

# Neuropsychology

## **Discrimination and Recognition of Facial Expressions of Emotion and Their Links With Voluntary Control of Facial Musculature in Parkinson's Disease**

Michelle Marneweck, Romina Palermo, and Geoff Hammond

Online First Publication, June 16, 2014. <http://dx.doi.org/10.1037/neu0000106>

### CITATION

Marneweck, M., Palermo, R., & Hammond, G. (2014, June 16). Discrimination and Recognition of Facial Expressions of Emotion and Their Links With Voluntary Control of Facial Musculature in Parkinson's Disease. *Neuropsychology*. Advance online publication. <http://dx.doi.org/10.1037/neu0000106>

# Discrimination and Recognition of Facial Expressions of Emotion and Their Links With Voluntary Control of Facial Musculature in Parkinson's Disease

Michelle Marneweck  
University of Western Australia

Romina Palermo  
University of Western Australia and ARC Centre of Excellence  
in Cognition and Its Disorders

Geoff Hammond  
University of Western Australia

**Objective:** To explore perception of facial expressions of emotion and its link with voluntary facial musculature control in Parkinson's disease (PD). **Method:** We investigated in 2 sets of experiments in PD patients and healthy controls the perceptual ability to discriminate (a) graded intensities of emotional from neutral expressions, (b) graded intensities of the same emotional expressions, (c) full-blown discrepant emotional expressions from 2 similar expressions and the more complex recognition ability to label full-blown emotional expressions. We tested an embodied simulationist account of emotion perception in PD, which predicts a link between the ability to perceive emotional expressions and facial musculature control. We also explored the contribution of the ability to extract facial information (besides emotion) to emotion perception in PD. **Results:** Those with PD were, as a group, impaired relative to controls (with large effect sizes) in all measures of discrimination and recognition of emotional expressions, although some patients performed as well as the best performing controls. In support of embodied simulation, discrimination and recognition of emotional expressions correlated positively with voluntary control of facial musculature (after partialing out disease severity and age). Patients were also impaired at extracting information other than emotion from faces, specifically discriminating and recognizing identity from faces (with large effect sizes); identity discrimination correlated positively with emotion discrimination and recognition but not with voluntary facial musculature control (after partialing out disease severity and age). **Conclusions:** The results indicate that impaired sensory and sensorimotor processes, which are a function of disease severity, affect emotion perception in PD.

**Keywords:** Parkinson's disease, emotion perception, embodied simulation, facial expression, facial masking

**Supplemental materials:** <http://dx.doi.org/10.1037/neu0000106.supp>

The ability to perceive the emotional facial expressions in others is central to the regulation of social behavior. Findings from studies that have investigated whether those with Parkinson's disease (PD) have impaired perception of facial expressions of emotion have been mixed. Some studies have reported impaired

perception of emotional facial expressions in PD (Ariatti, Benuzzi, & Nichelli, 2008; Assogna et al., 2010; Baggio et al., 2012; Bediou et al., 2012; Buxton, MacDonald, & Tippett, 2013; Clark, Neargarder, & Cronin-Golomb, 2008; Clark, Neargarder, & Cronin-Golomb, 2010; Dujardin et al., 2004; Herrera, Cueto, &

Michelle Marneweck, School of Psychology, University of Western Australia; Romina Palermo, School of Psychology, University of Western Australia, and ARC Centre of Excellence in Cognition and Its Disorders, Sydney, New South Wales, Australia; Geoff Hammond, School of Psychology, University of Western Australia.

This work was supported by the Australian Postgraduate Award, Jean Rogerson Postgraduate Scholarship, and a Parkinson's Western Australia Research Grant. 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 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](mailto:tott0006@tc.umn.edu) for more information concerning the stimulus set. We also thank Assistant Professor Linda Jeffery from the University of Western Australia for suggesting the use of stimuli that vary in facial distinctiveness for our psychophysical measures. We are also grateful to Miss Ainsley Reid for her assistance with Adobe Photoshop and FantaMorph Software.

Correspondence concerning this article should be addressed to Michelle Marneweck, School of Psychology (M304), University of Western Australia, Crawley, WA, 6009, Australia. E-mail: [michelle.marneweck@uwa.edu.au](mailto:michelle.marneweck@uwa.edu.au)

Rodriguez-Ferreiro, 2011; Ibarretxe-Bilbao et al., 2009; Kan, Kawamura, Hasgawa, Mochizuki, & Nakamura, 2002; Lawrence, Goerndt, & Brooks, 2007; Narme, Bonnet, Dubois, & Chaby, 2011; Narme et al., 2013; Sprengelmeyer et al., 2003; Suzuki, Hoshino, Shigemasa, & Kawamura, 2006; Yip, Lee, Ho, Tsang, & Li, 2003), whereas others have found no impairment (Adolphs, Schul, & Tranel, 1998; Cohen, Gagne, Hess, & Pourcher, 2010; Haeske-Dewick, 1996; Pell & Leonard, 2005; Ventura et al., 2012; Wieser et al., 2012). Although the results from individual studies are mixed, a recent meta-analysis found that, overall, PD groups were impaired in perceiving emotions from facial cues, documented by an averaged moderate effect size (Hedges'  $g = .48$ ) for all of the "basic emotions" (Gray & Tickle-Degnen, 2010).

Gray and Tickle-Degnen (2010) documented substantial variability in emotion-perception impairment in PD, reflected in wide confidence intervals of effect sizes, which was not related to medication, depression, or disease severity. The studies in the meta-analysis measured disease severity with the Hoehn and Yahr staging scale (Hoehn & Yahr, 1967), which, although widely used and simple to administer, has been criticized as insensitive. Goetz and colleagues (2004) reported that the scale is heavily weighted toward postural instability, leaving other important components of PD unassessed; furthermore, with only five scale options, a large range of impairment severity is collapsed together. The Movement Disorders Society-sponsored revision of the Unified Parkinson's disease Rating Scale (MDS-UPDRS) has been recommended as a more sensitive measure (Goetz et al., 2008). The Gray and Tickle-Degnen meta-analysis also indicated that the variability in emotion perception in PD was not due to a broader inability to extract information other than emotion from faces, as recognition of unfamiliar face identities was intact. Most studies in the meta-analysis measured this ability with the Benton Facial Recognition Test (BFRT; Benton, Sivan, Hamsher, Varney, & Spreen, 1994). However, the BFRT has been shown to be an insensitive measure of face-identity-processing skill, and sensitive only to large deficits (Duchaine & Weidenfeld, 2003). The link between emotion perception and the broader ability to extract information other than emotion from faces using sensitive measures such as the Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006), has been relatively unexplored in PD.

The determinants of impaired perception of facial expression of emotion in a disorder of movement are not well understood. The theory of embodied simulation of emotion perception, which states that perceiving emotions of others is facilitated by overtly or covertly simulating the observed behavior (see Goldman & Sri-pada, 2005, for a review), suggests one potential determinant of the impairment seen in PD. In line with covert embodied simulation theories, it might be that motor systems with mirror-like properties that are responsible for control of facial musculature simulation of observed expressions are compromised by the neurodegenerative processes of PD, thereby contributing to reduced facial musculature control (i.e., facial masking) and impaired perception of emotional expressions. A link between voluntary control of facial musculature and perception of emotional expressions in PD will provide support for this simulationist account of emotion perception in PD.

Studies on perception of facial expression of emotion have typically been investigations of the ability to discriminate emotional expressions (by judging whether two or more stimuli ex-

press the same or a different emotion) or the ability to recognize emotional expressions (by selecting from a list the emotion word that best fits the presented expression). Most previous researchers on perception of facial expressions of emotion in PD have measured the ability to recognize emotional expressions. Some studies (Ariatti et al., 2008; Jacobs, Shuren, Bowers, & Heilman, 1995; Pell & Leonard, 2005; Ventura et al., 2012) have measured the ability to discriminate whether a series of expressions presented simultaneously belong to similar or discrepant emotion-label categories. Most previous studies also only assess the ability to perceive emotions that are expressed at full-blown intensity, when in everyday life emotions are expressed with varying intensities. In the current experiments, we studied basic perceptual abilities of discriminating graded expressions of emotion with psychophysical methods. Forced-choice psychophysical procedures offer objective and sensitive measures of perceptual processes that are relatively free from response criterion effects. In Experiment 1, we used previously developed psychophysical measures of discriminating graded intensities of emotional facial expressions from neutral expressions and discriminating different intensities of the same facial expressions of emotion (Marnebeck, Loftus, & Hammond, 2013). In Experiment 2, we again used measures of discriminating different intensities of the same emotional expressions, as well as measures of labeling full-blown emotional expressions, discriminating discrepant from similar expressions, and sensitive measures of face identity perception. To test an embodied simulation account of emotion perception, we measured in both experiments the relationship between continuous measures of the ability to voluntarily control facial musculature and the ability to discriminate and recognize emotional facial expressions in PD.

