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Effects of Emotional Facial Expression on Time Perception in Patients with Parkinson's Disease

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Abstract

Objectives: Previous studies have demonstrated that emotional facial expressions alter temporal judgments. Moreover, while some studies conducted with Parkinson's disease (PD) patients suggest dysfunction in the recognition of emotional facial expression, others have shown a dysfunction in time perception. In the present study, we investigate the magnitude of temporal distortions caused by the presentation of emotional facial expressions (anger, shame, and neutral) in PD patients and controls. **Methods:** Twenty-five older adults with PD and 17 healthy older adults took part in the present study. PD patients were divided into two sub-groups, with and without mild cognitive impairment (MCI), based on their neuropsychological performance. Participants were tested with a time bisection task with standard intervals lasting 400 ms and 1600 ms. **Results:** The effect of facial emotional stimuli on time perception was evident in all participants, yet the effect was greater for PD-MCI patients. Furthermore, PD-MCI patients were more likely to underestimate long and overestimate short temporal intervals than PD-non-MCI patients and controls. **Conclusions:** Temporal impairment in PD-MCI patients seem to be mainly caused by a memory dysfunction. (*JINS*, 2016, *22*, 890–899)

Keywords: Time perception, Parkinson's disease, Mild cognitive impairment, Time bisection task, Facial expression, Emotion

INTRODUCTION

Adequate temporal abilities are essential to perform most of our everyday activities. Temporal judgments are based on three processing stages: clock, memory, and decision (Gibbon, 1977; Treisman, 1963). The clock stage is composed of a pacemaker that emits pulses that are stored in an accumulator (for a review, see Grondin, 2010). The memory stage is conceptualized as the storing system that accumulates pulses in working memory for comparison with content in reference memory (i.e., the long-term memory representation of pulses accumulated across prior temporal experience). The final stage is the decision stage, in which the current duration is compared with those stored in reference memory. Many studies on time estimation have focused on properties of the pacemaker. Variations in arousal level are known to affect the rate of the pulses' emission: an increased level of arousal increases the speed of the pacemaker. For a given duration period, if the pacemaker runs faster, more pulses reach the accumulator, and this duration is judged to be longer (Droit-Volet, Brunot, & Niedenthal, 2004; Effron, Niedenthal, Gil, & Droit-Volet, 2006).

Variations in an individual's arousal level, and consequently on the rate of the internal clock and perceived duration, can be influenced by the presentation of emotional stimuli. Several studies, conducted on healthy participants, showed that emotional pictures generating high arousal lead to greater overestimation of time, compared to emotional pictures generating less arousal (Angrilli, Cherubini, Pavese, & Manfredini, 1997; Droit-Volet et al., 2004; Droit-Volet & Gil, 2009; Gil & Droit-Volet, 2011; Lee, Seelam, & O'Brien, 2011; Noulhiane, Mella, Samson, Ragot, & Pouthas, 2007; Tipples, 2008). In particular, facial expressions of anger, fear, happiness, and sadness lead to an overestimation of time (Droit-Volet et al., 2004; Effron et al., 2006; Gil & Droit-Volet, 2011; Lee et al., 2011; Tipples, 2008), but facial expressions of shame lead to an underestimation of time (Droit-Volet & Meck, 2007; Droit-Volet & Gil, 2009). The effect of disgust on time perception is more mixed. In some cases, viewing facial expressions of disgust do not provoke time distortions (Gil & Droit-Volet, 2011); however, viewing a disgusting image (e.g., body mutilations) results in longer

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perceived duration (Angrilli et al., 1997; Grondin, Laflamme, & Gontier, 2014) and viewing disgusting food pictures results in shorter perceived duration (Gil, Rousset, & Droit-Volet, 2009).

Parkinson's disease (PD) is a movement disorder characterized by bradykinesia, tremor, rigidity and postural instability. Disease symptoms occur as a result of selective, progressive, and chronic degeneration of the nigrostriatal and mesocortico-limbic dopamine systems (Jankovic & Tolosa, 2007). It offers an opportunity to study the possible influence of these dopaminergic pathways on emotional processing (Gray & Tickle-Degnen, 2010; Péron, Dondaine, LeJeune, Grandjean, & Vérin, 2012). In fact, it is generally assumed that abnormalities in the recognition of facial emotions in PD patients are caused by dysfunction of fronto-subcortical systems (including dopaminergic neurons) involved in facial emotion recognition (Blonder & Slevin, 2011; Dujardin et al., 2004; Gray & Tickle-Degnen, 2010; Lawrence, Goerendt, & Brooks, 2007; Péron et al., 2012; Sotgiu & Rusconi, 2013; Sprengelmeyer et al., 2003).

