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Research report

Facial expression decoding in early Parkinson's disease

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Abstract

The ability to derive emotional and non-emotional information from unfamiliar, static faces was evaluated in 21 adults with idiopathic Parkinson's disease (PD) and 21 healthy control subjects. Participants' sensitivity to emotional expressions was comprehensively assessed in tasks of discrimination, identification, and rating of five basic emotions: happiness, (pleasant) surprise, anger, disgust, and sadness. Subjects also discriminated and identified faces according to underlying phonemic ("facial speech") cues and completed a neuropsychological test battery. Results uncovered limited evidence that the processing of emotional faces differed between the two groups in our various conditions, adding to recent arguments that these skills are frequently intact in non-demented adults with PD [R. Adolphs, R. Schul, D. Tranel, Intact recognition of facial emotion in Parkinson's disease, Neuropsychology 12 (1998) 253–258]. Patients could also accurately interpret facial speech cues and discriminate the identity of unfamiliar faces in a normal manner. There were some indications that basal ganglia pathology in PD contributed to selective difficulties recognizing facial expressions of disgust, consistent with a growing literature on this topic. Collectively, findings argue that abnormalities for face processing are not a consistent or generalized feature of medicated adults with mild-moderate PD, prompting discussion of issues that may be contributing to heterogeneity within this literature. Our results imply a more limited role for the basal ganglia in the processing of emotion from static faces relative to speech prosody, for which the same PD patients exhibited pronounced deficits in a parallel set of tasks [M.D. Pell, C. Leonard, Processing emotional tone from speech in Parkinson's disease: a role for the basal ganglia, Cogn. Affect. Behav. Neurosci. 3 (2003) 275–288]. These diverging patterns allow for the possibility that basal ganglia mechanisms are more engaged by temporally-encoded social information derived from cue sequences over time.

Theme: Disorders of the nervous system
Topic: Degenerative disease: Parkinson's

Keywords: Nonverbal communication; Facial expression; Emotion; Disgust; Group study

1. Introduction

Abnormalities in face processing have been cited as one of the cognitive sequelae of idiopathic Parkinson's disease (PD) without dementia [26,28,45]. Human faces are subject to an array of processes that are thought to be modular in structure [18,19] and which fractionate in various ways in the context of acquired brain illnesses such as PD [23,25,40,65]. According to Bruce and Young's well-known model [18], functional components of the face processing system include the ability to detect familiarity about known faces based on their structural properties and to make various 'semantic' judgements about the sex, age, intelligence, and trustworthiness of individuals whose face is encountered, to name but a few. Of key interest here, the early structural elaboration of faces serves as the foundation for deriving two distinct 'codes' that are largely independent of recognizing the identity or familiarity of a face: a code for deriving the emotional expression or meaning of the face; and facial speech codes that facilitate linguistic processes of speech perception during verbal discourse [18,23]. These

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latter two functional components permit key inferences to be drawn about faces that shape communicative interactions and interpersonal behavior; given the paramount social importance of these functions, coupled with claims that face processing is frequently affected by PD, the present study sought to investigate these functions in the context of PD in a more comprehensive manner.

While the integrity of face processing skills in PD has been called into question, relevant findings are still limited and conclusions about what processes are affected are decidedly mixed. An influential study conducted by Dewick, Hanley, Davies and colleagues [28] tested a range of face processing skills in non-demented adults with and without PD, involving: discrimination, matching, and short-term recall of unfamiliar faces by their identity; discrimination of faces by sex or emotion expression; and discrimination of visually-articulated speech sounds (i.e., facial speech processing or "speech-reading"). With the exception of the emotion task which yielded a ceiling effect for both groups, individuals with PD were significantly impaired in all conditions, a finding the authors attributed to a basic deficit in the structural encoding of faces. The investigators argued that processing of emotion expressions would have been negatively affected by such a deficit but that their emotion task was insensitive to these processes in the PD group. The idea that PD is associated with relatively basic defects in the visual perceptual (i.e., structural) analysis of faces, with repercussions at later stages of encoding for these events, echoes earlier results for 43 PD patients studied by Beatty et al. [10] and is supported by some recent work [26,34]. When this hypothesis has been examined in greater detail [26], there are indications that structural processing failures in PD may center around visual tasks of configural rather than componential processing of faces, especially when facial stimuli are degraded in some way (e.g., black and white line drawings).

Not all findings indicate that face processing difficulties in PD are manifested at the level of structural encoding. For instance, Jacobs et al. [41] noted that 12 PD patients could accurately discriminate unfamiliar faces by their distinguishing properties (identity) but not by emotional expression. Sprengelmeyer and colleagues [60] also described groups of medicated and unmedicated adults with PD who could normally discriminate unfamiliar faces by identity or sex, but who displayed specific impairments in the recognition of emotional faces taken from the Ekman and Friesen [30] series. Results of these and other studies [16,42] are more conducive to a specific emotional face processing deficit in PD. In the Sprengelmeyer et al. investigation, which is the sole one to date to examine face processing abilities in unmedicated as well as medicated PD patients, the influence of dopamine status on emotional face processing in PD was strongly highlighted; L-dopa therapy appeared to diminish the severity of deficits for recognizing particular expressions of emotion such as disgust in medicated patients, in spite of the advanced stage of disease in this group. The possibility that recognizing specific emotional expressions such as disgust is critically reliant on the intact basal ganglia, and therefore susceptible to disruption in PD and other disorders of these structures, is a claim that has been proposed on several occasions [20,31,33,59,63] and should be monitored further.

Still other, well-controlled studies have identified little evidence that emotional face processing is disturbed in a detectable manner by PD. For example, there are two reports that the ability to label the six basic emotions from the Ekman series is intact in mild-moderate PD without dementia [14,61]. Borod et al. further noted that the discrimination of serially-presented emotional face expressions was intact in her sample of 20 adults with PD, consistent with Dewick et al.'s earlier observations. Adolphs et al. [5] required 18 PD patients to complete the Benton face discrimination task and an emotional rating paradigm in which subjects judged the presence of pre-designated emotional attributes of Ekman faces along an intensity continuum (this paradigm provides a more sensitive index of emotional processes in PD according to the researchers). This investigation revealed no indications that PD patients were deficient in either the structural or emotional face processing task, questioning the actual extent to which basal ganglia degeneration and associated pathology in PD are tied to deficits in (emotional) face processing. The possibility that PD yields a more selective pattern of emotion deficits, affecting knowledge about only specific emotions such as disgust, was also not strongly indicated by their data [5] or by some other PD studies that have tested the recognition of disgust [10,14,29].

Equivocal claims about the status and specificity of emotional face processing deficits in PD call for additional, fine-grained evaluation of these skills in a well-defined patient sample. The goals of this study were to establish how individuals in the early stages of PD interpret the emotional value of faces in different task processing contexts that require them to discriminate, identify/label, or rate emotional features along an intensity gradient; concurrently, we examined how well these patients process non-emotional facial information (facial speech cues) that can also be derived from the structural description of faces [18]. Data from both experimental conditions were interpreted in light of a selected battery of neuropsychological background tests, including the ability to discriminate structural descriptions of faces by their physical identity. Our testing incorporated a series of perceptually-validated, color face stimuli [53] to extend previous findings on PD to a new set of items and to establish a tight comparison between abilities on emotional face expression, facial speech processing, and emotional prosody [55] tasks which employed stimuli posed by the same actors.

