Facial Emotion Recognition and Visual Functioning in the Early Stage of Parkinson's Disease

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Abstract

Facial emotion recognition (FER) can be impaired in Parkinson's disease (PD) patients and may influence relationships and quality of life. Previous studies however are inconsistent on the presence of FER difficulties in early stage patients. In addition, it has been suggested that lower- and higher-order visual functions could be associated with FER ability. The aim of this study is to create more insight into FER and visual functions in newly diagnosed, treatment-naïve PD patients. A group of PD patients (n=152, 72% male) was compared to healthy controls (HC; n=105, 52% male). All participants underwent the same neuropsychological assessment, in which FER was measured by the Ekman 60 faces test of the Facial Expressions of Emotion: Stimuli and Tests (FEEST), and higher-order visual functions were measured by the Judgment of Line Orientation (JOLO) and Test of Everyday Attention (TEA): Map Search. In addition, lower-order visual function of the PD group was measured by the Pelli-Robson chart and indicated poor contrast sensitivity. Analyses show that the PD group scored lower on the FEEST ($F = 7.76$, $p = .006$), the JOLO ($F = 10.06$, $p = .002$) and the TEA Map Search ($F = 27.75$, $p < .001$) than the HC group. Further analyses show significant relationships between the FEEST and the Pelli-Robson chart ($r_s = .35$, $p < .001$), the FEEST and the JOLO ($r_s = .21$, $p = .009$), and the FEEST and the TEA Map Search ($r_s = .42$, $p < .001$). When investigating predictors of the FEEST, age and gender contributed significantly to the regression model (ß = -.339, $p < .003$ and ß = .172, $p = .050$, respectively) and the visual functions did not significantly contribute to the model. Therefore, it can be concluded that FER can be impaired in newly diagnosed, treatment-naïve patients. The visual functions and FER were related, but could not explain the variance in the FER task outcomes.

Keywords: early stage, Parkinson's disease, facial emotion recognition, lower-order visual function, higher-order visual function.

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Facial Emotion Recognition and Visual Functioning in the Early Stage of Parkinson's Disease

Parkinson's disease (PD) is a progressive neurodegenerative disease in which there is a loss of dopaminergic neurons in the substantia nigra. PD is characterized by both motor and non-motor symptoms. The most prominent motor symptoms are tremor, muscle rigidity, bradykinesia, and postural instability (Ogden, 2005). