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Unaltered emotional experience in Parkinson's disease: Pupillometry and behavioral evidence

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ABSTRACT

Introduction: Recognizing emotions in others is a pivotal part of socioemotional functioning and plays a central role in social interactions. It has been shown that individuals suffering from Parkinson's disease (PD) are less accurate at identifying basic emotions such as fear, sadness, and happiness; however, previous studies have predominantly assessed emotion processing using unimodal stimuli (e.g., pictures) that do not reflect the complexity of real-world processing demands. Dynamic, naturalistic stimuli (e.g., movies) have been shown to elicit stronger subjective emotional experiences than unimodal stimuli and can facilitate emotion recognition.

Method: In this experiment, pupil measurements of PD patients and matched healthy controls (HC) were recorded while they watched short film clips. Participants' task was to identify the emotion elicited by each clip and rate the intensity of their emotional response. We explored (a) how PD affects subjective emotional experience in response to dynamic, ecologically valid film stimuli, and (b) whether there are PD-related changes in pupillary response, which may contribute to the differences in emotion processing reported in the literature.

Results: Behavioral results showed that identification of the felt emotion as well as perceived intensity varies by emotion, but no significant group effect was found. Pupil measurements revealed differences in dilation depending on the emotion evoked by the film clips (happy, tender, sadness, fear, and neutral) for both groups.

Conclusions: Our results suggest that differences in emotional response may be negligible when PD patients and healthy controls are presented with dynamic, ecologically valid emotional stimuli. Given the limited data available on pupil response in PD, this study provides new evidence to suggest that the PD-related deficits in emotion processing reported in the literature may not translate to real-world differences in physiological or subjective emotion processing in early-stage PD patients.

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Everyday social interactions involve inferring other people's emotional states through diverse facial, vocal, and gestural cues. The ability to extract meaning from subtle changes in emotional expression is vital for maintaining interpersonal connections (Gray & Tickle-Degnen, 2010), and the manner in which emotional cues are processed and appraised can dictate the *subjective* experience of emotion (Scherer, 2009). Thus, in order to understand real-world emotion processing, it is critical to explore the connection between perceptual and cognitive processes that facilitate emotion recognition and the resulting subjective emotional experience. Insight on this topic is particularly germane to understanding the real-world implications for

patients with conditions involving deficits in emotion recognition and social functioning, such as Parkinson's disease (for a recent review see Péron, Dondaine, Le Jeune, Grandjean, & Vérin, 2012).

Parkinson's disease (PD) is a common neurodegenerative condition clinically defined by its motor symptoms. However, PD patients additionally experience a host of nonmotor symptoms that include changes in sensory perception, cognitive processing, and emotion recognition (Bodden et al., 2010; Herrera, Cueto, & Rodríguez-Ferreiro, 2011). Given the current lack of evidence available on the relationship between the physiological and cognitive processes that give rise to PD patients' subjective emotional experience, PD-

induced socioemotional deficits are still poorly understood.

With few exceptions (e.g., Borod et al., 1990; Brozgold et al., 1998), the majority of what we know about socioemotional processing in PD has been drawn from investigations using emotion *recognition* tasks (e.g., Breitenstein, Van Lancker, Daum, & Waters, 2001; Dara, Monetta, & Pell, 2008; Pell, Cheang, & Leonard, 2006; Pell & Leonard, 2003). Recent work implies that emotion recognition in PD tends to improve when stimuli provide a rich set of multimodal cues that portray more naturalistic social settings (Pell et al., 2014), suggesting the need to experimentally employ ecologically valid, multimodal stimuli in order to accurately index real-world processing abilities in this clinical population.

In contrast to their impaired emotion recognition ability, the intensity with which PD patients report experiencing subjective emotion appears to be relatively preserved (Simons, Pasqualini, Reddy, & Wood, 2004; Smith, Smith, & Ellgring, 1996; Vicente et al., 2011). The literature on PD and emotion processing implies a potential disease-induced disconnect such that emotional experience appears to be generally preserved, while the ability to spontaneously express and recognize emotions from different types of stimuli is shown to be impaired (see Gray & Tickle-Degnen, 2010, for review). Recent evidence has shown that multimodal stimuli facilitate emotion recognition (Calvo, Avero, Fernández-Martín, & Recio, 2016; Pell et al., 2014), which could suggest that previous studies reporting PD-induced impairments in response to unimodal emotional stimuli may not accurately index PD patients' real-world emotion processing experience. In the present study, we explore the relationship between physiological reactions and subjective emotional experience to more clearly delineate the two processes.

To gather a more robust understanding of how PD affects emotional experience, it is valuable to supplement explicit self-report measures with online measures, such as pupillometry. Pupil responses are thought to reflect changes in arousal when processing emotionally relevant stimuli (Aboyoun & Dabbs, 1998; Bradley, Miccoli, Escrig, & Lang, 2008; Partala & Surakka, 2003). Recent data indicate that pupillary size is likely to increase when participants view either pleasant or unpleasant pictures relative to neutral ones (Bradley et al., 2008; Partala & Surakka, 2003). Laeng et al. (2013) provided evidence for emotion-specific changes in pupillary response when they observed participants' increased pupil dilation to fearful, as compared to happy, facial expressions. Collectively, these data suggest that pupil size can be used to measure a

participant's online evaluation of emotional stimuli, with larger responses expected for events that induce both positive and negative emotions (relative to neutral stimuli).