Despite the undisputedly mixed findings to date, we hypothesized that PD status would be associated with deficits on certain emotional processing tasks, particularly the identification of facial expressions of emotion from an

array of verbal response alternatives [16,42,60]. In the absence of detailed information on how PD patients decode facial speech information as an independent function, we predicted that deficits in the processing of both emotional and non-emotional faces, if observed, would bear a strong relationship to underlying cognitive features of our PD participants, especially the ability to structurally encode faces (as indexed through background measures such as the Benton face discrimination subtest). The possibility that basal ganglia damage in PD might selectively influence the perception of disgust or anger faces was also considered relevant in face of a growing literature on this topic. Finally, by documenting emotional face processing skills in PD in a variety of task-processing conditions, we sought to compare these abilities in the visual modality with data on how the same patients understand communicative displays through emotional speech tone (prosody) [55], for which there is more uniform evidence of processing deficiencies associated with early PD [51,55].

2. Materials and methods

2.1. Subjects

Participants were 21 individuals with idiopathic PD and 21 healthy individuals matched on a one-to-one basis for sex, age, and educational status (see Table 1 for major demographic and clinical features of each group). Subjects in the PD group ranged in age from 51 to 83 years and were recruited through a Self Management Program at the Baycrest Centre for Geriatric Care, Toronto, Canada. Idiopathic PD was confirmed on the basis of accepted motor criteria [22] by a residing neurologist. Individuals with other serious medical conditions (e.g., stroke, primary psychiatric disorder), history of substance abuse, or who had undergone surgical interventions for control of PD were ineligible for the study. The absence of dementia in PD patients was established by the research team at study onset using the Dementia Rating Scale [49]; all participants in the PD sample were high functioning with full-scores on this scale between 137 and 144 out of 144 (where scores less than 123 are indicative of intellectual decline). Severity of motor signs within the PD sample tended to be mild according to Hoehn and Yahr (Mean = 2.0, SD = 0.5) and unified Parkinson's disease rating scale (Mean = 14.5, SD = 7.1) motor criteria; these signs were characterized as left dominant (n = 11), right dominant (n = 7), or bilateral (n = 3). The average duration of PD within the sample was 3.9 years (SD = 1.9). All patients except one were tested while being administered anti-Parkinsonian medication ("on-state"), distributed as follows: carbidopa/L-dopa (n = 17); d2-agonist (n = 11); MAO-B inhibitor (n = 1); COMT inhibitor (n = 1); amantadine (n = 3); anticholinergics (n = 1). One PD participant (PD7) was receiving an antidepressant (paroxetine).

Table 1
Major characteristics of participants with Parkinson's disease (PD) and for healthy controls (HC) (mean ± standard deviation)

Variable	Group	
	PD	HC
Sex (f/m)	10/11	10/11
Age (years)	61.7 ± 8.6	61.9 ± 8.5
Education (years)	16.0 ± 3.7	16.0 ± 2.6
Disease duration (years)	3.9 ± 1.9	N/A
Hoehn and Yahr rating score	2.0 ± 0.5	N/A
Motor UPDRS	14.5 ± 7.1	N/A
Mattis Dementia Rating Scale (/144)	141.2 ± 2.1	142.5 ± 1.8
Hamilton Depression Inventory (/33)[a]	4.7 ± 3.4	2.3 ± 2.9

[a] Short form, maximum = 33, increased scores indicate greater impairment.

Twenty-one healthy aging control (HC) subjects with a negative history of neurologic and psychiatric disease were recruited to the study from the Montréal, Canada region. Control subjects were administered the Mattis Dementia Rating Scale to verify intact intellectual status (full-score range = 138–144). All patient and control participants reported normal or corrected-to-normal vision, and intact hearing was formally established in all subjects by administering a puretone audiometric screening of both ears at frequencies important to speech intelligibility (minimum 30 dB HL at 0.5, 1, 2, and 4 kHz, for the better ear). Presence and severity of depression were estimated in both PD and HC participants using the Hamilton Depression Inventory—Short form [57]. Informed written consent was obtained from each subject prior to testing, and subjects were paid a modest fee for their involvement. Ethical approval of the protocol was granted by the McGill Faculty of Medicine Institutional Review Board and the joint Baycrest Centre/University of Toronto ethics committee.

2.2. Materials

An inventory of face stimuli was developed and perceptually validated to achieve a highly controlled comparison of how adults with PD process cues to emotion expression, facial speech, and emotional prosody [55] from stimuli elicited from the same actors (see [53] for details of stimulus construction and validation). Facial expressions were produced by four male and four female actors and then saved as color photographs (bitmaps) depicting the actor's face, hair, and shoulders in the manner described by Ekman and Friesen [30]. Poses representing five distinct emotions (happiness, (pleasant) surprise, anger, disgust, and sadness) were chosen for the purported universality of these target emotions, coupled with the desire to closely balance positive and negative-valenced emotions within the data set [15]. The same actors were recorded producing five highly visible vowel and consonant speech sounds (/a/, /i/, /sh/, /f/, /m/) which were saved at the point of their articulation at which the identity of the sound was thought to be greatest. Based on perceptual data gathered for items in our face inventory [53], only tokens which were unambiguous about their

emotion- or sound-based meaning were used to construct experimental tasks, i.e., those that had been correctly identified by at least 80% of a group of 30 young, healthy decoders in a forced, multiple-choice recognition task. An example of emotional and "speech-reading" face stimuli posed by one actor is furnished in Fig. 1.

2.3. Face processing tasks

Validated face stimuli were presented in distinct processing conditions that varied how subjects evaluated the underlying significance of the display. Emotional face expressions were presented for discrimination, identification/labeling, and rating of individual features along an intensity continuum. Facial speech stimuli were only presented for discrimination and identification of the sound being produced, since linguistic face gestures are less conducive to continuous judgements about their underlying meaning. An equal number of exemplars posed by female and male actors were always entered into emotional and facial speech tasks.

2.3.1. Discrimination

(i) Emotional expression discrimination: the ability to discriminate face pairs according to the emotion conveyed by the expression was assessed by eliciting a same/different judgement to 30 trials (representing an equal ratio of "same" and "different" emotional pairings). The two faces in each trial were presented serially separated by a 1-s inter-stimulus interval and always involved actors of the same sex. "Same" trials reflected three distinct combinations of exemplars for each of the five emotions, whereas "different" trials involved tokens for each category coupled with those for every other category at least once. Accuracy of the same/different judgement was recorded.

(ii) Facial speech discrimination: in a similarly-structured task, subjects were required to discriminate face pairs according to the speech sound articulated by the speaker using a same/different judgement to 30 trials (half "same" and half "different" pairings). Face pairs involved combinations of five speech sounds and were combined in trials according to the same principles described in the emotion discrimination task. Accuracy was recorded.

2.3.2. Identification

(i) Emotional expression identification: categorizing the emotional relevance of faces was evaluated in a multiple choice format with a closed set of verbal labels as response alternatives. Subjects viewed a series of static facial expressions representing one of five emotions (happiness, pleasant surprise, anger, disgust, and sadness), and for each trial, indicated the one response alternative that best described the meaning of the face. Response accuracy was analyzed for eight separate tokens representing each target value (8 tokens × 5 targets = 40 trials).