While studies conducted with PD patients generally show dysfunction in emotional facial expression recognition (Assogna, Pontieri, Caltagirone, & Spalletta, 2008; Clark, Neargarder, & Cronin-Golomb, 2008; Dujardin et al., 2004; Lawrence et al., 2007; Péron et al., 2010; Sprengelmeyer et al., 2003), there is partial discordance about the type of emotions affected by this dysfunction. Sprengelmeyer et al. (2003) tested medicated and un-medicated PD patients. Relative to controls, both PD patient groups showed impairment in facial expression recognition, but un-medicated PD patients were consistently worse in recognition of disgust than medicated PD patients and controls. Similarly, previous findings revealed significant impairment in recognition of facial expression of fear (Kan, Kawamura, Hasegawa, Mochizuki, & Nakamura, 2002), disgust (Dujardin et al., 2004; Kan et al., 2002), anger (Dujardin et al., 2004), and sadness (Dujardin et al., 2004) in PD patients. In addition, results from work by Lawrence et al. (2007) indicated that recognition of anger was impaired in PD patients who had been temporarily removed from dopamine replacement therapy.

Dysfunctions in dopamine transmission have also been identified as the main cause of temporal impairment in PD patients (Harrington, Zimbelman, Hinton, & Rao, 2010; Harrington et al., 2011; Meck, 2005; Meck & Benson, 2002). Evidence suggests that PD patients show dysfunctions in time perception when using finger tapping tasks (Artieda, Pastor, Lacruz, & Obeso, 1992; O'Boyle, Freeman, & Cody, 1996; Pastor, Jahanshahi, Artieda, & Obeso, 1992), as well as tasks involving time reproduction, time production, and time estimation (Lange, Tucha, Steup, Gsell, & Naumann, 1995; Pastor, Artieda, Jahanshahi, & Obeso, 1992; Perbal et al., 2005). For duration discrimination, one study (Harrington, Haaland, & Knight, 1998) revealed lower discrimination level in PD patients, while another study (Ivry & Keele, 1989) failed to find differences between PD patients and controls when using the same task. Smith, Harper, Gittings, and Abernethy (2007) found that PD patients were less sensitive to duration differences than controls with a time bisection task in conditions involving either auditory or visual signals for marking time. It is possible that some of the contradictory findings reported in the literature on timing and time perception with PD patients might be explained by the motor responses required in some timing tasks (Jones, Malone, Dirnberger, Edwards, & Jahanshahi, 2008; see also Mioni, Stablum, McClintock, & Grondin, 2014).

The current project plans to investigate if the same temporal distortion produced by emotional stimuli observed in healthy controls, is present in PD patients. This can have important implications from an experimental and clinical prospective. In fact, we can better understand temporal and emotional processing in PD patients and further investigate the effect of emotional stimuli on time perception. Moreover, we can better plan rehabilitation programs on those emotions that are scarcely recognized by PD patients. If PD patients present a dysfunction in recognizing emotional stimuli, we should not expect any distortion in time perception. On the other hand, if emotional stimuli are correctly identified by PD patients, we should observe a variation in temporal judgment similar to that observed in healthy controls.

CURRENT INVESTIGATION

Taken together, previous studies showed that temporal processes can be modulated by the presentation of stimuli with emotional content (Gil & Droit-Volet, 2011). Moreover, previous studies showed emotional recognition dysfunction (Gray & Tickle-Degnen, 2010; Péron et al., 2012) as well as temporal dysfunctions in PD patients (O'Boyle et al., 1996; Harrington et al., 1998; Perbal et al., 2005). In the present study, we investigate the effect of emotional stimuli on time perception. This is the first study addressing this issue in PD patients.

We have three main aims in the present study. The first aim is to investigate time perception in PD patients. In particular, we investigate if differences in temporal judgments in PD patients relative to healthy controls are related to level of cognitive function in PD patients. Previous studies conducted with children (Zélanti & Droit-Volet, 2011), healthy adults (Perbal, Droit-Volet, Isingrini, & Pouthas, 2002), and severe traumatic brain injury patients (Mioni, Mattalia, & Stablum, 2013) have already pointed out the importance of adequate high cognitive functions in time perception. Cognitive impairments or dementia symptoms are often associated with PD (Litvan et al., 2012). Consequently, it is of great interest to assess cognitive functions as a possible mediator of lower temporal abilities in PD patients. To this end, we divided PD patients in two sub-groups according to criteria specified by Litvan et al. (2012; see the Method section). We predict that PD patients with a diagnosis of mild cognitive impairment (MCI) would be less accurate and more variable in their temporal judgments than PD without MCI and controls due to their reduced cognitive abilities.