## Method

### Participants

Sixty-six participants (patient  $n = 34$ , control  $n = 32$ ) were tested in Experiment 1 and 49 (patient  $n = 25$ , control  $n = 24$ ) were tested in Experiment 2, approximately 1 year after Experiment 1. Forty participants participated in both experiments (patient  $n = 22$ , control  $n = 18$ ) whereas 26 participants (patient  $n = 12$ , control  $n = 14$ ) were unique to Experiment 1 and nine participants (patient  $n = 3$ , control  $n = 6$ ) were unique to Experiment 2. Table 1 shows demographic and clinical characteristics of both groups in each experiment; groups were, in aggregate, well-matched for age and scores on measures of general cognitive functioning and depressive symptoms. Patients were diagnosed by a neurologist and recruited from the Parkinson's Centre (Nedlands, Western Australia) research database and through Parkinson's Western Australia newsletter advertisements. The Centre's Institutional Ethics Committee approved the procedures and all participants gave written informed consent.

### Design

There were three testing sessions in Experiment 1 and two testing sessions in Experiment 2, with all sessions separated by at least 24 hr. In each of the two experiments, PD patients were tested at the same time of the day in each of the testing sessions (~1 to 1.5 hr prior to their next medication intake) with the aim that

Table 1

*Demographic and Clinical Characteristics of Participant Groups in Experiment 1 (Control: n = 32; Patient: n = 34) and Experiment 2 (Control: n = 24; Patient: n = 25) With Hedges' g Quantifying Group Differences*

Demographic	Experiment 1			Experiment 2		
	Control	Patient	<i>g</i>	Control	Patient	<i>g</i>
Age (years)	66 (51–79)	66 (46–80)	.28	67 (55–80)	67 (53–81)	.00
Males (Females)	11 (21)	20 (14)	—	12 (12)	17 (8)	—
Education (years)	15 (7–22)	12 (7–20)	.56	16 (8–22)	12 (7–20)	.49
MoCA	27 (21–30)	28 (22–30)	.00	28 (25–30)	27 (15–30)	.76
GDS	1 (0–5)	2 (0–13)	.62*	1 (0–5)	2 (0–10)	.77*
Years diagnosed	—	5 (1–19)	—	—	7 (1–20)	—
MDS-UPDRS-III	—	38 (10–56)	—	—	41 (19–56)	—
LED	—	788 (0–2046)	—	—	916 (0–2312)	—

*Note.* 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  $\geq 26$  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 (Tomlinson et al., 2010). \*  $p < .05$ .

performance in each session would receive the same limited effect from anti-Parkinson medication (however, Gray & Tickle-Degnen, 2010, reported no such effects). Control participants completed each of the sessions at the same time of day. In each experiment, patients were initially assessed for disease severity using the MDS-UPDRS motor-severity subscale (Goetz et al., 2008). We took measures of the ability to voluntarily control facial musculature (the Upper and Lower Face Apraxia Test; Bizzozero et al., 2000), general cognitive functioning (Montreal Cognitive Assessment, MoCA; Nasreddine et al., 2005), and depressive symptoms (Geriatric Depression Scale, GDS; Sheikh & Yesavage, 1986). The MoCA has been shown to be a sensitive measure of general cognitive functioning in PD, discriminating very well between no cognitive impairment, mild cognitive impairment and dementia in PD (Dalrymple-Alford et al., 2010; Nazem et al., 2009; Zadikoff et al., 2008). The GDS has also been shown to be a sensitive measure of depressive symptoms in PD (Weintraub, Oehlberg, Katz, & Stern, 2006). In Experiment 1, we used psychophysical measures of the ability to discriminate graded intensities of emotional from neutral expressions and of the ability to discriminate graded intensities of the same emotional expressions. In Experiment 2, we again used the measure of discriminating graded intensities of the same emotional expression (with an increased range in stimulus levels to capture a wider range of sensitivities than in Experiment 1), measures of discriminating and recognizing expressions at full-blown intensity, and the CFMT (Duchaine & Nakayama, 2006) to measure identity recognition. We also included a psychophysical measure of the ability to extract information besides emotion from faces, (i.e., the ability to discriminate differences in facial distinctiveness, defined as how much a face stands out in a crowd, Bruce & Young, 2012, p. 274). This measure was matched to the psychophysical measure of discriminating differences in emotional intensities. Distinctiveness predicts identity recognition (Bartlett, Hurry, & Thorley, 1984; Light, Kayra-Stuart, & Hollander, 1979; Vokey & Read, 1992) and has been included as an important dimension in "face-space" models of identity recognition (Busey, 1998; Valentine, 1991). There were standardized instructions for all measures.

## Materials and Procedure

**Psychophysical measures of discriminating facial expressions of emotion of graded intensity.** The ability to discriminate an emotional from a neutral expression and to discriminate between different intensities of expression of the same emotion was measured in two tasks (with two variants of the second) using a two-interval forced-choice procedure with the method of constant stimuli, for each of four emotions, anger, disgust, happiness, and sadness (Marneweck et al., 2013). On each trial, two faces of the same model were presented successively on a computer screen for 200 ms with a 200-ms blank interstimulus interval. Each of the four emotions (NimStim Face Stimulus Set, Tottenham et al., 2009), expressed by two models in Experiment 1 and four models in Experiment 2, were graded in emotional intensity by morphing full-blown expressions of each model with their neutral expression (see Marneweck et al., 2013 for details).

In the task that required discrimination of a neutral from an emotional expression (Experiment 1), the face with the neutral expression appeared randomly in either the first or the second interval and a face expressing one of seven levels of intensity of the tested emotion appeared in the other interval. The seven intensity levels ranged from 5% to 35% of the full-blown expression in equally spaced increments. On each trial, participants signaled the interval containing the emotional face by clicking either the left or right button on a mouse for the first or second interval, respectively. There were a total of 280 trials with 40 trials for each intensity increment.

In the task that required discrimination between different intensities of the same emotion (Experiments 1 and 2), each of two faces expressing different intensities was randomly assigned to the two intervals and participants signaled the interval containing the face expressing the higher intensity by clicking either the left or right mouse button for the first or second interval, respectively. In Experiment 1, the two facial expressions varied in five intensity steps from 5% to 25% in equally spaced increments and two variants of this task were run: one sampled emotional intensities from a low-intensity range (from 10% to 50% of the full-blown

expression) and the other from a high-intensity range (from 50% to 90% of the full-blown expression). In Experiment 2, the five intensity steps varied in a multiplicative of 2 from 3% to 48% to capture a wider range of sensitivity to expression of emotion. Intensities were sampled from a midintensity range (from 22% to 76% of the full-blown expression). The intensity pairs used to define each intensity difference for each of the experiments are shown in Supplementary Table 1. For Experiment 1, there were 200 trials, giving 40 trials for each intensity difference. For Experiment 2, with an increase to four models expressing the varying intensities of emotional expressions, there were 240 trials with 48 trials for each intensity difference.

All measures were repeated for each of four emotions: anger, disgust, happiness, and sadness, with breaks between each. Presentation of the two psychophysical measures in Experiment 1 was counterbalanced and the presentation of the four emotions followed a Latin square sequence in both experiments.

**Psychophysical measures of discriminating graded differences in facial distinctiveness.** The ability to discriminate graded differences in facial distinctiveness was measured using a two-interval forced-choice task with the method of constant stimuli. The stimulus duration, interstimulus interval, stimulus size, and viewing distance were identical to those in the psychophysical measures of emotion discrimination. The measure was also piloted to be of equal difficulty to psychophysical measures of emotion discrimination for control participants. To create a set of faces that varied in distinctiveness, we had 62 participants rate the distinctiveness of each of 10 Caucasian faces (with neutral expressions; Tottenham et al., 2009). Participants were asked to rate the distinctiveness of each face on a 9-point Likert scale (1 = *average, typical looking, would not stand out in a crowd* to 9 = *very distinctive, would stand out very much in a crowd*). Two male and two female models with the highest mean rating of distinctiveness were selected and morphed using standard morphing procedures, with an average face of the same sex (created by morphing 26 faces of males and females, respectively; Rhodes et al., 2011), creating a set of faces that varied in distinctiveness from an average, typical face to a very distinctive face.