To date, only one study has investigated measurements of pupil size in response to emotional stimuli in the context of PD; Dietz, Bradley, Okun, and Bowers (2011) showed that pupil dilation was significantly greater when viewing emotional, as opposed to neutral, pictures for both PD patients and controls. The authors grouped stimuli according to valence, but did not distinguish between individual emotions. Furthermore, the relationship between subjective emotional appraisal and concomitant physiological (pupillary) response has yet to be fully explored. Given the extreme heterogeneity of PD (Foltynie, Brayne, & Barker, 2002) and the knowledge that different brain regions are activated depending on stimuli modality (Phan, Wager, Taylor, & Liberzon, 2002), the current study sought to explore physiological (pupillary) response patterns and subjective emotional experience when PD patients and healthy matched controls viewed emotional, dynamic film clips, to holistically appraise how emotion processing may be affected by PD.

The first stage of this project involved developing and validating a set of film stimuli that would reliably elicit target emotions in adults between the ages of 50 and 80 years, given evidence that older adults respond differently to emotional stimuli than young adults on both physiological and perceptual levels (Lima, Alves, Scott, & Castro, 2014; Montepare, Koff, Zaitchik, & Albert, 1999; Ruffman, Henry, Livingstone, & Phillips, 2008; Sullivan, Ruffman, & Hutton, 2007; Tsai, Levenson, & Carstensen, 2000). We predicted that adults with and without PD would display similarities in how they report subjective emotional experience (Simons et al., 2004; Smith et al., 1996; Vicente et al., 2011). On the basis of evidence from earlier studies using static stimuli, we predicted differences in sympathetic arousal when watching emotional versus neutral movie clips, but no impairment for the PD group (see Dietz et al., 2011). However, since Dietz and colleagues (2011) used static pictures and did not distinguish between different emotions, using dynamic stimuli could reveal differences between PD patients and controls not previously indexed.

Method

Participants

Seventeen patients with idiopathic Parkinson's disease (PD, eight male, nine female) and 22 age- and

education-matched healthy controls (HC, 12 male, 10 female) took part in the experiment. Participants were recruited in Montréal through a combination of existing databases, online advertisements, and fliers posted in movement disorder clinics at the McGill University Health Centre and Parkinson's disease support groups. Diagnosis of idiopathic PD in the "mild" to "moderate" severity range was confirmed by the patient's neurologist. The average number of years since Parkinson's diagnosis was 9.9 years ($SD = 6.2$).

The two groups did not significantly differ in age (PD: $M = 64.7$ years, $SD = 6.8$; HC: $M = 62.8$ years, $SD = 7.4$) or years of education (PD: $M = 16.8$ years, $SD = 2.6$; HC: $M = 16.9$ years, $SD = 1.6$). Two of the male HC participants were later excluded from the study due to not adhering to task instructions and having a history of neurological injury that was undisclosed preexperimentally. The remaining 20 controls had no history of neurological or psychiatric disorders (by self-report). Participants were native English speakers with normal or corrected-to-normal vision and adequate hearing ability as determined by an audiometric screening test administered prior to testing (minimum criteria of 35 dB in the better ear when exposed to frequencies of .5, 1, and 2 kHz). All participants were screened for dementia using the Dementia Rating Scale (Mattis, 1988); although neither group included individuals who performed at a level that would indicate the presence of dementia, the PD group had significantly lower scores ($M = 141.41$, $SD = 2.81$) on this measure than the HC group ($M = 143.25$, $SD = 1.06$) who performed near ceiling level overall, $F(1, 36) = 7.38$, $p < .05$. Each PD and HC participant completed a battery of background tests to index their perceptual, cognitive, and emotional functioning (please see Table 1 for background tests and group comparisons). No significant group differences were evident for any of the emotion processing, empathy, or depression measures (all $ps > .05$).

Materials

Stimulus construction/validation

Since previous film inventories for inducing emotion have all been validated on young adults (Carvalho, Leite, Galdo-Álvarez, & Gonçalves, 2012; Gross & Levenson, 1995; Schaefer, Nils, Sanchez, & Philippot, 2010), we developed a set of film stimuli that could reliably elicit target emotions in adults between the ages of 50 and 80 years. We focused on four emotions for an experimental design balanced in terms of valence (two negative, two positive). For the negative emotions, we selected sadness and fear because the

Table 1. Characteristics of patients with Parkinson's disease and healthy controls on standardized neuropsychological tests.