The second aim of the present study is to investigate the effect of emotional facial expression on time perception. According to previous studies, facial emotional stimuli influence time perception and the direction of temporal distortion depends on the type of emotional stimulus presented (Gil & Droit-Volet, 2011, 2012; Lee et al., 2011; Mella, Conty, & Pouthas, 2011; Tipples, 2008). We included anger and shame as emotional stimuli, given that they have generated different effects on time perception (Gil & Droit-Volet, 2011). In particular, we predicted an overestimation of temporal intervals when the stimulus marking time represents anger and an underestimation of temporal intervals when the stimulus represents shame.

Finally, the third aim of the present investigation is to combine the previous two aims and further investigate if the magnitude of temporal distortions caused by the presentation of the facial expression of emotions would be the same for PD patients (with or without MCI) and controls.

METHOD

Participants

Twenty-five older adults with PD (11 males, 14 females) and 17 healthy older adults (9 males, 8 females) took part in the present study. PD participants were recruited from a major hospital in Ospedale S. Bortolo, Vicenza, Italy. All PD participants had been diagnosed with idiopathic PD by a movement disorders neurologist, and evaluated with the "Unified Parkinson's disease Rating Scale" (UPDRS; Fahn et al., 1987), which indicates the progression of PD. Controls or non-PD participants were volunteers from the local community (Vicenza and Bari of Italy; Table 1). Controls were matched to PD participants on the basis of age and education (±2 years respect to PD sample).

Exclusionary criteria included possible dementia or severe cognitive impairment, treatment with anticholinergic medications, treatment with certain dopaminergic or benzodiazepine medications known to interfere with cognitive functioning, history of neurosurgery or other neurological conditions (aside from PD for PD participants), significant history or current psychiatric disorders, or any condition (e.g., depression) which would interfere with testing.

Possible cognitive impairment was detected with the following tasks. The *Mini-Mental State Examination* (MMSE; Folstein, Folstein, & McHugh, 1975) was used to evaluate global cognitive functioning. The total possible score is 30 points; a score of 24 or above is considered within the normal range. The *Montreal Cognitive Assessment* (MoCA, Nasreddine et al., 2005) was used to screen for mild cognitive and executive dysfunctions. The total possible score is 30 points; a score of 26 or above is considered within the normal range. The *Frontal Assessment Battery* (FAB, Appollonio et al., 2005) was administrated to evaluate frontal lobe functions; higher scores indicate better performance, maximum score is 18. The *Beck Depression Inventory* is a self-report questionnaire (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) used to evaluate the level of depression in PD patients and controls.

Importantly, we divided the PD groups in two sub-groups based on the scores at neuropsychological tasks (see the *Neuropsychological assessment* section for the details of the tasks included). Litvan et al. (2012) defined five cognitive domains (Attention and working memory; Executive functions; Language; Memory, and Visuo-spatial function) and proposed a list of tasks for each domain. According to Litvan's criteria, patients with a diagnosis of PD that failed at least two tasks (below two standard deviations) in the same domain or in different domains were defined as PD-MCI in the current study. PD-non-MCI patients were PD patients that did not meet criteria to be considered as a PD-MCI patient.

The three groups (PD-MCI, PD-non-MCI, and controls) did not differ with respect to age, education, MMSE, and BDI (all p's > .05). PD-MCI patients had lower scores on the FAB [$F(2,42) = 4.20$; $p = .022$; $\eta^2_p = .177$] and MOCA [$F(2,42) = 7.92$; $p = .001$; $\eta^2_p = .289$], compared to PD-non-MCI patients and controls. No differences were observed between PD-non-MCI and controls on these tests (Table 1).

Table 1. Demographic and clinical characteristics of PD patients and controls.

	PD-MCI $n = 15$	PD-non-MCI $n = 10$	Control group $n = 17$
	M (*SD*)	*M* (*SD*)	*M* (*SD*)
Age	72.60 (5.3)	67.90 (7.1)	68.35 (7.5)
Education	7.80 (3.7)	10.50 (4.7)	9.00 (3.5)
UPDRS	15.25 (6.1)	9.78 (6.9)	–
MMSE	28.33 (1.0)	28.70 (1.8)	28.53 (1.2)
MOCA	21.33 (3.3)	24.00 (2.6)	27.20 (3.4)
FAB	15.13 (1.8)	16.70 (1.6)	16.53 (1.3)
BDI	8.53 (7.2)	4.50 (3.5)	6.31 (5.3)

Note: UPDRS = Unified Parkinson's disease Rating Scale; MMSE = Mini Mental State Examination; MOCA = Montreal Cognitive Assessment; FAB = Frontal Assessment Battery; BDI = Beck Depression Inventory.

Procedure

PD patients were tested at the hospital S. Bortolo, Vicenza, Italy, whereas controls were tested in their own home. During the tasks, participants were seated at a distance of approximately 60 cm in front of a 15-inch PC monitor screen. E-Prime®2.0 was used to program and run the experiment. PD patients were tested during one experimental session that lasted approximately 50 min. Neuropsychological information of PD patients were collected from clinical records, whereas controls were tested in one experimental session lasting approximately 90 min for completion of the time bisection task and neuropsychological assessment. Informed consent was collected from all participants and the study was conducted in accordance with Helsinki Declaration (59th WMA General Assembly, Seoul, 2008).

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Time Bisection Task

The experimental session started with the learning phase in which participants were required to memorize two standard durations: 400 ms (short standard) and 1600 ms (long standard). Both standard durations were presented 10 times. During the learning phase, the stimulus used for marking time was a gray oval with a size similar to that of the target stimuli. After the training phase, participants were required to perform four blocks with pictures of female facial expressions (Figure 1a) and four blocks with pictures of male facial expressions (Figure 1b). Within each block, 12 pictures of females or males were randomly presented for each of the comparison durations (400, 600, 800, 1000, 1200, 1400, 1600 ms), for a total of 84 stimuli. Stimuli represented the facial expression of anger or shame, or a neutral expression. After the presentation of the comparison durations, participants were required to press the key labeled "B" ("B" refers to the Italian word "Breve" = short) if the duration presented was closer to the short standard, or to press the key labelled with "L" ("L" refers to the Italian word "Lungo" = long) if the duration presented was closer to the long standard. The participants were asked to respond with their left and right index fingers and response keys were counterbalanced between participants. After the response, there was a 1000-ms inter-trial interval.

Neuropsychological Assessment

Neuropsychological tasks were included to investigate cognitive abilities in PD patients and controls. Moreover, performances on the following tasks were used to divide the PD sample into two sub-groups (PD-MCI and PD-non-MCI), according to criteria outlined by Litvan et al. (2012).

Attention and working memory

The *Trial Making Test* (TMT; Reitan, 1958; Italian normative data in Giovagnoli, Del Pesce, Simoncelli, Laiacona & Capitani, 1996) is composed of two parts (TMT Parts A and B). In Part A, participants are required to connect a series of 25 numbers in numerical order. In Part B, the subject connects 25 encircled numbers and letters in numerical and alphabetical order, alternating between numbers and letters.

Fig. 1. Example of the emotional facial expressions used for female (a) and male (b).

Part A is generally presumed to be a test of visual search and motor speed skills; whereas Part B is considered also to be a test of higher level cognitive skills such as mental flexibility. Performance is evaluated in time (seconds) to execute the task. In the present study, we use the time to execute Part A and Part B, as well as the difference (in seconds) between Parts B and A.

Executive functions

The *Semantic Fluency* task (Novelli et al., 1986) requires generating words belonging from a category: fruit, cities, color, and animals. Each of the four trials lasts 60 s. The semantic fluency test is a good indicator of cognitive flexibility; lower performance might indicate cognitive impairment. The score is the number of correct words produced. The *Modified Card Sorting Test* (MCST, Nelson, 1976; Italian normative data in Caffarra, Vezzadini, Dieci, Zonato, & Venneri, 2004) was used to evaluate abstract reasoning, mental flexibility (ability to shift set), and problem solving skills. Participants are required to sort 48 cards based on an unknown rule that changes during the test through use of feedback from the examiner. Performance on the MCST was scored by computing the number of categories achieved by the participant, and the number of perseverative errors.

Language

The *Naming on Confrontation* sub-test from Aachen Aphasia Test (AAT; Luzzatti, Willmes, & De Bleser, 1991). The task requires naming objects from different categories. Performance is based on number of objects correctly named.

Memory

The *Rey-Osterrieth Complex Figure Test* (ROCF; Osterrieth, 1944; Italian normative data in Caffarra, Vezzadini, Dieci, Zonato, & Venneri, 2002) was used to investigate visuo-spatial constructional functions, visuo-graphic memory, and some aspects of planning and executive function. Participants were presented the ROCF stimulus card, showing a complex black-and-white figure, and asked to copy the same figure. Subsequently, they were instructed to draw what they remembered about the same figure (immediate recall), without the stimulus card present. After a delay of 30 min, participants were required to draw the same figure again (delayed recall). The *Word-list recall* task (Rey, 1958; Italian normative data in Carlesimo et al., 1996) consists of five consecutive immediate free-recall trials of a list of 15 words read aloud by the examiner (immediate recall). After 15 min, a delayed recall trial is given (delayed recall).

Visuo-spatial functions

The *Clock Drawing Test* (CDT; Goodglass & Kaplan, 1972; Italian normative data in Mondini, Mapelli, Vestri & Bisiacchi, 2003) requires participants to draw a clock with numbers (from 1 to 12) and both minute and hour hands.

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The CDT has been proposed as a useful neuropsychological screening instrument for dementia and has demonstrated good sensitivity to constructional, visuo-perceptual, and conceptual deficits.

RESULTS

Time Bisection Task

In the time bisection task,[1] we calculated the proportion of "long" responses for each stimulus duration and these were included in a mixed-design ANOVA with *group* (PD-MCI, PD-non-MCI and controls) as a between-subject factor and *emotion* (anger, shame, and neutral) and *temporal interval* (400, 600, 800, 1000, 1200, 1400, and 1600 ms) as within-subjects factors. All significant effects were followed by *post hoc* analyses performed with a Bonferroni correction to reduce the Type I error rate, and the effect size was estimated with partial eta squared (η^2_p).

Significant main effects for emotion [$F(2,78) = 4.10$; $p = .020$; $\eta^2_p = .095$] and temporal intervals [$F(6,234) = 593.26$; $p = .001$; $\eta^2_p = .938$] were found. No main effect of group was found ($p = .716$; $\eta^2_p = .017$), but group significantly interacted with temporal interval [$F(12,234) = 3.52$; $p = .001$; $\eta^2_p = .153$]. Moreover, the interaction group × emotion × temporal interval [$F(24,468) = 1.80$; $p = .012$; $\eta^2_p = .085$] was found (Figure 2). *Post hoc* analyses showed that PD-MCI judged the long temporal intervals (1200, 1400, and 1600 ms) as shorter, and the short temporal intervals (400 and 600 ms) as longer, compared to PD-non-MCI and controls. PD-non-MCI and controls equally judged the temporal intervals in all emotions. Only in the case of PD-MCI, at 400 ms, were significant differences observed between emotional stimuli (anger and shame facial expressions) and neutral stimuli. This finding indicates that PD-MCI patients pressed more often "long" at 400 ms when the stimulus has a neutral emotional valence than when anger or shame is shown.

The temporal bisection point was also calculated for investigating perceived duration; the index is defined as the *x* value corresponding to the .50 probability of "long" responses on the *y*-axis, serving as a measure of perceived duration. The observed shift of the bisection point for the different facial expression of emotions presented on groups can be interpreted as an indicator of differences in these conditions, with smaller bisection point values meaning longer perceived durations (Grondin, 2008). *Group* (PD-MCI, PD-non-MCI and controls) was the between-subject factor and *emotion* (anger, shame, and neutral) was the within-subject factor. A significant effect of group was found [$F(2,78) = 2.55$; $p = .045$; $\eta^2_p = .134$]. Results indicated that PD-MCI patients ($M = 948$) perceived temporal intervals as shorter than PD-non-MCI patients ($M = 844$) and controls ($M = 844$). No effect of emotion or interactions was found (all $ps > .05$).

We also calculated an index (*d* scores) for each stimulus duration (see Gil & Droit-Volet, 2011). The *d* corresponds to the difference between the proportion of "long" responses for the emotional and neutral faces, and was used as an index of emotional distortion on time perception. A *d* value greater than 0 reflects an overestimation of time for emotional faces, compared to neutral faces, and a *d* value lower than 0 reflects an underestimation of time. Data were included in a mixed-design ANOVA with *group* (PD-MCI, PD-non-MCI and controls) as a between-subjects factor and *emotion* (anger, shame) and *temporal interval* (400, 600, 800, 1000, 1200, 1400, and 1600 ms) as within-subjects factors. A main effect of emotion was found [$F(1,39) = 6.06$; $p = .018$; $\eta^2_p = .135$], indicating that being exposed to facial expressions of anger produces an overestimation of temporal intervals ($d = .013$). The facial expression of shame produced an underestimation of temporal intervals ($d = -.010$). No other main effects or interactions were found (all $ps > .05$).

To further explore the effect of emotional valence on time perception in the three groups we have also conducted correlations between indices (*d* scores) for anger and shame and the BDI score. A significant correlation was observed only between the index of anger and the BDI score in PD-MCI ($r = -.576$; $p < .001$).

Neuropsychological Tasks

Separate one-way ANOVAs were conducted on performances at neuropsychological tasks in PD-MCI, PD-non-MCI patients, and controls (Table 2). Significant differences were observed between groups on CDT [$F(2,42) = 8.87$; $p = .001$; $\eta^2_p = .313$], ROCF immediate recall [$F(2,42) = 4.74$; $p = .014$; $\eta^2_p = .196$], ROCF delayed recall [$F(2,42) = 10.67$; $p = .001$; $\eta^2_p = .354$], semantic fluency [$F(2,42) = 3.52$; $p = .039$; $\eta^2_p = .153$], word list immediate recall [$F(2,42) = 4.45$; $p = .018$; $\eta^2_p = .186$], word list delayed recall [$F(2,42) = 6.54$; $p = .004$; $\eta^2_p = .251$], TMT part B [$F(2,42) = 10.08$; $p = .001$; $\eta^2_p = .372$], and TMT B-A [$F(2,42) = 8.06$; $p = .001$; $\eta^2_p = .328$]. Specifically, except for CDT, PD-MCI were less accurate than PD-non-MCI and controls, and PD-non-MCI performed as accurately as controls. In the case of CDT, PD-MCI patients were less accurate than PD-non-MCI and controls, and PD-non-MCI performed more poorly than controls. No differences between groups were observed on AAT, TMT part A and MCST on both category and perseverative errors (all $ps > .05$).

DISCUSSION

A large number of studies conducted with PD patients have almost uniformly reported difficulties for judging the duration of intervals in the millisecond and second range

[1] Preliminary analyses were conducted to control for the effect of gender of participants and stimuli. Neither main effect of gender of participants or gender of stimuli nor interactions were found ($p > .05$). We have used a least-square fitting procedure.

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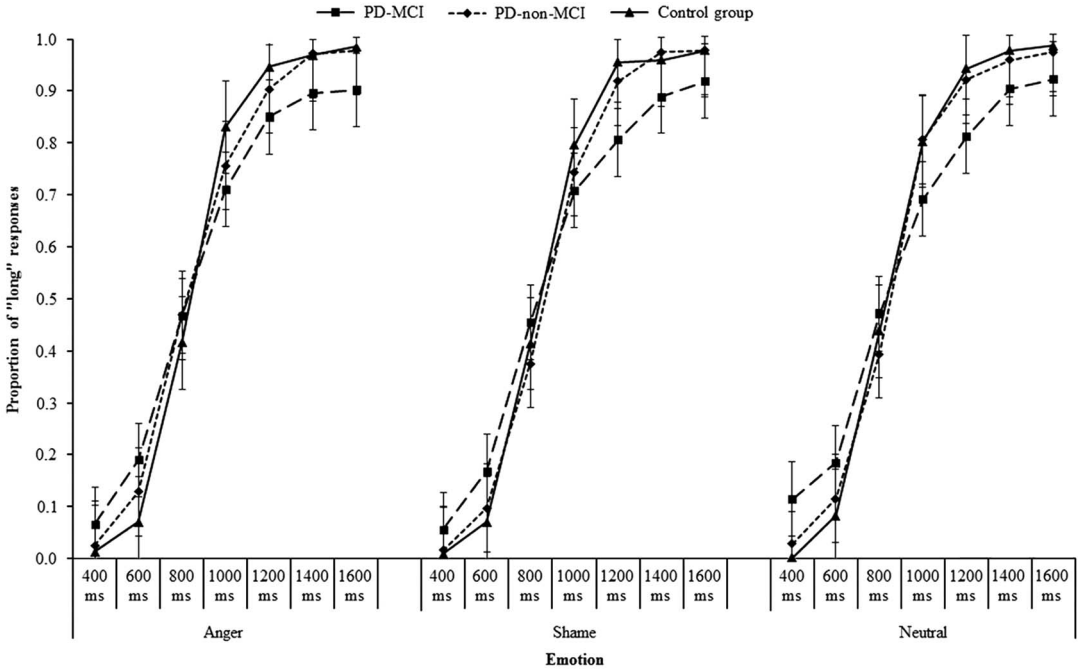

Fig. 2. Psychometric function (pooled data) for each emotional condition and each group. The error bars indicate ±1 SE.