On each trial of the measure of discriminating differences in facial distinctiveness, two faces that varied in distinctiveness were randomly assigned to one of two intervals. The two faces varied in five distinctiveness steps, 30, 40, 60, 90, and 120%. Participants were asked to indicate which interval contained the more distinctive face by clicking the left or right mouse button for the first or second observation interval, respectively. Supplementary Table 2 shows the stimulus pairs that defined each distinctiveness difference. The pairs were presented in randomized blocks of 60 trials: three definitions for each of five differences in distinctiveness expressed by four models. There were four blocks for a total of 240 trials, giving 48 trials for each distinctiveness difference.

**Discriminating discrepant from similar expressions of full-blown intensity.** The ability to discriminate the discrepant emotional facial expression from two expressions of the same emotion was measured in a three-alternative forced-choice measure (Palermo, O'Connor, Davis, Irons, & McKone, 2013). On each trial, three faces, two expressing the same emotion and the third expressing a discrepant emotion, were presented simultaneously and side by side for 4,500 ms. Participants signaled which of the three faces expressed the discrepant emotion by pressing the 1, 2, or 3

key to identify its location. Keypad responses were recorded during the 4,500-ms presentation of the faces and up to 7,000 ms after the faces were erased. A total of 100 target faces (Karolinska Directed Emotional Faces database, Lundqvist, Flykt, & Öhman, 1998) expressed anger, disgust, sadness, happiness, fear, and surprise at full-blown emotional intensity.

**Verbally labeling emotional expressions at full-blown intensity.** The ability to verbally label a facial expression from a list of basic emotions, anger, disgust, fear, happy, sad, and surprise, was measured in a six-alternative forced-choice measure (Palermo et al., 2013). On each trial, a target face expressing one of six full-blown emotional expressions was presented for 600 ms. A total of 144 target faces (Lundqvist et al., 1998) were selected, with 24 from each emotion category. On each trial, participants were required to say out loud the appropriate label from the six options provided. Verbal responses were recorded during the 600-ms presentation period and for a further 10,000 ms, during which the six emotion labels remained across the bottom of the screen.

**Learning and recognizing unfamiliar faces.** For the CFMT (Duchaine & Nakayama, 2006), participants recognized images of six target faces in three stages. In the first stage, each of the six target faces was presented as a separate item, each appearing for 3,000 ms at three viewing angles, after which participants were required to identify the target face from two distractor faces. Participants were asked to identify the target face with novel lighting and viewing angles in stage two and colored noise added to the images in stage three. A total possible score of 72 is obtained by summing the number of correct items across the three stages.

**Voluntarily controlling facial musculature.** A modification of the Upper and Lower Face Apraxia Test (Bizzozero et al., 2000) required participants to make movements of the upper (nine items) and lower (29 items) faces that do not necessarily convey emotion. Upper facial movements comprised forehead, eye, and nose movements and lower facial movements comprised cheek and mouth movements. Some items required sequential movements. All items required visual input; some items required auditory and visual input to reproduce the movement (e.g., whistling). In the original test, the examiner demonstrated each item, and the participant's response followed immediately thereafter. For the purposes of standardization in our experiments, the instructions and demonstrations of each item were recorded in a short video clip and watched by all participants, whose responses were filmed for scoring. Participants attempted to reproduce the intensity and duration of each demonstration movement as accurately as possible. Two independent raters, one blind to the experiment, scored the accuracy of each reproduction as a *pass* (given a score of 1) or *fail* (given a score of 0). Initial observations of typical errors committed by both groups led to a reclassification of errors. An item was scored as an error in voluntary control of facial musculature if (a) the reproduction was preceded by a pause, during which unsolicited movements might have been present; (b) there was a loss of individuation (i.e., the instructed movement was executed, but was unfocused and accompanied by uninstructed movement that was intermittently or continuously present, or by an increase in the number of elements in a sequential movement); (c) the reproduction was executed but impoverished,

either by reduction of amplitude of movement or by reduction in the number of elements of a sequential movement; (d) there was no movement at all; or (e) there was a content error, such that reproductions resembled the demonstrated movement, but were incorrect in their content, for example, placing tongue in cheek when asked to puff out the cheek.

## Data Analysis

For the psychophysical measures of discrimination of emotional expressions and facial distinctiveness, accuracy was defined as the percent correct at each stimulus level. For Experiment 1, functions were not fitted to calculate absolute thresholds and slope because few participants reached asymptote as a result of range limitation in the constant stimuli. Although absolute thresholds and slopes were derived from functions fitted to data in Experiment 2, we chose to not report these for consistency between experiments. We used the mean percent scores across stimulus levels to quantify group difference on the psychophysical measures of emotion discrimination and distinctiveness discrimination. To limit underestimating group differences we excluded performance at the lowest constant-stimulus level, which was usually around chance performance. Accuracy was defined as mean percent correct scores for measures of discriminating discrepant from similar expressions, verbally labeling expressions, recognizing unfamiliar face identities, and voluntarily controlling facial musculature (means of two raters' percentage of error scores; Cronbach's alpha was deemed acceptable (Nunnally, 1978) at .98 and .97 for Experiment 1 and Experiment 2).

As suggested by Cumming, Fidler, Kalinowsky, and Lai (2012) in their paper on statistical recommendations for the American Psychological Association, we report measures of effect size (Hedges'  $g$ ) to quantify overall differences between control and patient groups. In addition to calculating overall differences between control and patient groups, we also compared control performance with patient performance, which, based on ranking their MDS-UPDRS-III motor scores that indicate overall motor disease severity, were allocated to one of two bands of disease severity: *low* (with scores ranging from 0 to 30; Experiment 1  $n = 10$ ; Experiment 2  $n = 8$ ) and *high* (with scores greater than 30; Experiment 1  $n = 24$ ; Experiment 2  $n = 17$ ). Also as recommended by Cumming et al. (2012), we report Pearson correlation coefficients with 95% confidence intervals (CI) to quantify associations between measures; CIs that do not include zero indicate a statistically significant association, where CIs that include zero indicate that the association is not statistically significant. Partial correlations are reported, removing the variance that is shared with disease severity (UPDRS-III motor score) and age (in years) when these variables correlated with each of the variables entered into the correlation. In Experiment 2, in which more than one independent variable (e.g., voluntary control of facial musculature, distinctiveness discrimination, CFMT accuracy) was correlated with the dependent variable, we adjusted for Type I error by dividing the  $p$  value of .05 by the number of independent variables that were correlated with the dependent variable. There were no significant correlations between general cognitive functioning, depressive symptoms, sex, or years of education and (a) measures of emotion perception, (b) measures of discriminating and identifying facial identity, and (c) measures of voluntary control of facial musculature (see Supplementary Table 3).

## Results

### Experiment 1

**Impairment in PD in discriminating graded intensities of emotional expressions.** Figure 1A shows that the mean accuracy for each group increased with increasing differentiation of the expression from the neutral face for each of the four emotions, and with increasing intensity differentiation of the emotional expressions for both intensity ranges. The figure also shows that the patient group performed more poorly than controls on all measures and that the group difference increased with stimulus separation. Table 2 shows that effect sizes of the group differences were larger than .8, and thus large by conventional standards. Despite the overall large group differences, the box-and-whisker plots (Figure 1B, show that some patients performed as well as some of the best-performing controls. As Table 3 shows, we found that the effect sizes were substantially greater when comparing control performance with those patients in the high-severity band than those in the low-severity band.

**The link between the ability to discriminate emotional expressions and the ability to voluntarily control facial musculature in PD.** The box-and-whisker plots in Figure 2 show that the patient group performed more poorly in the Face Apraxia Test than the control group ( $g = .83$ ), with individual variation in performance in both groups (but more so in the patient group). Errors by PD patients were mostly due to impoverishment of facial movement (49%) followed by individuation loss (40%), whereas errors by controls were mostly due to individuation loss (63%) followed by impoverishment (24%), indicating a shift toward impoverishment with the additional burden of PD. There was a strong, positive, and significant correlation in patient performance on psychophysical measures of emotion discrimination (mean  $r = .87$ , 95% CI [.75, .93],  $p < .05$ ). Aggregate accuracy from all emotion discrimination measures correlated negatively, highly, and significantly with the total percent of errors on the Face Apraxia Test ( $r = -.73$ , 95% CI [-.86, -.52],  $p < .05$ ). After partialing out common variance of disease severity (UPDRS-motor score) and age (in years) with voluntary control of facial musculature and emotion-discrimination accuracy, the correlation coefficient was negative, moderate, and significant (partial  $r = -.52$ , 95% CI [-.73, -.22],  $p < .05$ ).

