, Gur RC. The effects of right and left hemiparkinsonism on prosody. Brain Lang 1989;36(2):193–207.
[13] Borod JC, Welkowitz J, Alpert M, Brozgold AZ, Martin C, Peselow E, et al. Parameters of emotional processing in neuropsychiatric disorders: conceptual issues and a battery of tests. J Commun Disord 1990;23:247–71.
[14] Buxton SL, MacDonald L, Tippett L. Impaired recognition of prosody and subtle emotional facial expressions in Parkinson's disease. Behav Neurosci 2013;127(2):192–203.
[15] Clark US, Neargarder S, Cronin-Golomb A. Specific impairments in the recognition of emotional facial expressions in Parkinson's disease. Neuropsychologia 2008;46:2300–9.
[16] Clark US, Neargarder S, Cronin-Golomb A. Visual exploration of emotional facial expressions in Parkinson's disease. Neuropsychologia 2010;48:1901–13.
[17] Cohen S. Social relationships and health. Am Psychol 2004;59:676–84.
[18] Cohen H, Gagne M, Hess U, Pourcher E. Emotion and object processing in Parkinson's disease. Brain Cogn 2010;72(3):457–63.
[19] Cousins R, Hanley JR, Davies ADM, Turnbull CJ, Playfer JR. Understanding memory for faces in Parkinson's disease: the role of configural processing. Neuropsychologia 2000;38(6):837–47.
[20] Dewick HC, Hanley JR, Davies AD, Playfer J, Turnbull C. Perception and memory for faces in Parkinson's disease. Neuropsychologia 1991;29(8):785–802.
[21] Duchaine B, Weidenfeld A. An evaluation of two commonly used tests of unfamiliar face recognition. Neuropsychologia 2003;41:713–20.
[22] Dujardin K, Blairy S, Defebvre L, Duhem S, Noel Y, Hess U, et al. Deficits in decoding emotional facial expressions in Parkinson's disease. Neuropsychologia 2004;42:239–50.
[23] Gallant JL, Connor CE, Rakshit S, Lewis JW, Van Essen DC. Neural responses to polar, hyperbolic, and Cartesian gratings in area V4 of the macaque monkey. J Neurophysiol 1996;76:2718–39.
[24] Gallant JL, Shoup RE, Mazer JA. A human extrastriate area functionally homologous to macaque V4. Neuron 2000;27(2):227–35.
[25] Geday J, Ostergaard K, Gjedde A. Stimulation of subthalamic nucleus inhibits emotional activation of fusiform gyrus. Neuroimage 2006;33(2):706–14.
[26] Gluhm S, Goldstein J, Loc K, Colt A, Van Liew C, Corey-Bloom JC. Cognitive performance on the Mini-Mental State Examination and the Montreal Cognitive Assessment across the healthy adult lifespan. Cogn Behav Neurol 2013;26(1):1–6.
[27] Godefroy O, Fickle A, Roussel M, Auribault C, Bugnicourt JM, Lamy C, et al. Is the Montreal Cognitive Assessment superior to the Mini-Mental State Examination to detect poststroke cognitive impairment? Stroke 2011;42:1712–6.
[28] Goetz CG, Tilley BC, Shaftman SR, Stebbins GT, Fahn S, Martinez-Martin P, et al. Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): scale presentation and clinimetric testing results. Mov Disord 2008;23(15):2129–70.
[29] Goldman AI, Sripada CS. Simulationist models of face-based emotion recognition. Cognition 2005;94:193–213.
[30] Gray HM, Tickle-Degnen L. A meta-analysis of performance on emotion recognition tasks in Parkinson's disease. Neuropsychology 2010;24(2):176–91.
[31] Haeske-Dewick HC. Perception and memory for faces influenced by a specific age at onset factor in Parkinson's disease? Neuropsychologia 1996;34(4):315–20.
[32] Herrera E, Cuetos F, Rodriguez-Ferreiro J. Emotion recognition impairment in Parkinson's disease without dementia. J Neurol Sci 2011;310(1–2):237–40.
[33] Hipp G, Diederich NJ, Pieria V, Vaillant M. Primary vision and facial emotion recognition in early Parkinson's disease. J Neurol Sci 2014;338:178–82.