(ii) Facial speech identification: the ability to identify phonemic information from the face was assessed in a manner resembling the emotion identification task. Subjects viewed static facial stimuli which presented visual cues to one of five speech sounds (/a/, /i/, /sh/, /f/, /m/) and were required to indicate from a closed list

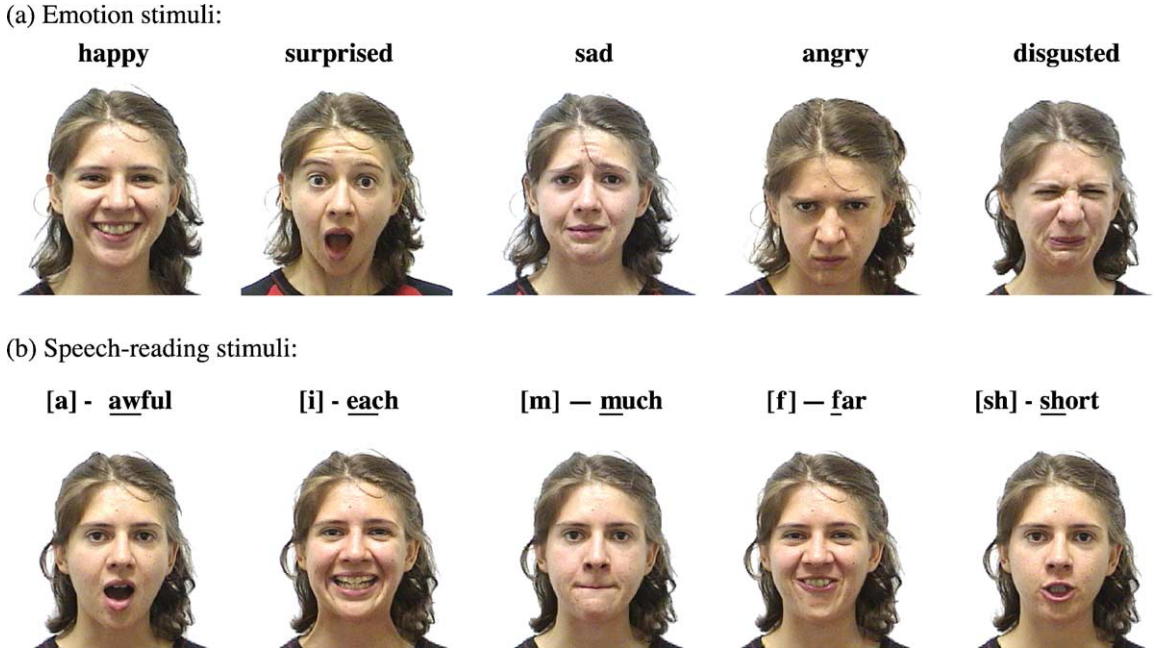

Fig. 1. Examples of emotional expressions and facial speech stimuli presented in face processing tasks posed by one actor.

which sound the speaker was saying. Data for eight tokens representing each target were recorded and analyzed (8 tokens × 5 targets = 40 trials).

2.3.3. Emotional expression rating

Sensitivity to the emotional quality of faces was assessed further by requiring subjects to rate the degree to which facial expressions conveyed particular emotions using a continuous scale signifying increased "presence" of the target emotion. Following Adolphs and colleagues [2,5], a single experiment was constructed involving the 40 face events presented in the emotional identification task (8 items × 5 emotions) plus 12 "filler" faces representing neutral expressions or emotional blends. Subjects were presented a randomized list of the 52 faces on five separate occasions; each time, subjects were instructed to attend to only one of the five target emotions and to rate each stimulus for "how much of the emotion was being expressed" on a scale from 0 ("not at all") to 5 ("very much"). This process culminated in five distinct ratings for each face token, providing an index of how each subject judged the presence of intended emotional features as well as their global sensitivity to the range of five emotional attributes potentially associated with exemplars of a particular target.

2.4. Neuropsychological background tests

Various neuropsychological functions that support face interpretation, and which may be susceptible to PD, were evaluated in an attempt to isolate contributions of the basal ganglia to specific operations for registering the expression or speech-related information of human faces. Minimally, our face decoding tasks required subjects to retain auditory information about task requirements, to process visual forms, to retrieve information related to emotions or speech sounds, to sustain and alternate visual attention to facial stimuli and written labels that acted as response prompts, and to shift mental sets across tasks which required related but different types of processing and responses. Accordingly, each participant completed the following emotional and non-emotional (i.e., perceptual or executive functioning) background tests:

(i) Identification of emotion to verbal descriptions: to ensure that subjects were familiar with the emotion response labels and could apply these to verbal descriptions, each subject listened to ten sentences that described prototypical situations that might elicit one of the five target emotions (2 items × 5 emotions). Subjects indicated how they would feel in each situation from the set of five emotion labels.

(ii) Identification of emotion from speech prosody: each subject performed an identical set of discrimination, identification, and rating tasks which evaluated their understanding of emotion from speech prosody; these data, which are the topic of a separate report [55], supply important background information on emotional processing abilities in our PD subjects and are compared briefly here. Items presented in prosody tasks were recordings of emotionally-inflected "nonsense" utterances (e.g., Someone migged the pazing) which were produced by the same actors in the same five emotions as the face stimuli (happiness, pleasant surprise, anger, disgust, sadness) (see Ref. [53] for a comparative analysis of the emotional face versus prosody stimuli).

(iii) Visual/auditory processing: the processing of visual information and the ability to match structural features of unfamiliar faces that contained no obvious emotional or linguistic cues were evaluated using appropriate discrimination subtests of the Benton Laboratory of tests (Visual Form Discrimination, Facial Discrimination [12]). Auditory discrimination of speech sounds was also assessed briefly through the Benton Phoneme Discrimination subtest. Accuracy on each task was inspected.

(iv) Cognitive/executive resource functioning: each participant completed the following tests: Forward Digit Span; Color Trails Test [27]; Wisconsin Card Sorting Test [32]; and a measure of verbal working memory capacity or "listening span" adapted for use with brain-damaged adults [62]. The latter test elicits a series of 42 true/false judgements to spoken propositions (e.g., Sugar is sweet) while requiring listeners to retain and recall the last word of each sentence within sets of an increasing number of utterances (see Ref. [62] for a rationale and complete list of items). Finally, the Attention subtest of the Mattis Dementia Rating Scale was examined separately to elaborate information on basic attentional functioning in each subject.

2.5. Procedure

Subjects were tested independently in a quiet laboratory, for participants in the PD group at a time of day when their motor symptoms were least severe. Testing began with the dementia, depression, and audiometric screenings, followed by a quasi-random administration of face processing and neuropsychological tasks intermixed over the course of four testing sessions, each separated by an interval of at least 1 week. Tasks within each face condition were assigned to different sessions whenever possible to minimize stimulus repetition and fatigue during a single session. Testing sessions were fully randomized for presentation order within the PD group and then matched with controls. Digital face photographs measuring 17.1 × 17.1 cm for computer display were automatically randomized by Superlab software (Cedrus Corporation, USA) and viewed on a high resolution monitor at a visual distance of 60 cm. For discrimination tasks, subjects were instructed to

make a same/different decision about the underlying emotional or phonemic meaning represented by the stimulus pair, whereas for identification tasks, subjects were instructed to choose the single response of the five choices provided that best signified the meaning of the face. For the emotion rating task, subjects were instructed to indicate "how much" of the target emotion was expressed by the face by choosing a number on the scale between zero and five. In all cases, subjects were invited to indicate their response verbally or by pointing to their decision on a card on the table in front of them. All decisions were recorded by the examiner and no time limits were imposed on their response. All tasks were preceded by verbal instructions and a practice block that oriented subjects to specific task goals.