### Experiment 2

**Impairment in PD in discriminating graded intensities of emotional facial expressions.** Figure 3 shows that, as in Experiment 1, accuracy increased with increasing intensity differentiation for each group. The patient group again performed more poorly than control group, with the group difference increasing with stimulus separation, and with some patients performing as well as some of the best-performing controls. Effect sizes of group differences in accuracy were large for all emotions (anger,  $g = 1.74$ ; disgust,  $g = 1.64$ ; happiness,  $g = 1.35$ ; sadness,  $g = 1.35$ ). We again found substantially greater effect sizes in the high-severity subgroup ( $n = 17$ ,  $g = 2.24$ ) than the low-severity subgroup ( $n = 8$ ,  $g = 1.35$ ).

For the 40 participants who completed both experiments (patient  $n = 22$ , control  $n = 18$ ), there was a positive, strong,

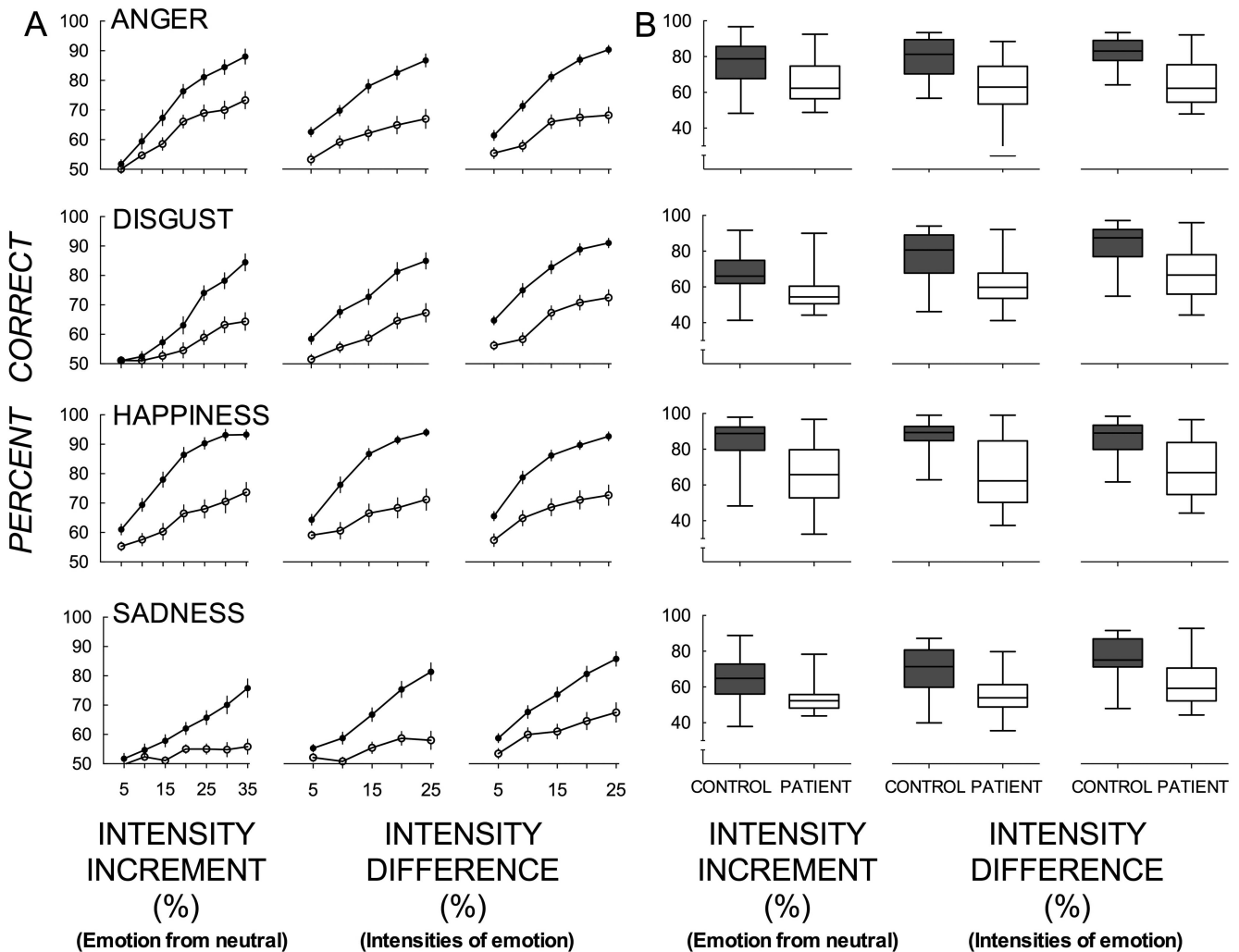


Figure 1. Panel A showing mean percent correct scores ( $\pm 1$  standard error) for patient (open circles) and control (closed circles) groups when discriminating emotion from neutral (left column) and when discriminating different emotional intensities in a low- (middle column) and high-intensity range (right column) in Experiment 1. Panel B showing box-and-whisker plots of mean percent correct scores for patient (clear) and control (dark) groups when discriminating emotions (of 10% to 35% emotional intensity) from neutral expressions (left) and when discriminating differences of 10% to 25% intensities of the same emotional expressions within a low- (middle) and high-intensity range (right). Results are shown for each of the four emotions presented, anger, disgust, happiness, and sadness.

and significant correlation between the measures of discriminating emotional expressions from the two experiments ( $r = .87$ , 95% CI [.77, .93],  $p < .05$ ), illustrating the reliability of the measures. The effect sizes that quantified group differences on emotion-discrimination measures for those participants who completed both experiments were identical in each experiment (both  $g$ 's = 1.79).

**Impairment in PD in discriminating discrepant from similar expressions and in verbally labeling expressions.** Figure 4 shows two features of interest that are similar to the emotion discrimination results from each experiment. First, patients performed more poorly than controls when discriminating discrepant from similar expressions ( $g = .92$ ) and when verbally labeling emotions ( $g = .96$ ). Second, both groups showed variability in

each of the measures, with generally more variability in the patient group, and with some patients performing as well, or almost as well, as the best-performing controls. Effect sizes were again substantially greater when comparing control performance with performance in the high- than low-severity subgroup when discriminating discrepant from similar expressions (low-severity:  $g = .13$ ; high-severity:  $g = 1.71$ ) and when verbally labeling expressions (low-severity:  $g = .29$ ; high-severity:  $g = 1.51$ ).

**The link between measures of discriminating and recognizing emotional expressions in PD.** There were positive, moderate to strong, and significant correlations in patient performance between measures of discriminating differences in intensity of the same emotional expressions, discriminating discrepant from similar expressions, and verbally labeling emotional expressions

Table 2

*Effect Size Measures (Hedges' G) of Group Differences Between Patient and Control Groups on Mean Percent Scores When Discriminating Emotional Expressions (Across 10–35% Emotional Intensity) From Neutral Expressions and When Discriminating 10–25% Differences in Intensity of the Same Emotional Expressions in a Low- and High-Intensity Range in Experiment 1 (Control: n = 32; Patient: n = 34)*

Emotion	Anger	Disgust	Happiness	Sadness
Emotion from neutral	0.88	0.96	1.35	1.05
Different intensities (low range)	1.22	1.14	1.43	1.24
Different intensities (high range)	1.65	1.48	1.32	1.02

(mean  $r = .67$ , 95% CI [.37, .84],  $p < .05$ ). To limit the number of comparisons made, we use the aggregate accuracy from all measures of emotion discrimination and recognition in the correlational analyses with measures of discriminating distinctiveness, recognizing facial identity, and voluntary control of facial musculature.

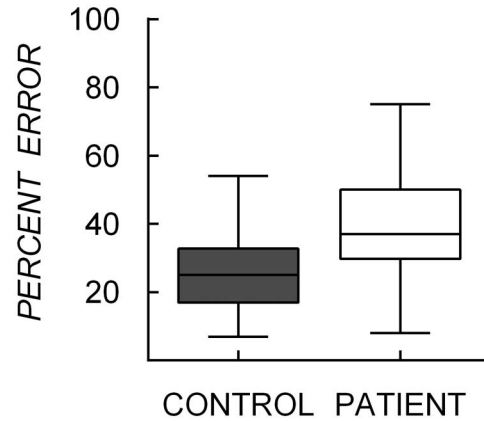
**The link between discriminating and recognizing emotional expressions and discriminating facial distinctiveness and recognizing unfamiliar facial identities in PD.** Figure 5 shows that on average, patients performed more poorly than controls when discriminating differences in facial distinctiveness; similar to the group differences on discrimination of emotional expressions, the effect size of group differences in accuracy was large ( $g = 1.44$ ). The same pattern, poorer average performance in the patient than control group, was seen in accuracy on the CFMT (patient:  $M = 55$ ,  $SD = 10$ ; controls:  $M = 67$ ,  $SD = 13$ ,  $g = .98$ ). After removing the common variance shared with disease severity and age, there was a positive, moderate to strong, and significant correlation between aggregate accuracy from measures of emotion discrimination and recognition and the measure of discriminating differences in facial distinctiveness (partial  $r = .67$ , 95% CI [.37, .84],  $p < .016$ ), but there was no significant correlation with

Table 3

*Effect Size Measures (Hedges' G) of Group Differences Between Control Groups and PD Severity Bands (Lower and Higher) on Mean Percent Scores When Discriminating Emotional Expressions (Across 10–35% Emotional Intensity) From Neutral Expressions and When Discriminating 10–25% Differences in Intensity of the Same Emotional Expressions in a Low- and High-Intensity Range in Experiment 1*

Severity band	Low	High
Emotion from neutral	.50	2.01
Different intensities (low)	.65	2.04
Different intensities (high)	.76	2.14

*Note.* UPDRS-III = Unified Parkinson's Disease Rating Scale. The lower severity band included participants ( $n = 10$ ) whose UPDRS-III scores ranged from 0–30. The higher severity band included those ( $n = 24$ ) whose scores ranged from 30 and beyond.