Test type	PD ($n = 17$)		HC ($n = 20$)		p
	M	SD	M	SD	
Digit Span (/9)	7.71	0.85	7.45	0.94	.40
Working Memory ^a (/42)	33.53	6.64	37.00	4.26	.06
Tower of London ^b (/10)	6.33	2.46	5.65	2.72	.59
Verbal Fluency-average	11.50	2.94	17.25	3.07	.03*
Benton Facial Recognition ^c (/54)	46.71	4.25	49.10	3.65	.07
Ekman Facial Emotion Recognition (/36) ^d	31.35	2.94	32.85	2.43	.10
Pell Prosody (/36) ^e	24.59	5.22	25.95	3.98	.38
Pell Semantics (/36) ^e	33.35	1.93	34.35	1.27	.07
Depression (GDS) ^f (/30)	7.53	4.81	5.85	4.78	.30
Empathy (IRI) ^g -Empathic Concern (/28)	22.00	4.97	22.00	3.37	>.99
Empathy (IRI) ^g -Perspective Taking (/28)	15.76	3.15	15.65	3.44	.92
Personality ^h -Extraversion (/7)	4.56	1.84	4.13	1.68	.46
Personality ^h -Agreeableness (/7)	5.59	1.08	5.13	0.93	.17
Personality ^h -Conscientiousness (/7)	5.65	1.17	5.45	1.11	.60
Personality ^h -Openness to Experiences (/7)	5.50	1.17	5.23	1.32	.51
Personality ^h -Emotional Stability (/7)	5.00	1.48	4.60	1.26	.38

Note. Scoring: For the Geriatric Depression Scale (GDS) a score of 10 or higher indicates depression; For each of the IRI empathy subscales, a higher score indicates higher empathy. PD = Parkinson's disease; HC = healthy controls.

^aTompkins, Bloise, Timko, and Baumgaertner (1994). ^bCulbertson and Zillmer (2001). ^cBenton, Sivan, Hamsher, Varney, and Spreen (1983).

^dEkman and Friesen (1976). ^ePell (2005). ^fSheikh and Yesavage (1986).

^gDavis (1980, 1983). ^hGosling, Rentfrow, and Swann (2003).

*Asterisk indicates significant differences between groups. All tests were two-tailed.

social function of these emotions is to elicit social support (Buss & Kiel, 2004; Marsh, Ambady, & Kleck, 2005), and we were interested in whether PD patients' processing of these stimuli may have real-world implications for prosocial interaction. For the positive emotions, we examined happiness and tenderness (the latter defined as the emotional surge accompanying caregiving love; see Kalawski, 2010).

Film stimuli were selected from a database of film clips that we constructed and validated in an audience of 10 healthy older adults ($M_{age} = 61.3$ years, $SD = 6.1$; five male, five female). Rating scales and procedures for the validation process were identical to those in the subsequent experiment (described below), with the exception of the order in which the films were viewed and the number of films included (24 in the validation experiment, 11 in the actual experiment; randomized in the validation experiment and blocked in the actual experiment). From this original candidate set of 24 film clips (please see Appendix for details), we selected 11 for use in the current study on the basis of each film clip's ability to: (a) reliably elicit the target emotion more strongly than all other emotions; and (b) elicit a target emotion of moderate to strong intensity (i.e., 4 or greater on a scale from 0–6). The 11 film clips,

Table 2. Description of film scenes serving as emotion elicitation stimuli.

Emotion	Film	Scene	Clip duration (min:s)	Mean target emotion hit rate in pilot test (%)	Mean intensity in pilot test (0–6)
Happy	<i>500 Days of Summer</i>	A man dances, cheered on by others	1:29	80	4.25
Happy	<i>Stepmom</i>	A mother and her children lip sync	1:11	70	4.6
Tender	<i>Forrest Gump</i>	A man learns he has a son	2:00	89	4.5
Tender	<i>Ghost</i>	A couple get cozy at the potter's wheel	1:44	50	4.6
Sad	<i>Marley and Me</i>	A sick dog is euthanized	2:01	90	5.13
Sad	<i>The Champ</i>	A boy grieves over the death of a boxer	2:05	80	5.3
Fear	<i>Copycat</i>	A police officer is attacked in a restroom	1:27	90	4.11
Fear	<i>Jurassic Park</i>	Children in a car are attacked by a dinosaur	1:41	90	4.11
Neutral	<i>Fly Away Home</i>	Men discuss how to build a plane	1:06	50	3.8
Neutral	<i>Dead Poets Society</i>	Boys are given assignments at the start of term	1:12	60	1.83
Neutral	<i>A Perfect World</i>	A woman meets her new colleagues	1:05	89	2.38

shown in Table 2, were controlled for their duration (between 1:05 min and 2:05 min). Two film clips represented each of the four emotion categories (happy, tender, sad, fear). Additionally, three film clips were validated as neutral in nature and served as buffers between emotional film clips. These 11 validated film clips served as the elicitation stimuli for gathering both the pupillary and behavioral measures in the current study.