3. Results

Data on emotion expression and facial speech processing abilities in PD were examined in sequence within each task processing condition and then compared to neuropsychological background variables. Table 2 summarizes group performance for key measures of both the emotional and facial speech processing tasks.

Table 2
Processing of emotional faces and facial speech cues by the PD and HC groups (mean ± standard deviation)

Condition/Measure	Group	
	PD (n = 21)	HC (n = 21)
Discrimination		
Facial emotion, total correct (/30)	26.0 ± 2.3	27.2 ± 1.9
Facial speech, total correct (/30)	26.1 ± 2.2	26.9 ± 2.2
Identification		
Facial emotion, total correct (/40)	35.5 ± 3.2	36.1 ± 3.1
Facial speech, total correct (/40)	32.3 ± 7.6	33.6 ± 6.4
Emotional expression rating		
Target = Happiness		
Mean target feature rating (scale 0–5)	4.26 ± 0.80	4.21 ± 0.66
Proportion "4 + 5" target ratings	0.78 ± 0.36	0.82 ± 0.25
Overall emotional sensitivity[a]	0.92 ± 0.07	–
Target = Pleasant surprise		
Mean target feature rating (scale 0–5)	4.24 ± 0.77	4.24 ± 0.65
Proportion "4 + 5" target ratings	0.83 ± 0.28	0.78 ± 0.23
Overall emotional sensitivity	0.86 ± 0.10	–
Target = Anger		
Mean target feature rating (scale 0–5)	3.86 ± 0.95	3.86 ± 0.59
Proportion "4 + 5" target ratings	0.72 ± 0.29	0.68 ± 0.20
Overall emotional sensitivity	0.74 ± 0.17	–
Target = Disgust		
Mean target feature rating (scale 0–5)	3.67 ± 0.84	3.86 ± 0.69
Proportion "4 + 5" target ratings	0.61 ± 0.32	0.68 ± 0.25
Overall emotional sensitivity	0.72 ± 0.19	–
Target = Sadness		
Mean target feature rating (scale 0–5)	3.83 ± 0.69	3.62 ± 0.81
Proportion "4 + 5" target ratings	0.69 ± 0.26	0.59 ± 0.27
Overall emotional sensitivity	0.81 ± 0.11	–

[a] Correlation of the five ratings assigned to emotional target faces by individual PD subjects compared to the mean ratings of the HC group.

3.1. Processing emotional and non-emotional faces by task

3.1.1. Discrimination

For emotional expressions, participants with and without PD were both highly reliable at discriminating serially-presented faces according to the underlying emotional significance of the expression; the accuracy of the PD (87 ± 8%) and HC (91 ± 6%) groups did not differ significantly on this task ($t(40) = -1.76$, $P = 0.09$). The sensitivity of each group to face pairs exemplifying the same versus distinct emotion expressions was probed briefly by focussing on the proportion of "different" emotion trials that each subject discriminated correctly ('hit') and the proportion of "same" trials that subjects incorrectly judged as distinct ('false alarm'). Mean 'hit' and 'false alarm' rates were relatively comparable for the PD (0.84, 0.10) and HC (0.89, 0.08) groups, indicating that discrimination performance in the PD group was not differentially biased by "same" versus "different" trials in the task. It was noted that three patients (PD9, PD12, PD21) and one healthy control subject (HC9) performed in excess of two standard deviations below the control group mean on the discrimination task, which was explained in two of these cases (PD9, PD12) by a failure to correctly detect real differences in the emotion depicted by face pairs.

In the facial speech discrimination task, a t test performed on mean accuracy scores revealed no differences in how individuals with and without PD judged faces portraying same or different combinations of visible speech sound articulations ($t(40) = -1.11$, $P = 0.27$). Inspection of confusion matrices for each group again revealed no obvious qualitative differences in the direction of errors elicited by "same" or "different" stimuli on the speech-reading task. One individual in each group (PD12, HC3) achieved scores below two standard deviations of the control group mean on this task. Fig. 2a illustrates the main findings by group when subjects discriminated emotional expressions versus facial speech cues.

3.1.2. Identification

For the emotional face identification (i.e., naming) task, corresponding accuracy scores were subjected to a two-way mixed ANOVA involving Group (PD, HC) and the repeated factor of Emotion (happiness, pleasant surprise, anger, disgust, sadness). There was no main effect of Group membership on the recognition of static expressions of emotion overall [$F(1,40) = 0.35$, $P = 0.56$], although accuracy varied significantly according to the Emotion category [$F(4,160) = 12.18$, $P < 0.001$]. Post hoc inspection of the Emotion main effect using Tukey's HSD procedure ($P < 0.05$) revealed that differences were due in a large part to a ceiling effect in the identification of happy faces which were identified virtually without error in the experiment overall (99.7% correct), significantly better than all other emotional face expressions. Pleasant surprise

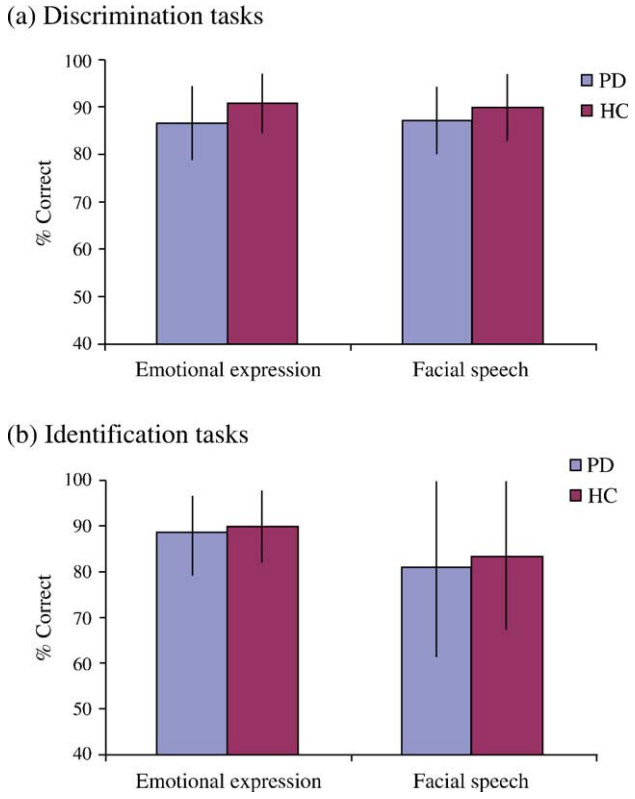

Fig. 2. Accuracy of the PD and HC groups on emotional expression and facial speech processing tasks for (a) discrimination and (b) identification.

(92% correct) was also categorized more readily than disgust which obtained the lowest consensus for all subjects overall (83% correct), although recognition of disgust did not differ significantly from anger or sadness (88% and 85% correct, respectively). There was no evidence that a diagnosis of PD influenced patterns for identifying the five facial expressions of emotion in the form of a group by emotion interaction [$F(4,160) = 0.02$, $P = 0.74$]. One patient (PD12) and one control subject (HC9) demonstrated marked discrepancies (<2 SD) from the control group mean owing to difficulties identifying the expression of disgust.