Table 2. Descriptive statistics for the neuropsychological tasks included in the study

	PD-MCI n = 15	PD-non-MCI n = 10	Control group n = 17
	M (*SD*)	*M* (*SD*)	*M* (*SD*)
TMT			
Part A	113.87 (86.4)	76.00 (33.6)	70.06 (22.4)
Part B	197.91 (78.4)	110.78 (45.9)	113.59 (32.2)
B – A	115.36 (78.5)	45.00 (37.2)	43.53 (22.8)
Semantic Fluency	31.73 (9.0)	40.80 (10.8)	39.41 (9.7)
MCST			
Category	4.47 (1.6)	4.30 (2.3)	5.50 (.9)
Perseverative errors	5.53 (5.9)	7.00 (12.7)	1.62 (2.1)
AAT (denomination)	18.00 (2.8)	19.30 (1.5)	19.56 (.9)
ROCF			
Immediate recall	26.90 (7.6)	30.50 (5.4)	33.00 (3.1)
Delayed recall	10.03 (3.7)	16.60 (7.0)	18.20 (5.1)
Word list			
Immediate recall	31.40 (6.7)	41.10 (10.4)	38.82 (9.4)
Delayed recall	5.93 (2.6)	9.70 (3.2)	8.35 (2.4)
CDT	7.20 (2.8)	9.55 (1.4)	9.79 (.5)

Note: CDT = Clock Drawing Test; ROCF = Rey-Osterrieth Complex Figure Test in immediate recall and delayed recall conditions; Word list = World-list recall task in immediate recall and delayed recall conditions; AAT = Aachen Aphasia Test; TMT = Trial Making Test in part A and B and difference in reaction time between parts B and A (B–A); MCST = Modified Card Sorting Test.

(Lange et al., 1995; Malapani, Deweer, & Gibbon, 2002; Malapani et al., 1998; Pastor, Artieda, et al., 1992; Perbal et al., 2005). Temporal dysfunction in PD patients has been attributed to disruption of central dopaminergic activity (Meck, 1996; Rammsayer, 1999). Disruption of dopaminergic neurons, resulting in dysfunction of fronto-subcortical systems, may also be responsible for abnormalities in emotional facial expression recognition in PD patients (Adolphs, 2002a,b; Dujardin et al., 2004; Lawrence et al., 2007; Sprengelmeyer et al., 2003). The aims of the present study were to investigate the effect of emotional facial expression on time perception in PD patients with and without MCI.

Results showed that PD-MCI patients were less accurate than PD-non-MCI patients and controls, such that PD-MCI

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patients perceived temporal intervals as shorter than the presented interval. Moreover, PD-MCI patients judged longer temporal intervals (1400 ms and 1600 ms) as shorter and short intervals (400 ms and 600 ms) as longer than the presented durations (migration effect, Buhusi & Meck, 2005; Koch et al., 2008; Malapani et al., 1998, 2002; Smith et al., 2007). This effect may be due to memory dysfunction rather than a change in clock speed (Koch, Brusa, Olivieri, Stanzione, & Caltagirone, 2005; Malapani et al., 1998, 2002). Malapani et al. (1998) tested PD patients "on" and "off" medication with a time reproduction task (8 s and 21 s). PD patients "off" medication overestimated the 8-s temporal intervals and underestimated the 21-s temporal intervals (Experiment 1). According to the authors, changes in clock speed would not cause any bias in temporal accuracy under conditions in which participants were trained and tested in the same neurological state ("on" or "off" medication). Conversely, memory dysfunction for a previous learned interval (during the training phase, when two temporal intervals are learned) would affect the estimation of the later learned interval, leading to a migration of the two target durations toward each other (Malapani et al., 1998). The migration effect was consistently observed when PD patients received feedback, leading to the conclusion that the migration effect is indeed caused by a memory storage/retrieval problem rather than a clock problem (Koch et al., 2005; Malapani et al., 1998, 2002; Perbal et al., 2005). Our results confirm this interpretation. Consistent with previous studies (Malapani et al., 1998, 2002), participants learned the two standard intervals during the training phase. It is possible that the PD-MCI patients created an inaccurate representation of the two standard intervals leading to a subsequent overestimation of short temporal intervals and underestimation of long temporal intervals. Additionally, in support with the memory interpretation of the migration effect, only PD-MCI patients with severe cognitive memory dysfunctions presented the migration effect.

The second aim of the present study was to investigate the effect of emotional facial expression on time perception. The results showed an effect of emotional stimuli on time perception. When stimuli showed facial expressions of anger, temporal intervals were overestimated whereas when stimuli showed facial expressions of shame, temporal intervals were underestimated. These results are consistent with previous findings revealing facial expression of anger were associated with overestimations of time, among children and adults (Gil & Droit-Volet, 2011; Gil, Niedenthal, & Droit-Volet, 2007). According to the internal clock model (Gibbon, Church, & Meck, 1984), temporal intervals are overestimated when the pacemaker runs faster; indeed, when the pacemaker runs faster, more pulses are stored into the accumulator and the duration is considered to be longer. Anger is a particularly arousing emotion (Calder, Keane, Lawrence, & Manes, 2004; Phelps & Ledoux, 2005), and increasing arousal level has been demonstrated to increase the speed of the internal clock (Angrilli et al., 1997; Gil & Droit-Volet, 2012; Mella et al., 2011; Rammsayer, 1997; Wearden & Penton-Voak, 1995). Consequently, time is overestimated when facial expressions of anger are presented.