Apparatus

Pupillary data were acquired using a remote eye-tracker (SMI iView X 2.5 RED system) that was attached to a panel below the computer screen. The eye-tracking system is a video-based pupil and corneal reflex system, recording data at 60 Hz. The screen resolution was set at 1600 × 900 pixels, and the average viewing distance between the screen and the participants was 631 mm. Physical stimulus dimensions were 344 mm horizontal and 200 mm vertical. Experiment Suite 360° (SMI) was used for presentation of stimuli (movie clips, instructions, questionnaire) as well as for the measurement of pupillary responses.

Procedure

Participants were randomly assigned to view the films in one of two different sequences. “List A” contained positive valence films (happy followed by tender) then negative valence films (fear followed by sad), whereas the order of valence blocks was reversed for “List B.” Emotions within each valence block were always shown in the same order. A neutral film was inserted on either side of each valence

block (see Figure 1). Films were blocked according to valence to minimize any potential emotional carry-over effects, as had been reported in another study involving emotional film clips (Tsai et al., 2000). Ten HC and nine PD participants were randomly assigned to List A, and 10 HC and eight PD participants viewed List B.

Participants were told that this was an experiment on emotion processing. Participants were seated in front of a computer screen containing a webcam with integrated microphone. Pupillometry and audiovisual data were gathered throughout the testing period. The examiner led the participant through the initial eye-gaze calibration, then took a seat slightly behind the participant so that her presence could be felt, but her face was not visible to the participant.

Participants were first led through a practice round to familiarize them with the task. Following each film, participants saw a screen, which read: “What was the *main* emotion you felt while watching this clip?” Responses were recorded by participants clicking a box corresponding to one of seven options: happy, tender, sad, fear, angry, disgust, neutral/no emotion. Next, a screen appeared with the question, “How intensely did you experience that emotion?” followed by a scale from 0 (not at all) to 6 (very much). At a third stage, a screen appeared reading: “Did you experience any other emotions while watching the last film clip?” Participants were able to select multiple emotions, again from the same list of seven options, during this secondary emotion stage. Finally, for the purposes of a companion study (Schwartz & Pell, 2016), a screen appeared after certain films in each block, which read, “While looking at the webcam, please explain, as if you’re speaking to someone who hasn’t seen the film: What was that last

		List A	List B		
POSITIVE	HAPPY	Practice: Harry Potter [+Interview]	Practice: Harry Potter [+ Interview]	NEGATIVE	FEAR
		Stepmom	Jurassic Park		
		500 Days of Summer	Copycat		
		Fly Away Home	Dead Poets Society [+Interview]		
		Ghost	Champ		
	TENDER	Forrest Gump [+Interview]	Marley & Me [+Interview]		SAD
		A Perfect World	A Perfect World		
		Jurassic Park	Stepmom		
		Copycat	500 Days of Summer		
		Dead Poets Society [+Interview]	Fly Away Home		
NEGATIVE	FEAR	Champ	Ghost		HAPPY
		Marley & Me [+Interview]	Forrest Gump [+Interview]		
	SAD				TENDER

Figure 1. The two orders of film stimuli presentation.

movie clip about and how did it make you feel? Press the space bar when you are done.”

Data analyses

Behavioral judgments

Self-reported accuracy and intensity ratings of the films were grouped according to their emotional category: neutral, happy, tender, sad, and fear. Accuracy of the emotion judgment was defined by whether a participant reported feeling the prevalidated target emotion elicited by each film. For intensity ratings (0–6), we initially ran two separate 2 (PD, HC) $\times$ 4 (happy, tender, sad, fear) repeated measures analyses of variance (ANOVAs): one that included all intensity ratings regardless of the accuracy of reported emotion, and one that only included intensity ratings from trials in which subjects reported experiencing the target emotion. As there was no difference in significant effects produced by the two analyses, our main analyses included intensity ratings of all items to increase power. Neutral was not included in intensity analyses because neutral films were specifically designed to *not* evoke emotion; thus, an intensity value for a film about which participants felt neutral would not be meaningful.

Pupillary data

The software package Begaze (Version 3.1, SMI, Berlin) was used for analysis of pupillary data. Pupil size (measured in pixels) and pupil dilation (in mm) were extracted in BeGaze. For the statistical analysis, pupil measurements for all fixations were included. In order to better focus analyses of pupil changes to film segments associated with high emotional intensity, we conducted a brief pilot study to track the perceived emotional intensity of time frame(s) within each stimulus. No pupillometry data were acquired during this study. Using a putative emotional slider paradigm, 10 new participants ($M_{\text{age}} = 26.1$, $SD = 3.6$) rated the felt emotional intensity on a scale from 1–10 while watching the video clips. The experiment was conducted using the Max Software (Max/MSP) on a laptop. Participants watched the movie clips in pseudorandomized order while listening via headphones. They were instructed to dynamically rate their felt emotional intensity to the film via the track pad. Following each clip, participants chose between seven emotional responses (angry, sad, fear, disgust, neutral, happy, and tender). The raw data were subsequently averaged across all participants, with a sample point for each 10 s (see Figure 2 for averaged intensity ratings by emotion). Visual

Figure 2. Emotional slider results by emotion.

inspection of the slider data revealed that all videos were most emotionally intense during approximately the last 30 seconds of the clip (except for neutral vignettes). As a result, we extracted data for the analysis of all pupillary responses from the last 30 s of each movie stimulus in order to index maximum affective responses.