For the facial speech identification task, a two-way ANOVA involving Group (PD, HC) and facial speech Sound (/a/, /i/, /sh/, /f/, /m/) indicated that overall accuracy on this task did not vary significantly by Group [$F(1,40) = 0.38$, $P = 0.54$], although there was a significant main effect for Sound [$F(4,160) = 5.49$, $P = 0.001$]. Post hoc inspection of the Sound main effect revealed that /m/ and /a/ were identified from faces more accurately than /f/ overall. Of greater interest, there was no evidence that patterns of facial speech identification were dependent on group membership in a significant manner [$F(4,160) = 0.63$, $P = 0.60$]. Three patients (PD3, PD9, PD12) and one control subject (HC16) performed poorly on the facial speech identification task but there were no obvious systematic errors for particular sounds for this subset of individuals. Fig. 2b summarizes the overall group findings in the identification condition when subjects were required to identify emotional expressions or facial speech cues.

3.1.3. Emotional expression rating

This condition further assessed subjects' ability to interpret the presence of specific emotional qualities in faces along an ordinal scale of increasing emotion, without the need to explicitly categorize the events verbally. Rating performance was first analyzed in reference to how well subjects with PD detected intended emotional targets of facial expressions. Recall that each facial stimulus was rated separately according to all five emotional qualities, but that a subset of these ratings indexed "how much" of the actual target emotion the subject correctly detected (i.e., the set of "happy" ratings for happiness faces, etc.). For this portion of the data (8 items × 5 emotions × 21 subjects = 840 data points per group), a high frequency of ratings at the upper end of the six-point scale was expected, especially "4" and "5" responses, owing to the construction of facial stimuli that were unambiguously associated with one of the target emotions. The proportion of combined "4" and "5" ratings assigned to intended target emotions was entered as the dependent measure in a 2 × 5 ANOVA involving Group and Emotion type; the proportion of high ratings assigned on the ordinal scale differed significantly by Emotion [$F(4,160) = 7.06$, $P < 0.001$]. Post hoc Tukey's comparisons established that each positively-valenced emotional expression (happiness, pleasant surprise) was rated as more strongly indicative of the target than each of the negatively-valenced emotional expressions (anger, disgust, sadness). These patterns corresponded to differences in the mean intensity ratings assigned to the five emotions across subjects which were: happiness (4.2), pleasant surprise (4.2), anger (3.9), disgust (3.8), and sadness (3.7). There were no main or interactive influences of Group on how intended target emotions were evaluated according to the proportion of combined "4 and 5" responses or the mean rating intensity (both P's > 0.27).

A series of chi square tests conducted on the frequency of ratings assigned at each interval of the six-point scale failed to establish the independence of the individual group distributions for any of the five target facial expressions (all P's = ns: Happiness [$\chi^2(5) = 7.99$, $P = 0.09$]; Surprise [$\chi^2(5) = 7.07$, $P = 0.22$]; Anger [$\chi^2(5) = 9.19$, $P = 0.10$]; Disgust [$\chi^2(5) = 3.07$, $P = 0.69$]; Sadness [$\chi^2(5) = 5.87$, $P = 0.32$]). More generally, the manner in which the two groups assigned ratings to all intended target emotions–defined by the summed frequency of ratings to the five target emotions at each interval of the scale (involving 840 observations per group)–was highly comparable and did not vary in the rating condition overall [$\chi^2(5) = 2.65$, $P = 0.75$].

Sensitivity to the range of intended and unintended emotional qualities potentially associated with different facial expressions was evaluated briefly following methods

and rationale proposed by Adolphs and colleagues (see [1,3]). The five emotional ratings that each PD participant assigned to a single face token were correlated with the set of mean ratings assigned to that item by the 21 HC subjects as a group; individual correlations were subsequently transformed and averaged across items expressing the same emotion. Set correlations between the PD and HC groups ranged from a low of 0.72 for disgust to a high of 0.92 for happiness, with a mean similarity of 0.81 in the rating condition overall (correlations further from 1 imply increased "distance" or impairment from normal patterns of sensitivity to this range of emotional features). A one-way ANOVA on the mean Z transformed correlation coefficients by facial expression type indicated that PD group's rating sensitivity varied significantly as a function of Emotion [$F(4,80) = 12.85$, $P < 0.001$]. Post hoc Tukey's comparisons indicated that PD ratings approximated those of healthy subjects more closely for happiness than for all other emotions. The patients also resembled the HC group more closely for surprise than for anger or disgust and for sadness over disgust. A lack of previous ratings for these stimuli involving a distinct control group precluded a direct comparison of our two groups for the correlation measures. The estimated "distance" of the PD group's overall ratings for each emotion from the control group mean is displayed graphically in Fig. 3.

3.2. Relationship between face processing and background measures

Subject groups were constructed to control for demographic variables of sex, age, and years of formal education which did not differ (review Table 1). Although the PD and HC groups demonstrated a similar range of scores on the Mattis Dementia Rating Scale and all participants in the study were unimpaired on this measure, the group distribution of scores on the DRS was significantly lower within the PD group [$t(40) = -2.15$, $P = 0.04$]. Depression scores tended to be higher in the patient than in the control group [HDI-SF: $t(40) = 2.45$, $P = 0.02$]; however, only two patients and one control subject (PD7, PD14, HC11) satisfied criteria for mild depression (HDI scores between 10 and 12).

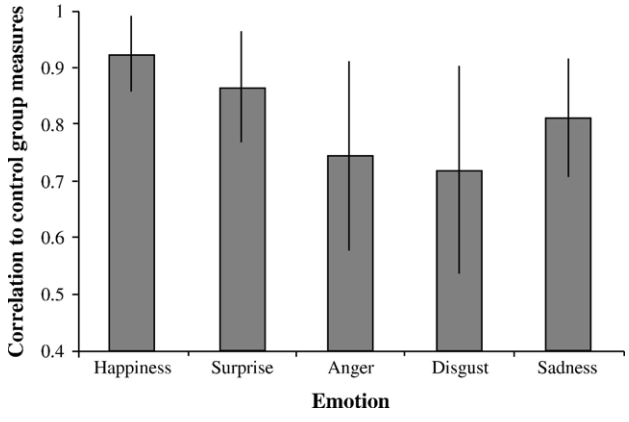

Fig. 3. Overall sensitivity of the PD group to five emotional qualities in the rating condition by target emotion. Measures further from "1" represent increased departure from the mean set of ratings assigned to the stimuli by the control group as a whole.

Table 3 supplies additional data on neuropsychological characteristics of the two groups. There were no differences between the two groups on the Benton subtests evaluating discrimination of visual forms [$t(40) = 0$, $P = 1.00$] or unfamiliar faces [$t(40) = -0.23$, $P = 0.82$]. In contrast, there was a clear attenuation in the performance of the PD group on certain auditory tasks: Benton phoneme discrimination [$t(40) = -2.46$, $P = 0.02$]; and words recalled in the verbal working memory test [$t(40) = -3.67$, $P < 0.001$]. The two groups performed comparably on measures of attention (DRS subscore: $t(40) = -1.51$, $P = 0.14$), digit span [$t(40) = 0.15$, $P = 0.88$], and on two 'traditional' estimates of frontal executive functioning: the Color Trails-B (time to complete, $t(40) = -1.28$, $P = 0.21$)[2]; and the Wisconsin Card Sorting Test (categories: $t(40) = -1.67$, $P = 0.10$; perseverative errors: $t(40) = 1.50$, $P = 0.14$; nonperseverative errors: $t(40) = 0.71$, $P = 0.48$).

Finally, in comparison to tasks of emotion processing, it was noted that individuals with PD were capable of interpreting emotions from verbal scenarios describing emotion-inducing situations in a normal manner [$t(40) = -0.79$, $P = 0.43$]. However, these subjects were unable to derive emotional meanings from prosodic inflections of spoken utterances that were devoid of meaningful lexical-semantic content; as summarized in Table 3 and reported in detail in our companion report [55], prosodic deficits were apparent on tasks of discrimination, identifying, and rating the emotional significance of speech prosody despite relatively unimpaired abilities in parallel conditions of emotional face processing described above (see Discussion and [55] for an elaboration of the cross-channel findings).

Pearson correlations were computed between scores on individual tasks of emotional expression and facial speech processing to infer what relationship may have existed in the skills tapped by these tasks for the PD group (emotional rating performance was represented by the proportion of combined "4" and "5" target responses across emotions). As illustrated in Table 4, the ability to discriminate versus identify the meaning of facial stimuli was significantly correlated in both the emotion expression ($r = 0.75$, $P < 0.001$) and facial speech ($r = 0.60$, $P < 0.05$) conditions. The ability to interpret emotional expressions

[2] One patient, PD12, represented an extreme outlier on this task (performance greater than 10 standard deviations above the control group mean). Exclusion of this subject from the PD group revealed more comparable completion times for the PD (Mean = 94.8 ± 28.9 s) and HC (Mean = 87.7 ± 17.8 s) groups and reinforced the lack of statistically significant differences between the two groups on this measure ($P = 0.35$).

Table 3
Neuropsychological features of individuals in the PD and HC groups (mean ± SD)

Variable	Group	
	PD (n = 21)	HC (n = 21)
Benton visual form discrimination (/32)	30.5 ± 2.4	30.5 ± 1.8
Benton (unfamiliar) face discrimination (/52)	46.8 ± 3.4	47.0 ± 3.4
Benton phoneme discrimination (/30)	26.4 ± 3.2	28.3 ± 1.7*
Emotion identification from verbal description (/10)	7.7 ± 1.7	8.1 ± 1.4
Emotional prosody discrimination, total correct (/30)[a]	21.8 ± 3.4	23.6 ± 2.5***
Emotional prosody identification, total correct (/40)[a]	27.4 ± 4.9	31.6 ± 3.4**
Emotional prosody feature rating[a],**		
Target = Happiness		
Proportion "4 + 5" target ratings	0.39 ± 0.29	0.42 ± 0.30
Overall emotional sensitivity	0.62 ± 0.36	–
Target = Surprise		
Proportion "4 + 5" target ratings	0.45 ± 0.31	0.57 ± 0.29
Overall emotional sensitivity	0.65 ± 0.31	–
Target = Anger		
Proportion "4 + 5" target ratings	0.50 ± 0.32	0.60 ± 0.33
Overall emotional sensitivity	0.58 ± 0.23	–
Target = Disgust		
Proportion "4 + 5" target ratings	0.62 ± 0.30	0.69 ± 0.27
Overall emotional sensitivity	0.54 ± 0.14	–
Target = Sadness		
Proportion "4 + 5" target ratings	0.49 ± 0.33	0.65 ± 0.33
Overall emotional sensitivity	0.68 ± 0.24	–
Dementia Rating Scale, Attention subtest (/37)	36.5 ± 0.8	36.8 ± 0.4
Forward digit span	7.3 ± 1.0	7.2 ± 1.0
Verbal working memory (words recalled /42)	36.2 ± 3.6	39.7 ± 2.3**
Color Trails Test B (seconds to complete)	103.4 ± 48.5	87.7 ± 17.8
Wisconsin Card Sorting Test		
Categories achieved (max = 6)	4.6 ± 2.1	5.3 ± 1.5
Nonperseverative errors (%)	11.3 ± 7.6	9.9 ± 4.5
Perseverative errors (%)	17.4 ± 15.0	11.9 ± 7.7

[a] Data reported originally by Pell and Leonard [54,55].
* HC > PD, $P < 0.05$.
** $P < 0.01$.
*** $P = 0.06$.

versus facial speech cues was significantly correlated only when the identification paradigm was administered ($r = 0.60$, $P < 0.05$). The observation that rating scores did not bear a strong relationship to those in either the discrimination or identification tasks for emotional processing replicates a finding we noted in the parallel set of tasks evaluating emotional prosody in PD [55], implying a certain level of independence in the processes tapped by these different tasks.

To determine the relationship between emotional expression processing in PD and key background variables of these subjects, a combined emotion discrimination/identification score and the emotional rating score were compared to measures of disease duration (years), motor severity (UPDRS motor score), education (years), Benton face recognition score, depression (HDI score), cognitive status (Mattis DRS full score), and verbal working memory (words recalled). Motor severity bore a significant negative relationship to emotion expression processing confined to when PD patients rated face targets ($r = -0.63$, $P < 0.05$). The ability to discriminate/identify facial expressions of emotion did not vary significantly according to any of the predictor variables (all P's > 0.06). To briefly explore whether the severity of motor signs in individual PD subjects was related to difficulties in the rating of specific emotions, Pearson correlations were computed between subjects' UPDRS motor score and the proportion of "4 + 5" ratings assigned to each of the five emotion targets; there was a marginally significant negative association between increased motor severity and decreased ratings for faces of disgust ($r = -0.59$, $P = 0.07$). The ability to rate each of the other emotional expressions was also inversely related to motor severity in PD, but these correlations did not approach significance (happiness: $r = -0.56$, $P = 0.13$; pleasant surprise: $r = -0.32$, $P = 1.00$; anger: $r = -0.35$, $P = 1.00$; sadness: $r = -0.56$, $P = 0.12$).

4. Discussion

Models of face recognition have proposed distinct functional components for determining a face's identity, for deriving information about the emotional value of (known or unknown) faces, for deciphering facial speech cues, and for assigning other "visually directed" social attributions to faces [18,25]. This investigation examined how individuals with Parkinson's disease derive information from unfamiliar human faces, focussing on how they analyze prototypical expressions of emotion and speech cues in this channel. As noted earlier, neuropsychological reports contend that PD pathology is associated with selective deficits in the encoding of emotional faces [16,41,42,60], more basic defects in the structural encoding

Table 4
Pearson correlations between measures of emotion expression and facial speech discrimination (discrim) and identification (ID) for the PD group (n = 21)

	Face processing condition				
	Emotion discrim	Emotion ID	Emotion Rating	Speech discrim	Speech ID
Emotion discrim	1.00				
Emotion ID	0.75**	1.00			
Emotion rating	−0.04	−0.03	1.00		
Speech discrim	0.46	0.49	0.29	1.00	
Speech ID	0.49	0.60*	−0.12	0.60*	1.00

* $P < 0.05$.
** $P < 0.001$.

of faces [10,26,28,34], or no discernable impairment in face recognition at either level of encoding [5,14,61]. The latter opinion–that functions needed to appreciate the emotional or speech-related value of human faces are largely operational in cognitively unimpaired adults with PD–is suggested strongly here where we found little consistent evidence that face processing was adversely affected in our PD sample. These data question the extent to which face processing difficulties are indeed present in adults with PD or under what conditions.