[34] Ibarretxe-Bilbao N, Junque C, Tolosa E, Marti M, Valldeoriola F, Bargallo N, et al. Neuroanatomical correlates of impaired decision-making and facial emotion recognition in early Parkinson's disease. Eur J Neurosci 2009;30(6):1162–71.
[35] Jacobs DH, Shuren J, Bowers D, Heilman KM. Emotional facial imagery, perception, and expression in Parkinson's disease. Neurology 1995;45:1696–702.

Please cite this article as: Marneweck M, Hammond G, Discriminating facial expressions of emotion and its link with perceiving visual form in Parkinson's disease, J Neurol Sci (2014), http://dx.doi.org/10.1016/j.jns.2014.08.014

[36] Johnson AM, Almeida QJ, Stough C, Thompson JC, Singarayer R, Jog MS. Visual inspection time in Parkinson's disease: deficits in early stages of cognitive processing. Neuropsychologia 2004;42:577–83.
[37] Larner AJ. Screening utility of the Montreal Cognitive Assessment (MoCA): in place of- or as well as- the MMSE? Int Psychogeriatr 2012;24(3):391–6.
[38] Lawrence AD, Goerendt IK, Brooks DJ. Impaired recognition of facial expressions of anger in Parkinson's disease patients acutely withdrawn from dopamine replacement therapy. Neuropsychologia 2007;45(1):65–74.
[39] Lee E, Cowan N, Vogel EK, Rolan T, Valle-Inclan F, Hackley SA. Visual working memory deficits in patients with Parkinson's disease are due to both reduced storage capacity and impaired ability to filter out irrelevant information. Brain 2010;133(9):2677–89.
[40] Lee J-Y, Lee DW, Cho S-J, Na DL, Jeon HJ, Kim S-K, et al. Brief screening for mild cognitive impairment in elderly outpatient clinic: validation of the Korean version of the Montreal Cognitive Assessment. J Geriatr Psychiatry Neurol 2008;21:104–10.
[41] Loffler G. Perception of contours and shapes: low and intermediate stage mechanisms. Vision Res 2008;48(2):2106–27.
[42] Loffler G, Wilson HR, Wilkinson F. Local and global contributions to shape discrimination. Vision Res 2003;43(5):519–30.
[43] Luis CA, Keegan AP, Mullan M. Cross validation of the Montreal Cognitive Assessment in community dwelling older adults residing in the southeastern US. Int J Geriatr Psychiatry 2009;24:197–201.
[44] Kan Y, Kawamura M, Hasegawa Y, Mochizuki S, Nakamura K. Recognition of emotion from facial, prosodic, and written verbal stimuli in Parkinson's disease. Cortex 2002;38:623–30.
[45] Madeley P, Ellis AW, Mindham RHS. Facial expressions and Parkinson's disease. Behav Neurol 1995;8(2):115–9.
[46] Marneweck M, Loftus A, Hammond G. Psychophysical measures of sensitivity to facial expression of emotion. Front Psychol 2013;4:1–6.
[47] Marneweck M, Palermo R, Hammond G. Discrimination and recognition of facial expressions of emotion and their links with voluntary control of facial musculature in Parkinson's disease. Neuropsychology 2014, June 16.
[48] Michelsen H, Bildt C. Psychosocial conditions on and off the job and psychological ill health: depressive symptoms, impaired psychological well-being, heavy consumption of alcohol. Occup Environ Med 2003;60:489–96.
[49] Middleton FA, Strick PL. The temporal lobe is a target of output from the basal ganglia. Proc Natl Acad Sci U S A 1996;93(16):8683–7.
[50] Narme P, Bonnet A, Dubois B, Chaby L. Understanding facial emotion perception in Parkinson's disease: the role of configural processing. Neuropsychologia 2011;49:3295–302.
[51] Narme P, Mouras H, Roussel M, Duru C, Krystkowiak P, Godefroy O. Emotional and cognitive social processes are impaired in Parkinson's disease and are related to behavioral disorders. Neuropsychology 2013;27(2):182–92.