Statistical analysis

All behavioral and pupil measures were analyzed in R (R Core Team, 2013) and lme4 (Bates, Maechler, Bolker, & Walker, 2014) by means of linear mixed effects (LME) models analysis. We applied the Satterthwaite (1946) approximation for computing p -values for t -statistics, as implemented in the lmerTest package Version 2.0–6 (Kuznetsova, Brockhoff, & Christensen, 2014). As fixed effects, we entered emotion and group (with and without interaction terms) into the model. The structure of random effects for analyzing accuracy and intensity consisted of intercepts for subjects and items, while the pupillometry analysis included intercepts for subjects, items (movies), as well as by-subject slopes for the effect of emotion. LME models were built for accuracy, intensity, pupil size, and pupil dilation. For all datasets, the general approach was the same: First, we defined a base model, which included only one random effect (subject). Refined models were then identified by performing model comparisons using the ANOVA function in R, and systematically

comparing the full model with the model reduced by random and fixed effects in turn. Models were compared based on χ^2 , Akaike information criterion (AIC; Bozdogan, 1987), beta estimates (b), explained variance (R^2), and p values.

Results

Behavioral (self-report) data

Table 3 shows the mean accuracy rates (defined as the proportion of trials in which the target emotion was reportedly felt by participants) and participants' reported intensity of emotion according to group status. For the purposes of ensuring that the films

Table 3. Mean accuracy and mean reported intensity according to emotion and group status.

Target emotion	Reported feeling	
	Hit rate	Mean intensity
PD group		
Happy	.88	4.75 (1.38)
Tender	.71	4.71 (1.16)
Sad	.88	5.23 (0.97)
Fear	.79	4.07 (1.57)
Neutral	.73	n/a
HC group		
Happy	.88	4.77 (0.81)
Tender	.78	4.61 (0.99)
Sad	.90	5.00 (1.08)
Fear	.80	4.34 (1.36)
Neutral	.68	n/a

Note. PD = Parkinson's disease; HC = healthy controls. Mean accuracy displayed as a hit rate, out of 1. Mean reported intensity on a scale of 0–6. Standard deviations in parentheses.

Table 4. Confusion matrices showing the hit rate for target emotion responses and actual reported responses.

Reported feeling	Target emotion						
	Happy	Tender	Sad	Fear	Neutral	Anger	Disgust
PD group							
Happy	.85	.06			.06		.03
Tender	.17	.71	.06		.03		.03
Sad		.06	.88				.06
Fear		.03		.79	.12		.06
Neutral	.12	.04	.02	.04	.73	.06	
HC group							
Happy	.88	.02			.10		
Tender	.10	.78	.07		.05		
Sad		.05	.90			.02	.03
Fear	.05		.05	.80	.10		
Neutral	.05	.17	.02	.03	.68	.03	.02

Note. PD = Parkinson's disease; HC = healthy controls. Due to different numbers of participants per group, all PD hit rates are out of 34 (17 participants with two films per emotion category), except neutral, which is out of 51 (due to three neutral films). All HC hit rates are out of 40 (20 participants with two films per emotion category), except neutral, which is out of 60. Cells in **bold** display accuracy hit rate (i.e., when subjects reported feeling the target emotion more strongly than any other emotion).

were eliciting the target emotions as intended, we additionally analyzed the patterns of nontarget responses using a confusion matrix (see Table 4). Inspection of these data suggests that emotional films designed to elicit happiness and sadness were most successful in evoking these target emotions in both groups (based on highest hit rates), whereas films associated with neutral affect or tenderness had lower accuracy rates for both groups. Nonetheless, it can be seen that accuracy rates for all target emotions were high across both groups, exceeding five times chance performance (14.3%), suggesting that all emotions of interest were elicited successfully by the stimuli.

Results of the LME analysis did yield a marginally significant effect of emotion on accuracy of the reported emotions: $\chi^2 = 7.97$, $p < .1$, $b = 1.4$, $R^2(\text{emotion}) = .04$. In particular, a model including emotion as a fixed effect revealed a difference between the more complex (AIC = 364.8) compared to a simple model (AIC = 364.7). Post hoc

comparisons show higher accuracy rates for sad ($M = .87$, $SD = .34$) and happy ($M = .85$, $SD = .36$) videos than for neutral videos ($M = .67$, $SD = .47$). However, including group as a fixed effect did not significantly improve the model, $p > .9$, $b = -0.007$, $R^2(\text{group}) = .0001$, when compared to the simple model. Regarding felt intensity, adding emotion to the simple model significantly improved the model fit: $\chi^2 = 10.98$, $p < .05$; AIC simple model = 890.09; AIC emotion model = 885.11, $b = 3.5$, $R^2(\text{emotion}) = .1$. Further contrasts show that fearful movies ($M = 3.55$, $SD = 1.83$) were perceived as less intense than tender ($M = 4.66$, $SD = 1.19$) and sad movies ($M = 4.90$, $SD = 1.17$). Again, including group as a fixed effect did not significantly improve the model: $p > .8$, $b = 0.05$, $R^2(\text{group}) = .0003$.