*Figure 2.* Box-and-whisker plots showing percent error scores for patient (clear) and control (dark) groups when voluntarily controlling facial musculature in the Upper and Lower Face Apraxia Test (Bizzozero et al., 2000) in Experiment 1.

recognizing unfamiliar facial identity in the CFMT (partial  $r = .11$ , 95% CI [–.30, .48],  $p > .016$ ).

**The link between discriminating and recognizing emotional expressions and voluntarily controlling facial musculature in PD.** As in Experiment 1, the patient group ( $M = 39$ ,  $SD = 14$ ) showed higher mean percent errors than the control group ( $M = 25$ ,  $SD = 12$ ) on the Face Apraxia Test ( $g = 1.05$ ). There was again a shift in PD toward impoverishment of facial movement, indicating that patient errors were mostly due to impoverishment (48%), followed by individuation loss (42%), whereas errors by controls were mostly due to individuation loss (54%) followed by impoverishment (31%). After partialing out disease severity and age, there was a negative, moderate, and significant correlation between voluntary control of facial musculature and aggregate accuracy from emotion discrimination and recognition measures (partial  $r = -.59$ , 95% CI [–.80, –.26],  $p < .016$ ). After removing disease severity and age, there was no significant partial correlation between voluntary control of facial musculature and mean percent score in the measure of discriminating facial distinctiveness (partial  $r = -.26$ , 95% CI [–.59, .15],  $p > .025$ ) and recognizing facial identity (partial  $r = -.20$ , 95% CI [–.55, .33],  $p > .025$ ).

**The link between disease severity and discriminating and recognizing emotional expressions after removing the variance shared with general cognitive functioning, depressive symptoms, age, and years since diagnosis.** In both experiments, we found that impaired perception of emotional expressions in PD was a function of disease severity. We considered the possibility that larger impairment in the high- than low-severity bands on measures of emotion discrimination and recognition were due to an increase in general cognitive functioning impairment, age, or depressive symptoms in the high-severity band. To do this, we correlated disease severity with measures of emotion discrimination and recognition in PD after removing the variance shared with general cognitive functioning, depressive symptoms, age, and years since diagnosis in each of the two experiments. Disease severity correlated negatively, moderately, and significantly with measures of emotion discrimination in Experiment 1 (partial

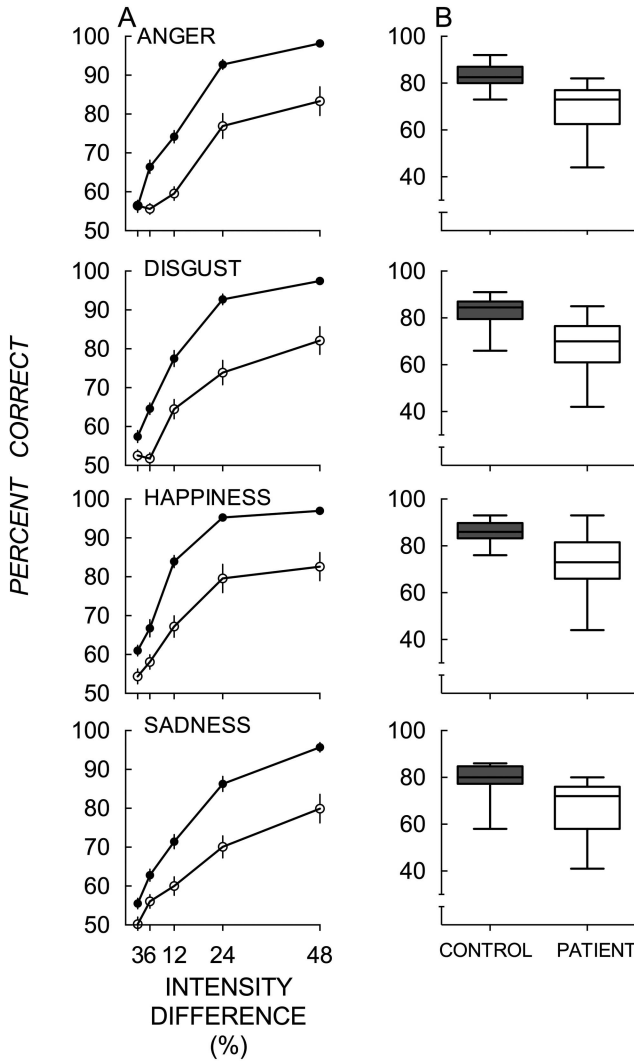


Figure 3. Panel A showing mean percent correct scores ( $\pm$  standard error) for patient (open circles) and control (closed circles) groups when discriminating different intensities of the same expressions in a midintensity range in Experiment 2. Box-and-whisker plots in Panel B, showing mean percent correct scores for patient (clear) and control (dark) groups when discriminating intensity differences of 6% to 48%. Results are shown for each of the four emotions presented, anger, disgust, happiness, and sadness.

$r = -.49$ , 95% CI  $[-.71, -.18]$ ,  $p < .05$ ) and with measures of emotion discrimination and recognition in Experiment 2 (partial  $r = -.50$ , 95% CI  $[-.75, -.13]$ ,  $p < .05$ ), even after removing the variance shared with age, general cognitive functioning, depressive symptoms, and years since diagnosis.

### Discussion

The two experiments show impaired discrimination of emotional expressions of graded intensity and impaired discrimination and recognition of full-blown emotional expressions in those with PD. There were large group differences between patient and control groups on all measures, with the relative emotion-perception

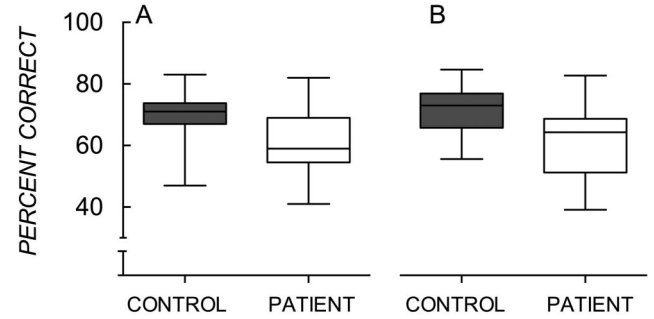


Figure 4. Box-and-whisker plots showing mean percent correct scores for patient (clear) and control (dark) groups when discriminating discrepant from two similar emotional expressions (panel A) and when verbally labeling six basic expressions of emotion (panel B) in Experiment 2.

impairment shown to be a function of disease severity that had little to no correlation with general cognitive functioning, depressive symptoms, sex, or number of years of education. The second experiment also showed impaired discrimination of distinctiveness and impaired recognition of identity from faces in PD which showed that distinctiveness discrimination, but not identity recognition, correlated with measures of emotion perception after removing the effect of disease severity and age. Both experiments showed that, after removing disease severity and age, the ability to voluntarily control facial musculature correlated with the ability to perceive emotional information from faces, but not with the ability to perceive nonemotional information from faces.