[52] Nasreddine ZS, Phillips NA, Bedirian V, Charbonneau S, Whitehead V, Collin I, et al. The Montreal Cognitive Assessment, MOCA: a brief cognitive screening tool for mild cognitive impairment. J Am Geriatr Soc 2005;53:695–9.
[53] Pell MD, Leonard CL. Facial expression decoding in early Parkinson's disease. Cogn Brain Res 2005;23:327–40.
[54] Poewe W. Non-motor symptoms in Parkinson's disease. Eur J Neurol 2008;15:14–20.
[55] Rainville SPJ, Yourganov G, Wilson HR. Closed-contour shapes encoded through deviations from circularity in lateral–occiptal complex (LOC): an fMRI study. J Vis 2005;5(8):471.
[56] Rossetti HC, Lacritz LH, Munro Cullum C, Weiner MF. Normative data for the Montreal Cognitive Assessment (MoCA) in a population-based sample. Neurology 2011;77:1272–5.
[57] Sheikh JI, Yesavage A. Geriatric depression scale GDS: recent evidence and development of a shorter version. In: Brink TL, editor. Clinical gerontology: a guide to assessment and intervention. New York: Haworth; 1986.
[58] Sprengelmeyer R, Young AW, Mahn K, Schroeder U, Woitalla D, Buttner T, et al. Facial expression recognition in people with medicated and unmedicated Parkinson's disease. Neuropsychologia 2003;41:1047–57.
[59] Suzuki A, Hoshino T, Shigemasu K, Kawamura M. Disgust-specific impairment of facial expression recognition in Parkinson's disease. Brain 2006;129:707–17.
[60] Tessitore A, Hariri AR, Fera F, Smith WG, Chase TN, Hyde TM, et al. Dopamine modulates the response of the human amygdala: a study in Parkinson's disease. J Neurosci 2002;22(20):9099–103.
[61] Tomlinson CL, Stowe R, Patel S, Rick C, Gray R, Clarke CE. Systematic review of levodopa dose equivalency reporting in Parkinson's disease. Mov Disord 2010;25(15):2649–53.
[62] Tottenham N, Tanaka JW, Leon AC, McCarry T, Nurse M, Hare TA, et al. The NimStim set of facial expressions: judgments from untrained research participants. Psychiatry Res 2009;168:242–9.
[63] Ventura MI, Baynes K, Sigvardt KA, Unruh AM, Acklin SS, Kirsch HE, et al. Hemispheric asymmetries and prosodic emotion recognition deficits in Parkinson's disease. Neuropsychologia 2012;50(8):1936–45.
[64] Waldron-Perrine B, Axelrod BN. Determining an appropriate cutting score for indication of impairment on the Montreal Cognitive Assessment. Int J Geriatr Psychiatry 2012;27:1189–94.
[65] Wieser MJ, Klupp E, Weyers P, Pauli P, Weise D, Zeller D, et al. Reduced early visual emotion discrimination as an index of diminished emotion processing in Parkinson's disease? — Evidence from event-related brain potentials. Cortex 2012;48(9):1207–17.
[66] Wilkinson F, James TW, Wilson HR, Gati JS, Menon RS, Goodale MA. An fMRI study of the selective activation of human extrastriate form vision areas by radial and concentric gratings. Curr Biol 2000;10(22):1455–8.
[67] Wilkinson F, Wilson HR, Habak C. Detection and recognition of radial frequency patterns. Vision Res 1998;38(22):3555–68.
[68] Yip JTH, Lee TM, Ho SL, Tsang KL, Li LS. Emotion recognition in patients with idiopathic Parkinson's disease. Mov Disord 2003;18(10):1115–22.
[69] Bell J, Badcock DR. Luminance and contrast cues are integrated in global shape detection with contours. Vision Research 2008;48:2336–44.
[70] Palmeri TJ, Gauthier I. Visual object understanding. Nature Reviews Neuroscience 2004;5:291–303.

Please cite this article as: Marneweck M, Hammond G, Discriminating facial expressions of emotion and its link with perceiving visual form in Parkinson's disease, J Neurol Sci (2014), http://dx.doi.org/10.1016/j.jns.2014.08.014