Pupillometry data

Pupillometry data from 15 PD patients and 16 healthy controls were used for the analysis; the remaining two PD and four HC participants' data had to be excluded because pupil tracking failed in more than 25% of all trials.¹ The model comparison for pupil size revealed no significant main effects or interactions. For pupil dilation, the LME analysis (random effects: subject, stimuli) revealed significant results including emotion as a fixed effect: $\chi^2 = 11.17$, $p < .05$; AIC simple model = 21,379; AIC emotion model = 21,376, $b = 4.75$, $R^2(\text{group}) = .007$. Post hoc comparisons indicated that fearful film clips ($M = 4.8$, $SD = 0.78$) and sad film clips ($M = 4.89$, $SD = 0.77$) led to significantly larger pupil dilations overall than neutral clips ($M = 4.4$, $SD = 0.71$). Additionally, we found a significant difference between pupil dilations in response to sad versus happy movie clips ($M = 4.5$, $SD = 0.63$). These patterns were not influenced by the disease status of our two groups: $p > .9$, $b = 0.2$, R^2

Table 5. Pupillometry results for each parameter by group.

	Fear		Happy		Neutral		Sad		Tender	
	M	SD	M	SD	M	SD	M	SD	M	SD
Pupil size (pixels)										
HC ($n = 16$)	17.95	3.19	17.76	2.87	17.12	2.97	18.24	4.83	17.20	4.16
PD ($n = 15$)	17.49	2.97	15.90	2.93	15.93	3.37	17.27	3.20	16.39	3.02
Pupil dilation (mm)										
HC	4.62	0.71	4.53	0.58	4.34	0.64	4.84	0.71	4.56	0.64
PD	4.95	0.80	4.47	0.68	4.47	0.77	4.95	0.83	4.68	0.78

Note. PD = Parkinson's disease; HC = healthy controls.

Figure 3. Changes in pupil diameter over time for controls.

Figure 4. Changes in pupil diameter over time for Parkinson's disease (PD) patients.

(group) = .08. Please see Table 5 as well as Figures 3 and 4.

Discussion

To clarify how PD affects subjective and physiological measures of emotional experience, we used novel film clips that elicited happy, tender, fearful, and sad emotion in 17 PD and 20 age- and education-matched control participants. Results showed that happy and sad video clips were identified more accurately than neutral clips, while tender and sad clips were rated as more intense than fearful clips. However, we found no significant group differences in participants' report of which emotion was evoked by the films (i.e., the

"Accuracy" measure), nor did we find group differences in participants' reports of how intensely they experienced each of the four emotions of interest. Our results are consistent with the findings of previous studies that had used video clips to elicit emotion in PD patients, all of whom reported that PD patients' subjective emotional experience did not significantly differ from that of healthy controls (Simons et al., 2004; Smith et al., 1996; Vicente et al., 2011).

To better understand how Parkinson's disease affects the *online* processing of emotional stimuli, and to explore the relationship between physiological response and cognitive appraisal of emotional experience, we gathered new information on sympathetic arousal patterns (pupil size, pupil dilation) in PD and

HC participants in response to emotional film stimuli. The pupil measures revealed a larger pupillary response when viewing emotional than when viewing neutral stimuli, in line with findings from earlier studies (e.g., Bradley et al., 2008; Libby, Lacey, & Lacey, 1973; Partala, Jokiniemi, & Surakka, 2000). The largest pupil dilations were observed for fearful and sad movie clips relative to happy and tender items, extending similar findings (e.g., Laeng et al., 2013) to situations involving dynamic audiovisual stimuli. However, the fact that we observed no group differences in pupil measures implies that physiological responses associated with processing emotional events are largely intact in the early stages of Parkinson's disease, in keeping with a previous study that had used unimodal emotional stimuli (Dietz et al., 2011). Future studies that probe the relationship between physiological reactions and subjective emotional experience in PD using neuroinvestigative techniques are needed.

One limitation of the current study is the inability to fully control the brightness and contrast between video clips, which are known to have a large impact on pupil diameter (e.g., Barbur, 2004). Thus, it is possible that some of the differences found between emotions are due to differences in these parameters. However, the patterns in the data suggest that the emotion manipulation did effect changes in pupil dilation to some extent; evidence for this can be seen in the concurrent, parallel pattern of emotional intensity ratings rising in line with increased pupil dilation. Additionally, average pupil dilation in response to neutral clips is lowest when compared to emotional clips, whereas fear clips led to the largest pupil dilations. This pattern of results is in accordance with the literature, showing that negative emotions led to prominent pupil size changes when compared to neutral stimuli (see Kinner et al., 2017).