The impairment in PD in extracting emotional content from faces is not exclusive to full-blown expressions of emotion, as shown in the majority of previous research (Gray & Tickle-Degnen, 2010) and replicated in the current findings, but is also evident in discriminating emotional facial expressions at submaxi-

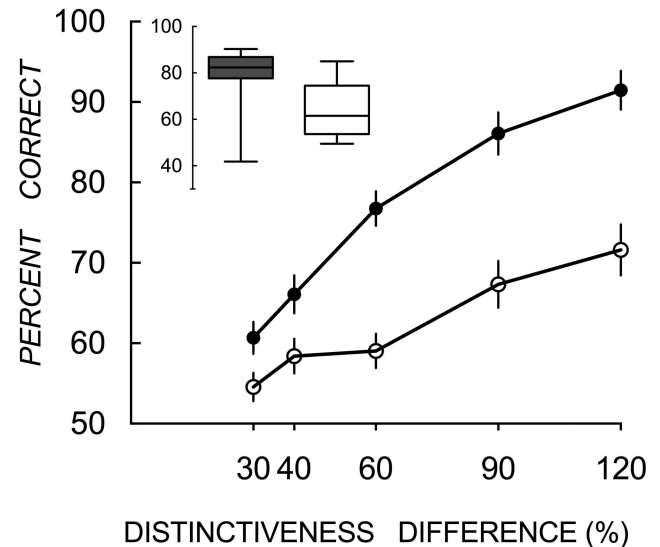


Figure 5. Mean percent correct scores ( $\pm$  1 standard error) and box-and-whisker inserts for patient (open circles/clear) and control (closed circles/dark) groups when discriminating 40% to 120% differences in facial distinctiveness in Experiment 2.

mal intensities. Impaired verbal labeling of submaximal intensities of emotional expressions in PD was recently shown by Buxton et al. (2013) and previously by Assogna et al. (2010) and Dujardin et al. (2004). The impairment in both discrimination and recognition of emotional expressions shown, in which psychophysical discrimination measures do not place an added demand on verbal processes, suggests a cascade of lower-to-higher order impairment in perception of facial expression of emotion in PD. Unlike the meta-analysis (Gray & Tickle-Degnen, 2010), which showed no relationship between emotion recognition and disease severity as measured by the Hoehn and Yahr staging scale (1967), we found performance in the patient group to be a function of disease severity as measured by the MDS-UPDRS; effect sizes were substantially greater when comparing controls with patients in a high-severity than in a low-severity subgroup. The link between disease severity and perception of emotion in PD was maintained even after removing the variance shared with cognitive functioning, age, depressive symptoms, and years since diagnosis. It is likely that the insensitivity of the Hoehn and Yahr (Goetz et al., 2004) obscured the link between disease severity and emotion perception in previous research. Similarly, unlike findings in the meta-analysis that indicated patients were not impaired in identity recognition, our data show impaired discrimination and recognition of facial identity in PD. The null findings by Gray and Tickle-Degnen (2010) are likely due to insensitive measures of identity recognition (Duchaine & Weidenfeld, 2003).

The link between voluntary control of facial musculature and emotion perception, but not with identity perception, is consistent with the embodied simulationist account that simulation of an observed facial expression of emotion contributes to perception of that expression of emotion. According to embodied simulationist accounts of emotion perception, the link between voluntary control of facial musculature and perception of emotional expressions in PD is mediated by simulation of observed expressions, which facilitates inference of emotional states of others. The process by which simulation occurs might be overt, covert, or both (see Goldman & Sripada, 2005). Interpretations of the link between voluntary control of facial musculature and perception of emotional expressions in PD from an overt simulationist perspective will differ from that of a covert simulationist perspective. According to the overt account of embodied simulation in emotion perception, PD patients with impaired voluntary control of facial musculature will be unable to physically simulate or mimic the expressions of others, thereby contributing to impaired perception of emotional expressions in PD. According to the covert account of embodied simulation, motor systems with mirror-like properties that are engaged by voluntary control of facial musculature and simulation of observed expressions are disrupted by the neurodegenerative processes in PD, thereby impairing both perception of emotional expressions and facial musculature control. The present data do not rule out either a covert or an overt account of embodied simulation, as we did not measure the process of simulation directly. However, data from others (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000; Anders et al., 2012; Calder, Keane, Cole, Campbell, & Young, 2000; Carr, Iacobini, Dubeau, Mazzotta, & Lenzi, 2003; Damasio, 1994; Hess & Blairy, 2001; Keillor, Barrett, Crucian, Kortenkamp, & Heilman, 2002; Wicker et al., 2003) have suggested that this simulation is likely a covert process. Evidence has been reported for a human mirror-neuron system in

healthy individuals in the ventrolateral premotor cortex and pars opercularis of the inferior frontal gyrus, which is activated during facial musculature control in producing emotional facial expressions, as well as during recognition of facial expression of emotion (Carr et al., 2003; Wicker et al., 2003). Support for a covert embodied simulationist account comes from Anders et al. (2012) who found that *Parkin* mutation carriers (who show mild reduction of dopamine metabolism in the basal ganglia in the absence of clinical motor signs) were, as a group, slightly impaired relative to controls in emotion recognition; carriers who were least impaired showed the strongest ventrolateral premotor cortex activity, consistent with an embodied simulationist hypothesis that compensatory activity in premotor cortex reduced the impairment. In addition, overt facial mimicry seems unlikely when discriminating facial expressions of emotions at the brief presentation durations (200 ms) in the psychophysical measures. Furthermore, there is accumulating evidence that physical mimicry of the expressions of others is not critical for intact emotion recognition in those with congenital facial muscular paralysis (Calder et al., 2000; Keillor et al., 2002) and in healthy observers (Hess & Blairy, 2001). Therefore, in line with the covert embodied-simulation account, disruption of a motor system with simulation properties in PD might partly explain their impaired perception of emotional expressions and loss of facial expressivity. As a limitation, the correlations between voluntary facial musculature control and emotion perception we reported were an indirect examination of the covert embodied-simulation account. Given that we did not manipulate covert simulation as a more direct approach, these findings do not provide strong definitive evidence for the covert embodied simulationist account. That this simulation is a covert process is speculative, given our present data. However, with evidence against overt simulation (Calder et al., 2000; Hess & Blairy, 2001; Keillor et al., 2002) and evidence that supports covert simulation (Anders et al., 2012; Carr et al., 2003; Wicker et al., 2003), we interpret that the link between voluntary facial musculature control and emotion perception is mediated by covert simulation, a system that is disrupted by neurodegenerative processes in PD, thereby impairing facial expressivity and emotion perception. The association of emotion production and recognition in PD reported by others (Benke, Bosch, & Andrew, 1998; Borod et al., 1990; Jacobs et al., 1995) might be mediated, at least to some extent, by the same sensorimotor neural circuitry that allows the inference of emotion from facial expressions. That facial distinctiveness discrimination was unrelated to voluntary control of facial musculature in PD suggests that the link between emotion discrimination and voluntary control of facial musculature was not mediated by a more general impairment in visually extracting any information from faces.

The link between the measures of emotion perception and distinctiveness discrimination suggest that visual sensory processes also contribute to impaired emotion perception in PD. The view that a broader underlying inability to extract visual information from faces impairs emotion perception in PD has also been supported by the correlation between emotion recognition and the ability to discriminate spatial differences in facial features (Narme et al., 2011) and by reports of abnormal visual scanning patterns during emotion recognition (Clark et al., 2010) in PD. Such a link between extracting visual information from faces and emotion recognition is inconsistent with the dominant theory of face per-

ception (Bruce & Young, 1986), which makes a division between recognition of emotional and nonemotional information on faces; a neuroanatomical division of these processes has also been proposed (Haxby, Hoffman, & Gobbini, 2000). However, findings from others (see Vuilleumier & Pourtois, 2007 for a review) have led to the proposition for an interaction of identity and emotion recognition in which both share perceptual encoding mechanisms that enable recognition. Our data suggest an interaction of identity- and emotion-perception processes, as evidenced by the link between distinctiveness discrimination and emotion perception; both might be impaired by a broader underlying visual impairment in PD (Archibald, Clarke, Mosimann, & Burn, 2009, for a review). Our data also suggest bifurcation of these processes, as evidenced by the link between voluntary facial musculature control and emotion perception, but not with identity, and by little or no correlation between identity recognition (CFMT performance) and emotion perception. Therefore, it appears that sensory and sensorimotor processes are impaired in PD and that both contribute to deficits in visually deciphering emotional content from faces.

Together, the results of these experiments show impairment in PD in lower and higher order abilities of perception of facial expressions of emotion as a function of disease severity. Although we show that this impairment in emotion discrimination and recognition is unrelated to general cognitive functioning, we cannot determine the role of decline in specific cognitive functions in impaired emotional expression perception in PD. Our results support the likelihood of a multifactorial contribution to impaired perception of emotional expressions in PD, which includes, but is not necessarily limited to, disrupted sensory and sensorimotor processes.