4.1. Impact of PD on emotional face processing

The present design manipulated underlying processing requirements of emotional face tasks in three distinct ways: participants were required to discriminate the underlying emotional meaning of faces; to categorize and name the emotional value of the face from a set of options (the most common paradigm in this literature); and to evaluate the relative presence or intensity of emotional cues associated with faces without need to categorize these values. Examining emotional processing abilities in each of the primary contexts that have contributed to present conclusions in the PD literature allowed potential breakdowns within the "expression analysis" component [18] of our patients to be studied with greater precision than previously undertaken. In addition, it was possible to infer whether conflicting results have partly arisen due to the selective administration of different perceptual paradigms that impose unique demands on PD patients in relation to background features.

In each of our three emotion conditions, individuals with PD performed very well as a group and did not differ significantly in any case from non-brain-damaged control subjects matched for sex, age, and educational attainment. For example, in the identification task which required subjects to name one of five emotions depicted by facial expressions, the PD group was accurate for 89% of the stimuli compared to 90% for the HC group overall. In the rating condition which probed the relative sensitivity of PD and HC subjects to particular emotional associations of face stimuli along a six-point scale, the distribution of responses assigned to each of the five target emotions was virtually identical for the two groups based on ratings for well over 800 items per group. In fact, a review of Table 2 reveals few or no measures that differentiated the two groups for this form of information processing, although adults with PD were significantly impaired in a predictable manner in other key areas of cognitive performance such as verbal working memory and comprehension of emotional prosody (discussed below). As such, our findings permit little doubt that PD patients were sensitive to underlying emotion knowledge represented by faces and could access this information in different processing conditions, extending similar results that have been based selectively on categorization/matching [14,28,61] or continuous rating [5] of emotion expressions by adults with PD.

The observation that emotional face processing was largely spared is inconsistent with some research that cites these functions as a specific area of concern for individuals with PD [16,41,42,60]. For instance, Jacobs and colleagues noted an (incomplete) impairment in 12 PD patients who were unable to discriminate emotional expressions but could match them according to four underlying emotions (happy, sad, angry, frightened). Using a variant of the same materials (Florida Affect Battery), Breitenstein and colleagues found that only the seven patients in their more advanced PD group were impaired relative to healthy control subjects on tasks of discriminating, naming, and matching faces according to five emotions (including the category neutral). In a recent undertaking that presented separate naming tasks composed of prototypical exemplars of emotion or ambiguous, "morphed" facial expressions taken from the Ekman series, Sprengelmeyer et al. [60] demonstrated that medicated (n = 20) and unmedicated (n = 16) adults with PD both exhibit difficulties identifying prototypical exemplars of the six basic emotions relative to healthy control subjects. In addition, unmedicated patients were inferior at recognizing ambiguous expressions of emotion compared to healthy subjects, and the patients' dopamine status appeared to be critical in the detection of certain emotions such as disgust which was selectively impaired in the unmedicated rather than the medicated PD group. Collectively, these and other recent findings [29,42,64] are inconsistent with the claim that processing of emotion expressions from faces is uniformly spared in individuals with mild-moderate PD, contrary to indications that this was true here and in other prominent reports in this literature (e.g., [5]).

At present, there is no obvious account for the divergent conclusions reached by studies documenting intact versus impaired emotional face processing in PD, although a brief analysis of potential contributing factors may help to structure future work. The impact of disease duration/motor symptom severity on emotional face processing skills was strongly implied by comparisons of mild and more advanced PD groups in two studies [16,64], and was hinted at here by correlations between UPDRS motor scores and emotional rating sensitivity within our PD group (see [29] for a similar, strong trend). However, this relationship is not always evident [34,41] and it is noteworthy that subjects in the more "advanced" PD group of Breitenstein et al.'s [16] study fit Hoehn and Yahr stage II motor criteria which is the typical average severity of PD subjects examined in the bulk of investigations that both support and refute the idea that emotional face processing is deficient in PD (cf. [5,42,60,61]). Thus, there can be little confidence at present that disease progress, as inferred by Hoehn and Yahr or other motor criteria, is strongly predictive of emotional face processing abilities in any general or absolute terms. Furthermore, Sprengelmeyer et al.'s results emphasize that face processing skills were significantly worse in their PD group with less advanced

motor signs who were not undergoing dopamine replacement therapy, a difference these authors instead attributed to the positive medication status of the PD group with less pronounced face recognition deficits. Future attempts to control for L-dopa status and the influence of other anti-Parkinsonian agents on face processing skills seem prudent in light of Sprengelmeyer et al.'s [60] recent findings (see [64] for related comments).

A further implication of Sprengelmeyer et al.'s data was that emotional processing difficulties in PD, when present, were strongly tied to knowledge about specific facial expressions such as disgust and to a lesser extent anger. The possibility of a more selective emotional processing deficit was also exemplified by the 19 PD patients examined by Kan et al. [42] who showed increased impairments for disgust and fear. These results emphasize the notion of dissociable neural systems for recognizing different emotions [8,21] and furnish specific evidence that basal ganglia dopamine plays a critical role in modulating distributed neural systems for the recognition of disgust [7,20,31,33,59,64]. Although there was no consistent evidence across our three emotion processing conditions that depictions of disgust or any other emotion were recognized less accurately by PD patients in the facial channel, it is noteworthy that the overall rating of disgust faces by our PD patients diverged most widely from that of control subjects than for the other emotions (review Fig. 3). Also, there was a strong corresponding trend for faces of disgust to be uniquely misrated by PD patients with advanced motor impairment. Finally, there were firm indications that the same PD patients we studied here were selectively less sensitive to expressions of disgust when communicated through speech prosody [55]. These patterns render it probable that, while differential impairments for disgust are not always detectable in adults with PD [5], the basal ganglia participate with functionally-adjacent structures such as the insula [21,56] in tasks that tap the recognition of disgust. These functional ties and the factors that best predict when basal ganglia degeneration in PD tends to yield selective impairments for disgust (such as increased motor impairment/disease duration as implied here) should continue to be monitored.

4.2. Emotion expression versus other face processing abilities in PD

Our findings establish that emotional face recognition was broadly spared in PD, and yet consensus in this literature is clearly lacking. To extend the purview of our data to "non-emotional" judgements of unfamiliar faces, we assessed whether adults with PD could reliably discriminate and identify phonemic/speech information from faces posed by the same actors (recall that facial speech recognition abilities are presumably encapsulated from other types of information processing of faces [18]). We uncovered no indications that facial speech processing for five highly visible speech sounds was compromised in our patients in any way, exemplifying that PD had little influence on the ability to derive two functionally distinct codes from facial events. For facial speech processing, our findings contrast with those of one earlier study that examined this capacity in a single matching task involving three vowel sounds [28]. An obvious distinction between the present results and Dewick et al.'s data, which also speak to the origins of emotion expression deficits cited in the previous section, was the capacity of PD subjects to structurally encode faces which were impaired in Dewick et al's sample but which were fully intact in the present subjects.