One potential explanation for why we did not find pronounced differences between PD patients and controls in pupillary response is that our patients were cognitively high functioning with relatively mild motor impairment. The decision to explore emotion processing using dynamic, multimodal movie clips may also have diminished group differences observed in previous unimodal emotion processing tasks by providing PD patients with a richer context within which to interpret the emotional content. Indeed, it has been suggested that PD patients may compensate for deficits in certain modalities when presented with a richer set of cues (Paulmann & Pell, 2010; Pell et al., 2014). In their review on emotion perception, Barrett, Mesquita, and Gendron (2011) summarize recent evidence demonstrating that efficient emotion perception is indeed influenced by the context in which affective stimuli appear. Thus, having an unfolding multimodal context may lead to enhanced emotion processing in PD patients.

Finally, it is possible that the absence of group differences may be due to insufficient power. While our patient sample is reasonably large compared to those in previous studies, it is possible that the sample size was too small and heterogeneity too large to detect differences between PD patients and controls. Future studies employing larger sample sizes are needed.

Availability of film stimuli

All film clips used in this study are freely available for use in other studies. Please consult the Pell Lab webpage (https://mcgill.ca/pell_lab/neuropragmatics-and-emotion-lab-pell-lab) to obtain a copy of the film clips. Of the 24 films, three (the clip from *Marley and Me*, the Tender scene from *Dead Poets Society*, and the execution scene from *The Green Mile*) were altered from the original film version by editing out segments not central to the emotional state, and adding transitions in order to reduce the total duration of the clip to fall within our database's uniform time range.

Note

1. An LME model rerun on the accuracy and intensity ratings, restricted to the subgroup of participants for the pupillometry analysis, confirmed that there were no significant group differences or emotion effects for either measure.

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Appendix

Please see Tables A1–A5 for a comprehensive description of 10 healthy older adult (5 male, 5 female; $M_{\text{age}} = 61.3$ years, $SD = 6.1$) pilot participants' emotional responses to the 24 happy, tender, sad, fear, and neutral film clips. With the exception of neutral films, which were designed to not elicit emotion, all films evoked an emotional intensity of 3.25 or greater on a 0–6 scale. Accuracy rates differed according to

emotional category, with tender films garnering the lowest hit rates. Hit rates were calculated as the number of target responses out of the total number of responses for that film item, resulting in the percentage of accurate responses. When participants reported experiencing multiple emotions, the secondary emotion fell primarily within the same valence category for happy, tender, and fear films, while sad films were more likely to evoke tenderness as the secondary emotion.

Table A1. Mean recognition accuracy and emotional intensity ratings of film clips assessed for suitability in eliciting happiness in older adults.

Happy clip Film name (min:s) Scene	Intensity rating of target emotion (0–6 scale)	Hit rate ^a (%)	Confused main emotion with (%)	Those reporting target emotion also felt (%)	Proportion of viewers who had seen film before ^b (%)
500 Days of Summer (1:29) A man dances, cheered on by others	4.25	80	Neutral (20)	Tender (13)	0
Stepmom (1:11) A mother and her children lip sync	4.6	70	Neutral (20) Anger (10)	Tender (43)	20
Stepmom (2:10) A girl makes a boy she likes jealous	3.4	80	Neutral (20)	Tender (25) Anger (25)	30
Free Willy (0:42) A whale jumps to freedom	3.33	60	Tender (20) Neutral (10) Disgust (10)	Tender (33)	20
Forrest Gump (0:55) A boy wearing leg braces learns he can run	4.25	80	Neutral (20)	Tender (50)	80
Harry Potter Order of the Phoenix (1:00) Harry teaches students to cast a spell	3.7	70	Neutral (30)	Tender (14)	10

Note. Films in **bold** were selected for inclusion in our database.

^aThe hit rate is the percentage of subjects who indicated that they felt the target emotion more intensely than any of the other nontarget emotions.

^bReports of whether the participants had seen the movie before were not always consistent between different scenes from the same movie, as some scenes were more recognizable than others.

Table A2. Mean recognition accuracy and emotional intensity ratings of film clips assessed for suitability in eliciting tenderness in older adults.

Tender clip Film name (min:s) Scene	Intensity rating of target emotion (0–6 scale)	Hit rate ^a (%)	Confused main emotion with (%)	Those reporting target emotion also felt (%)	Proportion of viewers who had seen film before ^b (%)
Forrest Gump (2:00) A man learns he has a son	4.5	89	Happy (11)	Happy (25) Sad (13)	80
Ghost (1:44) A couple get cozy at the potter's wheel	4.6	50	Happy (30) Disgust (20)	Happy (20) Sad (20)	50
As Good As It Gets (1:29) A woman receives the best compliment of her life	4.67	30	Happy (70)	None	50
Dead Poets Society (1:40) Students take a stand to support their teacher	4.33	30	Happy (30) Sad (20) Neutral (20)	Happy (33) Sad (67)	50

Note. Films in **bold** were selected for inclusion in our database.