## References

- Adolphs, R., Damasio, H., Tranel, D., Cooper, G., & Damasio, A. R. (2000). A role of somatosensory cortices in the visual recognition of emotion as revealed by three-dimensional lesion mapping. *The Journal of Neuroscience*, *20*, 2683–2690.
- Adolphs, R., Schul, R., & Tranel, D. (1998). Intact recognition of facial emotion in Parkinson's disease. *Neuropsychologia*, *12*, 253–258. doi:10.1037/0894-4105.12.2.253
- Anders, S., Sack, B., Pohl, A., Munte, T., Pramstaller, P., Klein, C., . . . Binkofski, F. (2012). Compensatory premotor activity during affective face processing in subclinical carriers of a single mutant *Parkin* allele. *Brain*, *135*, 1128–1140. doi:10.1093/brain/aws040
- Archibald, N. K., Clarke, M. P., Mosimann, U. P., & Burn, D. J. (2009). The retina in Parkinson's disease. *Brain*, *132*, 1128–1145. doi:10.1093/brain/awp068
- Ariatti, A., Benuzzi, F., & Nichelli, P. (2008). Recognition of emotions from visual and prosodic cues in Parkinson's disease. *Neurological Sciences*, *29*, 219–227. doi:10.1007/s10072-008-0971-9
- Assogna, F., Pontieri, F. E., Cravello, L., Peppe, A., Pierantozzi, M., Stefani, A., . . . Spalletta, G. (2010). Intensity-dependent facial emotion recognition and cognitive functions in Parkinson's disease. *Journal of the International Neuropsychological Society*, *16*, 867–876. doi:10.1017/S1355617710000755
- Baggio, H. C., Segura, B., Ibarretxe-Bilbao, N., Valldeoriola, F., Marti, M. J., Compta, Y., . . . Junque, C. (2012). Structural correlates of facial emotion recognition deficits in Parkinson's disease patients. *Neuropsychologia*, *50*, 2121–2128. doi:10.1016/j.neuropsychologia.2012.05.020
- Bartlett, J. C., Hurry, S., & Thorley, W. (1984). Typicality and familiarity of faces. *Memory & Cognition*, *12*, 219–228. doi:10.3758/BF03197669
- Bediou, B., Brunelin, J., d'Amato, T., Fecteau, S., Saoud, M., Henaff, M., . . . Krolak-Salmon, P. (2012). A comparison of facial emotion processing in neurological and psychiatric conditions. *Frontiers in Psychology*, *3*, 98–107. doi:10.3389/fpsyg.2012.00098
- Benke, T., Bosch, S., & Andrew, B. (1998). A study of emotional processing in Parkinson's disease. *Brain and Cognition*, *38*, 36–52. doi:10.1006/brcg.1998.1013
- Benton, A. L., Sivan, A. B., Hamsher, K., Varney, N. R., & Spreen, O. (1994). *Contributions to neuropsychological assessment*. New York, NY: Oxford University Press.
- Bizzozero, I., Costato, D., Della Sala, S., Papagno, C., Spinnler, H., & Venneri, A. (2000). Upper and lower face apraxia: Role of the right hemisphere. *Brain*, *123*, 2213–2230. doi:10.1093/brain/123.11.2213
- Borod, J. C., Welkowitz, J., Alpert, M., Brozgold, A. Z., Martin, C., Peselow, E., & Diller, L. (1990). Parameters of emotional processing in neuropsychiatric disorders: Conceptual issues and a battery of tests. *Journal of Communication Disorders*, *23*, 247–271. doi:10.1016/0021-9924(90)90003-H
- Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology*, *77*, 305–327. doi:10.1111/j.2044-8295.1986.tb02199.x
- Bruce, V., & Young, A. (2012). *Face perception*. East Sussex, UK: Psychology Press.
- Busey, T. A. (1998). Physical and psychological representation of faces: Evidence from morphing. *Psychological Science*, *9*, 476–483. doi:10.1111/1467-9280.00088
- Buxton, S. L., MacDonald, L., & Tippett, L. (2013). Impaired recognition of prosody and subtle emotional facial expressions in Parkinson's disease. *Behavioral Neuroscience*, *127*, 192–203. doi:10.1037/a0032013
- Calder, A. J., Keane, J., Cole, J., Campbell, R., & Young, A. J. (2000). Facial expression recognition by people with Mobius syndrome. *Cognitive Neuropsychology*, *17*, 73–87. doi:10.1080/026432900380490
- Carr, L., Iacobini, M., Dubeau, M. C., Mazziotta, J. C., & Lenzi, G. L. (2003). Neural mechanisms of empathy in humans: A relay from neural systems for imitation to limbic areas. *Proceedings of the National Academy of Sciences of the United States of America*, *100*, 5497–5502. doi:10.1073/pnas.0935845100
- Clark, U. S., Nearing, S., & Cronin-Golomb, A. (2008). Specific impairments in the recognition of emotional facial expressions in Parkinson's disease. *Neuropsychologia*, *46*, 2300–2309. doi:10.1016/j.neuropsychologia.2008.03.014
- Clark, U. S., Nearing, S., & Cronin-Golomb, A. (2010). Visual exploration of emotional facial expressions in Parkinson's disease. *Neuropsychologia*, *48*, 1901–1913. doi:10.1016/j.neuropsychologia.2010.03.006
- Cohen, H., Gagne, M., Hess, U., & Pourcher, E. (2010). Emotion and object processing in Parkinson's disease. *Brain and Cognition*, *72*, 457–463. doi:10.1016/j.bandc.2010.01.001
- Cumming, G., Fidler, F., Kalinowski, P., & Lai, J. (2012). The statistical recommendations of the *American Psychological Association publication manual*: Effect sizes, confidence intervals, and meta-analysis. *Australian Journal of Psychology*, *64*, 138–146. doi:10.1111/j.1742-9536.2011.00037.x
- Dalrymple-Alford, J. C., MacAskill, M. R., Nakas, C. T., Livingston, L., Graham, C., Crucian, G. P., . . . Anderson, T. J. (2010). The MoCA: Well-suited screen for cognitive impairment in Parkinson disease. *Neurology*, *75*, 1717–1725. doi:10.1212/WNL.0b013e3181fc29c9
- Damasio, A. R. (1994). *Descartes' error: Emotion, reason, and the human brain*. New York, NY: Grosset.
- Duchaine, B., & Nakayama, K. (2006). The Cambridge Face Memory Test: Results for neurologically intact individuals and an investigation of its validity using inverted stimuli and prosopagnosic participants. *Neuropsychologia*, *44*, 576–585. doi:10.1016/j.neuropsychologia.2005.07.001