Most researchers agree that deriving information "code" from faces such as emotional expressions or speech cues hinges on adequate structural encoding functions that capture distinguishing properties of these events. The integrity of these skills in PD has typically been characterized through performance on the Benton Facial Recognition Test [11]. On this measure and several others collected by Dewick and colleagues to assess structural encoding abilities, there was significant evidence that these skills were compromised by PD; these observations were used to explain the basis of poor facial speech processing abilities in their patients and promoted the authors' broader claim that deficits in structural encoding constitute the primary locus of face recognition difficulties in PD, including recognition of emotion expressions (although recall that their patients could accurately discriminate faces by emotional expression, implying that certain information about emotion could nonetheless be derived in the face of problems for structural encoding). In support of this view, other researchers have established that PD patients perform at an inferior level to control subjects on the Benton Face Recognition Test [10,34,45] or the Warrington Recognition Memory test for faces [26,28]. The PD group tested here was virtually indistinguishable from the healthy control group on the Benton face task, precluding the possibility that structural encoding of faces was implicated in any serious manner in our patient sample.[3] Many other investigations have also failed to detect differences between adults with and without PD on the Benton face task or related measures of discriminating unfamiliar face attributes, including all studies that have declared emotional face processing to be aberrant in PD when the structural encoding abilities of their patients were concurrently probed [5,16,41,42,60]. These findings emphasize that difficulties for expression analysis, when observed in PD, may be

[3] The possibility that structural or visual encoding difficulties contributed to poor performance in 2 both emotional expression and facial speech analysis was implied by the individual performance of two patients in our PD group (PD9, PD12). These two participants, who were frequently cited as performing outside the normal range on tasks of processing emotional expression and facial speech, presented with average motor impairments in our PD group (both were in H and Y stage 2) but accounted for the lowest score on the Benton Face task (PD9 = 39/54) and the two lowest scores on the Benton Visual Form task (PD9 = 28/32; PD12 = 22/32).

influenced by more basic structural encoding failures [18] but are frequently independent of abnormalities at this level [16,41,42,60].

What factors, then, contribute to the emergence of structural encoding abnormalities in adults with PD? Whereas it was argued that the severity of PD within the early stages of the disease is not a strong predictor of (more selective) emotional face processing deficits–despite new hints of an association between increasing motor severity and deficits for disgust in our emotion rating condition–advanced disability in PD may play a clearer role in the appearance of basic failures that impact on unfamiliar face processing at the encoding stage. Key studies that have reported disturbances at the level of structural encoding [10,28] have tended to include a larger proportion of PD patients with more severe disabilities; for example, 14/21 patients tested by Dewick et al. (Expt. 2 [28] and 9/13 early-onset patients tested by Haeske-Dewick [34] fit stages III–V on the Hoehn and Yahr scale) and half of the 28 patients examined recently by Cousins et al. [26] were diagnosed as stage III or IV. While Beatty and colleagues stated that the majority of their 43 patients fit either stage II or III on the Hoehn and Yahr scale, increased severity within their PD group is implied by the observation that nearly half of their patients scored outside the lower range of their control group on the MMSE [10]. Finally, although Yip and colleagues [64] did not specifically test structural face encoding in their 64 PD patients as one of their visual processing tasks, it is noteworthy that 47/56 of their more severe "bilateral" patient group fit the Hoehn and Yahr III–V criteria and that deficits in other aspects of visual processing and organization were considered the "best predictor" of emotional face processing skills in this investigation; these findings allow for the possibility that processes for structural face encoding were also impaired in more advanced PD patients and partly responsible for the marked emotion processing deficits observed. The fact that some of these studies have reported a significant, direct link between PD disease duration, Hoehn and Yahr severity, and/or MMSE scores with many of their face processing measures [10,28] is also of relevance.

For this set of studies, it may be inferred that advanced stages of PD pathology are more likely to interrupt functions devoted to basic structural encoding processes, with possible repercussions on subsequent stages of encoding for faces [10,28,cf,26]. Following previous suggestions, deficits at this level may reflect reduced efficiency of processes devoted to visual–perceptual operations which hamper the elaboration of "view-centered" descriptions of faces [18] such as reductions in contrast sensitivity and/or problems in the configural resolution of visual stimuli (see [10,26,34] for discussions). If shown to be true, the prevalence of structural face abnormalities in some typically more advanced patients with PD may be attributed to interruptions of distinct neural circuitry involving the basal ganglia which contribute to higher-order aspects of visual processing; these functions may decline independently of purported mechanisms specialized for the processing of emotion, such as the recognition of disgust, but would frequently impact on emotional operations when social stimuli are visual in nature. More work which includes longitudinal examination of face processing skills at different stages of PD would help to validate some of these initial conclusions.

4.3. Basal ganglia contributions to social communication: the influence of modality

In our efforts to highlight issues that may promote greater consensus about face recognition abilities in future research on PD, it must be re-emphasized that our data furnish rather compelling indications that deficits in unfamiliar face processing are not a consistent and generalized feature of non-demented adults in the mild-moderate stages of the disease. Rather, our findings fit recent data and models favoring a more limited role for the basal ganglia in emotional face processing [4,5,7], one which initially may be preferentially involved in recognizing specific emotions such as disgust [21,56]. The complex neural circuitry activated by emotional faces is likely to include dominant contributions of visual cortical areas (occipital and posterior temporal regions), limbic structures (amygdala, anterior cingulate), and inferior prefrontal and somatosensory cortices which are greater in the right hemisphere (see [6,39,43,50] for recent data and relevant discussions). Nonetheless, the connectivity of many established structures involved in emotional face processing to basal ganglia (especially neostriatal zones) and the dependency of some of these functional regions on nigro-striatal dopamine call for continued vigilance to the direct or indirect links between basal ganglia (and basal ganglia disease) and face processing skills. Within the context of idiopathic PD, it is also potentially relevant that subtle atrophy of the amygdala is itself part of the pathogenesis of the disease [24,35], although functional repercussions of these alterations are not yet understood.

An important observation that can be drawn from the broader literature on emotional communication in PD is that these patients are frequently impaired in the recognition of emotion from speech prosody or the tone of a speaker's voice [13,16,17,47,51,58,64]. In fact, difficulties understanding emotional prosody in PD have emerged with far greater consistency across studies than for understanding emotional faces, and reports to date that have directly compared prosodic versus facial expression processing in PD imply that prosody is somewhat more susceptible to basal ganglia disease [13,14,54,cf,42,64]. In a companion report [55], we established that the 21 PD patients described here were significantly impaired on tasks of naming and rating the emotional significance of prosodic cues in speech, despite intact access to these meanings from static facial expressions or semantic-contextual cues of spoken utterances. As argued in detail in that report, the possibility that basal ganglia mechanisms are relatively more involved in

the processing of emotion from speech prosody, rather than from static facial expressions, is consistent with the recognized importance of the striatum in timing behavior and time-dependent perceptual processes (see [48] for a recent review). Striatal mechanisms involved in such tasks as interval encoding and forming representations of changing temporal contexts from sensory input [9,36–38] are also likely to provide a critical substrate for appreciating communicative stimuli that gain their meaning through an analysis of cue sequences encountered over extended temporal domains [46,55]. This process is central to how emotional prosody is processed and understood [44,52] and may also apply to how the social significance of certain dynamic, but not static, facial events are interpreted.

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