^aThe hit rate is the percentage of subjects who indicated that they felt the target emotion more intensely than any of the other nontarget emotions.

^bReports of whether the participants had seen the movie before were not always consistent between different scenes from the same movie, as some scenes were more recognizable than others.

Table A3. Mean recognition accuracy and emotional intensity ratings of film clips assessed for suitability in eliciting sadness in older adults.

<i>Sad clip</i> <i>Film name (min:s)</i> Scene	Intensity rating of target emotion (0–6 scale)	Hit rate ^a (%)	Confused main emotion with (%)	Those reporting target emotion also felt (%)	Proportion of viewers who had seen film before (%)
Marley and Me (2:01) A sick dog is euthanized	5.13	90	Anger (10)	Tender (44) Disgust (22)	20
The Champ (2:05) A boy grieves over the death of a boxer	5.3	80	Anger (10) Disgust (10)	Tender (50) Anger (13)	30
<i>The Green Mile (1:00)</i> A prisoner explains how hard his life has been	5	80	Tender (10) Neutral (10)	Tender (50) Anger (13) Disgust (13)	50
<i>The Green Mile (1:42)</i> A prisoner is executed	5.33	60	Disgust (20) Fear (10) Anger (10)	Anger (33) Disgust (33) Tender (17)	50
<i>Dangerous Minds (2:05)</i> A teacher tells her class that a student was killed	3.75	80	Disgust (10) Neutral (10)	Anger (25) Fear (13) Tender (13) Disgust (13)	20
<i>My Girl (1:22)</i> A girl attends the funeral of her best friend	4.6	90	Fear (10)	Tender (67) Disgust (11)	30

Note. Films in **bold** were selected for inclusion in our database.

^aThe hit rate is the percentage of subjects who indicated that they felt the target emotion more intensely than any of the other nontarget emotions.

Table A4. Mean recognition accuracy and emotional intensity ratings of film clips assessed for suitability in eliciting fear in older adults.

<i>Fear clip</i> <i>Film name (min:s)</i> Scene	Intensity rating of target emotion (0–6 scale)	Hit rate ^a (%)	Confused main emotion with (%)	Those reporting target emotion also felt (%)	Proportion of viewers who had seen film before (%)
Copycat (1:27) Police officer is attacked in a restroom	4.11	90	Neutral (10)	Disgust (33) Anger (11)	20
Jurassic Park (1:41) Children in a car are attacked by a dinosaur	4.11	90	Neutral (10)	Anger (22)	50
<i>The Sixth Sense (0:58)</i> A boy is scared by a ghost under the bed	3.25	80	Neutral (20)	Happy (13)	40
<i>The Shining (1:29)</i> A deranged man breaks into a bathroom where his family is hiding from him	5.5	40	Disgust (20) Neutral (20) Sad (10) Happy (10)	None	50

Note. Films in **bold** were selected for inclusion in our database.

^aThe hit rate is the percentage of subjects who indicated that they felt the target emotion more intensely than any of the other nontarget emotions.

Table A5. Mean recognition accuracy and emotional intensity ratings of film clips assessed for suitability in eliciting a neutral affect in older adults.

<i>Neutral clip</i> <i>Film name (min:s)</i> Scene	Intensity rating of target emotion (0–6 scale)	Hit rate ^a (%)	Confused main emotion with (%)	Those reporting target emotion also felt (%)	Proportion of viewers who had seen film before ^b (%)
Fly Away Home (1:06) Men discuss how to build a plane	3.8	50	Happy (30) Disgust (10) Anger (10)	None	10
Dead Poets Society (1:12) Boys are given assignments at the start of term	1.83	60	Anger (10) Disgust (10) Tender (10) Happy (10)	None	20
A Perfect World (1:05) A woman meets her new colleagues	2.38	89	Disgust (10)	None	0
<i>Stranger Than Fiction (0:50)</i> A man keeps to his schedule using his wristwatch	1.83	60	Happy (40)	Happy (17)	0

Note. Films in **bold** were selected for inclusion in our database.

^aThe hit rate is the percentage of subjects who indicated that they felt the target emotion more intensely than any of the other nontarget emotions.

^bReports of whether the participants had seen the movie before were not always consistent between different scenes from the same movie, as some scenes were more recognizable than others.

Film Selection

After gathering intensity and accuracy data on the 24 films, we selected two films per emotion category (plus three films from the neutral category) to serve as emotion elicitation stimuli for the present study. These 11 films were chosen by a combination of the following criteria: having the highest hit rate per emotion category (and not being confused with any of the other target emotions more than 30% of the time);

eliciting an intensity rating greater than 4 on a scale of 0–6 (with the exception of neutral affect items, which were specifically designed to *not* evoke intense emotion); and evoking the purest emotion (i.e., having as few participants as possible rate that they “also experienced” other emotions in addition to the target). The three neutral clips were selected based on their low confusion rates—that is, participants did not report experiencing any specific emotion greater than 30% of the time.