Time distortions caused by the perception of angry facial expressions may be adaptive, as they prepare the organism to act for survival. This idea is consistent with studies showing that threatening stimuli or stressful situations induce an overestimation of time (Angrilli et al., 1997; Grondin, Laflamme, & Gontier, 2014). On the other hand, facial expression of shame leads to an underestimation of time. Shame is a secondary emotion, which develops later with social interactions and the internalization of social rules; shame does not have the same adaptive meaning as anger (Lagattuta & Thompson, 2007; Tangney & Dearing, 2002). Considering that shame has been interpreted as self-conscious emotion involving a reflexive attitude toward oneself (Haidt, 2003), some authors have concluded that facial expressions of shame attract attentional resources (Gil & Droit-Volet, 2011), resulting in an underestimation of time. According to the attentional gate model (Zakay & Block, 1996), when attention is not fully allocated on time, less temporal information is stored in the accumulator and the temporal interval is judged to be shorter than the objective duration.

The third aim was to investigate if stimuli of facial emotional expressions influence temporal judgments in PD patients and controls differently. Results showed significant differences between emotional stimuli (anger and shame) and neutral stimuli only at 400 ms in PD-MCI patients. Greater temporal dysfunction with short temporal intervals is a consistent finding in the literature with PD patients (Artieda et al., 1992; Harrington et al., 2010; Malapani et al., 1998; Pastor, Artieda, et al., 1992; Riesen & Schnider, 2001; Smith et al., 2007), reflecting a memory or storage/retrieval problem rather than a clock problem (Koch et al., 2005; Malapani et al., 1998, 2002; Perbal et al., 2005). We interestingly found an effect of emotional stimuli at 400 ms in PD-MCI patients. It is possible that a less stable temporal representation in PD-MCI patients is more prone to be distorted by emotional stimuli.

The three groups included did not differ for the level of depression, although PD-MCI patients showed a slightly higher level of depression. The correlation analyses conducted between the index (d score) of emotional distortion on time perception and depression index indicated that PD-MCI patients with higher levels of depression had a reduced distortion on time perception when the facial expression of anger was presented. One hypothesis for explaining that result is that PD-MCI patients with higher levels of depression were less prone to identify anger than less depressed participants.

To conclude, our study showed temporal dysfunctions in PD patients specifically related to level of cognitive impairment. Specifically, PD-MCI patients were less accurate than PD-non-MCI patients and controls, such that PD-MCI patients perceived temporal intervals as shorter than the presented interval. Moreover, PD-MCI patients judged longer temporal intervals (1400 ms and 1600 ms) as shorter and short intervals (400 ms and 600 ms) as longer than the presented durations. The migration effect observed is

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attributed to a distortion in the memory representation of time (Malapani et al., 2002). The current study also revealed interesting results regarding the effect of emotional stimuli on time perception in PD patients. When stimuli showed angry facial expressions, temporal intervals were overestimated; when stimuli showed shame facial expressions, temporal intervals were underestimated. This effect was particularly evident in PD-MCI patients when 400 ms was used.

The effect of emotional stimuli on time perception demonstrates that PD patients adequately recognized and processed the emotional stimuli of anger and shame. These results seem not to be in line with the literature on emotional facial recognition in PD patients. Importantly, PD-non-MCI and controls showed similar temporal abilities, and they present similar cognitive abilities as indicated by the neuropsychological evaluation. It is possible that they still have intact the networks involved in emotional facial recognition. Alternatively, it is possible that in our study, PD patients implicitly processed the emotional stimuli; in fact, participants were not explicitly questioned about emotional facial expressions during the time bisection task. It is possible that emotional facial recognition is preserved at an implicit level and that this has produced the effect observed. Future studies should consider the effect of other facial emotional stimuli on temporal processing in PD patients. Studies have shown that happiness and sadness are differently recognized in PD patients relative to controls (Clark et al., 2008; Yip, Lee, Ho, Tsang, & Li, 2003), and that recognition of disgust is dysfunctional in PD patients (Assogna et al., 2008; Sprengelmeyer et al., 2003; Suzuki, Hoshino, Shigemasu, & Kawamura, 2006).

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