- Duchaine, B. C., & Weidenfeld, A. (2003). An evaluation of two commonly used tests of unfamiliar face recognition. *Neuropsychologia*, *41*, 713–720. doi:10.1016/S0028-3932(02)00222-1
- Dujardin, K., Blairy, S., Defebvre, L., Duhem, S., Noel, Y., Hess, U., . . . Destee, A. (2004). Deficits in decoding emotional facial expressions in Parkinson's disease. *Neuropsychologia*, *42*, 239–250. doi:10.1016/S0028-3932(03)00154-4
- Goetz, C. G., Poewe, W., Rascol, O., Sampaio, C., Stebbins, G. T., Counsell, C., . . . Seidl, L. (2004). Movement Disorder Society task force report on the Hoehn and Yahr Staging Scale: Status and recommendations. *Movement Disorders*, *19*, 1020–1028. doi:10.1002/mds.20213
- Goetz, C. G., Tilley, B. C., Shaftman, S. R., Stebbins, G. T., Fahn, S., Martinez-Martin, P., . . . LaPelle, N. (2008). Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): Scale presentation and clinimetric testing results. *Movement Disorders*, *23*, 2129–2170. doi:10.1002/mds.22340
- Goldman, A. I., & Sripada, C. S. (2005). Simulationist models of face-based emotion recognition. *Cognition*, *94*, 193–213. doi:10.1016/j.cognition.2004.01.005
- Gray, H. M., & Tickle-Degnen, L. (2010). A meta-analysis of performance on emotion recognition tasks in Parkinson's disease. *Neuropsychology*, *24*, 176–191. doi:10.1037/a0018104
- Haeske-Dewick, H. C. (1996). Perception and memory for faces influenced by a specific age at onset factor in Parkinson's disease? *Neuropsychologia*, *34*, 315–320. doi:10.1016/0028-3932(95)00109-3
- Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences*, *4*, 223–233. doi:10.1016/S1364-6613(00)01482-0
- Herrera, E., Cuetos, F., & Rodriguez-Ferreiro, J. (2011). Emotion recognition impairment in Parkinson's disease without dementia. *Journal of the Neurological Sciences*, *310*, 237–240. doi:10.1016/j.jns.2011.06.034
- Hess, U., & Blairy, S. (2001). Facial mimicry and emotional contagion to dynamic facial expressions and their influence on decoding accuracy. *International Journal of Psychophysiology*, *40*, 129–141. doi:10.1016/S0167-8760(00)00161-6
- Hoehn, M. M., & Yahr, M. D. (1967). Parkinsonism: Onset, progression and mortality. *Neurology*, *17*, 427–442. doi:10.1212/WNL.17.5.427
- Ibarretxe-Bilbao, N., Junque, C., Tolosa, E., Marti, M., Valldeoriola, F., Bargallo, N., . . . Zarei, M. (2009). Neuroanatomical correlates of impaired decision-making and facial emotion recognition in early Parkinson's disease. *European Journal of Neuroscience*, *30*, 1162–1171. doi:10.1111/j.1460-9568.2009.06892.x
- Jacobs, D. H., Shuren, J., Bowers, D., & Heilman, K. M. (1995). Emotional facial imagery, perception, and expression in Parkinson's disease. *Neurology*, *45*, 1696–1702. doi:10.1212/WNL.45.9.1696
- Kan, Y., Kawamura, M., Hasgawa, Y., Mochizuki, S., & Nakamura, K. (2002). Recognition of emotion from facial, prosodic, and written verbal stimuli in Parkinson's disease. *Cortex*, *38*, 623–630. doi:10.1016/S0010-9452(08)70026-1
- Keillor, J. M., Barrett, A. M., Crucian, G. P., Kortenkamp, S., & Heilman, K. M. (2002). Emotional experience and perception in the absence of facial feedback. *Journal of the International Neuropsychological Society*, *8*, 130–135. doi:10.1017/S1355617702811134
- Lawrence, A. D., Goerendt, I. K., & Brooks, D. J. (2007). Impaired recognition of facial expressions of anger in Parkinson's disease patients acutely withdrawn from dopamine replacement therapy. *Neuropsychologia*, *45*, 65–74. doi:10.1016/j.neuropsychologia.2006.04.016
- Light, L. L., Kayra-Stuart, F., & Hollander, S. (1979). Recognition memory for typical and unusual faces. *Journal of Experimental Psychology: Human Learning and Memory*, *5*, 212–228. doi:10.1037/0278-7393.5.3.212
- Lundqvist, D., Flykt, A., & Öhman, A. (1998). *The Karolinska Directed Emotional Faces-KDEF* [CD ROM]. Stockholm, Sweden: Karolinska Institutet, Department of Clinical Neuroscience, Psychology Section.
- Marneweck, M., Loftus, A., & Hammond, G. (2013). Psychophysical measures of sensitivity to facial expression of emotion. *Frontiers in Psychology*, *4*, 63–68. doi:10.3389/fpsyg.2013.00063
- Narme, P., Bonnet, A., Dubois, B., & Chaby, L. (2011). Understanding facial emotion perception in Parkinson's disease: The role of configural processing. *Neuropsychologia*, *49*, 3295–3302. doi:10.1016/j.neuropsychologia.2011.08.002
- Narme, P., Mouras, H., Roussel, M., Duru, C., Krystkowiak, P., & Godefroy, O. (2013). Emotional and cognitive social processes are impaired in Parkinson's disease and are related to behavioral disorders. *Neuropsychology*, *27*, 182–192. doi:10.1037/a0031522
- Nasreddine, Z. S., Phillips, N. A., Bedirian, V., Charbonneau, S., Whitehead, V., Collin, I., . . . Chertkow, H. (2005). The Montreal Cognitive Assessment, MOCA: A brief cognitive screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, *53*, 695–699. doi:10.1111/j.1532-5415.2005.53221.x
- Nazem, S., Siderowf, A. D., Duda, J. E., Have, T. T., Colcher, A., Horn, S. S., . . . Weintraub, D. (2009). Montreal Cognitive Assessment performance in patients with Parkinson's disease with "normal" global cognition according to Mini-Mental State Examination score. *Journal of the American Geriatrics Society*, *57*, 304–308. doi:10.1111/j.1532-5415.2008.02096.x
- Nunnally, J. C. (1978). *Psychometric theory*. New York, NY: Pearson Educational
- Palermo, R., O'Connor, K. B., Davis, J. N., Irons, J., & McKone, E. (2013). New tests to measure individual differences in matching and labeling facial expressions of emotion, and their association with ability to recognize vocal emotions and facial identity. *PLoS ONE*, *8*, e68126. doi:10.1371/journal.pone.0068126
- Pell, M. D., & Leonard, C. L. (2005). Facial expression decoding in early Parkinson's disease. *Cognitive Brain Research*, *23*, 327–340. doi:10.1016/j.cogbrainres.2004.11.004
- Rhodes, G., Jaquet, E., Jeffery, L., Evangelista, E., Keane, J., & Calder, A. J. (2011). Sex-specific norms code face identity. *Journal of Vision*, *11*, 1–11. doi:10.1167/11.1.1
- Sheikh, J. I., & Yesavage, A. (1986). Geriatric depression scale GDS: Recent evidence and development of a shorter version. In T. L. Brink (Ed.), *Clinical gerontology: A guide to assessment and intervention* (pp. 165–173). New York, NY: Haworth.
- Sprengelmeyer, R., Young, A. W., Mahn, K., Schroeder, U., Woitalla, D., Buttner, T., . . . Przuntek, H. (2003). Facial expression recognition in people with mediated and unmedicated Parkinson's disease. *Neuropsychologia*, *41*, 1047–1057. doi:10.1016/S0028-3932(02)00295-6
- Suzuki, A., Hoshino, T., Shigemasa, K., & Kawamura, M. (2006). Disgust-specific impairment of facial expression recognition in Parkinson's disease. *Brain*, *129*, 707–717. doi:10.1093/brain/awl011
- Tomlinson, C. L., Stowe, R., Patel, S., Rick, C., Gray, R., & Clarke, C. E. (2010). Systematic review of levodopa dose equivalency reporting in Parkinson's disease. *Movement Disorders*, *25*, 2649–2653. doi:10.1002/mds.23429
- Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., . . . Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, *168*, 242–249. doi:10.1016/j.psychres.2008.05.006
- Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. *The Quarterly Journal of Experimental Psychology: A. Human Experimental Psychology*, *43*, 161–204. doi:10.1080/14640749108400966
- Ventura, M. I., Baynes, K., Sigvardt, K. A., Unruh, A. M., Acklin, S. S., Kirsch, H. E., . . . Disbrow, E. A. (2012). Hemispheric asymmetries and prosodic emotion recognition deficits in Parkinson's disease. *Neuropsychologia*, *50*, 1936–1945. doi:10.1016/j.neuropsychologia.2012.04.018

- Vokey, J. R., & Read, J. D. (1992). Familiarity, memorability, and the effect of typicality on the recognition of faces. *Memory & Cognition*, *20*, 291–302. doi:10.3758/BF03199666
- Vuilleumier, P., & Pourtois, G. (2007). Distributed and interactive brain mechanisms during emotion face perception: Evidence from functional neuroimaging. *Neuropsychologia*, *45*, 174–194. doi:10.1016/j.neuropsychologia.2006.06.003
- Weintraub, D., Oehlberg, K. A., Katz, I. R., & Stern, M. B. (2006). Test characteristics of the 15-item Geriatric Depression scale and the Hamilton Depression Rating scale in Parkinson's disease. *Journal of the American Geriatric Society*, *14*, 169–175.
- Wicker, B., Keysers, C., Plailly, J., Royet, J., Gallese, V., & Rizzolatti, G. (2003). Both of us disgusted in my insula: The common neural basis of seeing and feeling disgust. *Neuron*, *40*, 655–664. doi:10.1016/S0896-6273(03)00679-2
- Wieser, M. J., Klupp, E., Weyers, P., Pauli, P., Weise, D., Zeller, D., . . . Muhlberger, A. (2012). Reduced early visual emotion discrimination as an index of diminished emotion processing in Parkinson's disease? Evidence from event-related brain potentials. *Cortex*, *48*, 1207–1217. doi:10.1016/j.cortex.2011.06.006
- Yip, J. T. H., Lee, T. M. C., Ho, S., Tsang, K., & Li, L. S. W. (2003). Emotion recognition in patients with idiopathic Parkinson's disease. *Movement Disorders*, *18*, 1115–1122. doi:10.1002/mds.10497
- Zadikoff, C., Fox, S. H., Tang-Wai, D. F., Thomsen, T., de Bie, R. M. A., Wadia, P., . . . Marras, C. (2008). A comparison of the Mini Mental State Exam to the Montreal Cognitive Assessment in identifying cognitive deficits in Parkinson's disease. *Movement Disorders*, *23*, 297–299. doi:10.1002/mds.21837

Received January 8, 2014

Revision received March 15, 2014

Accepted April 21, 2014 ■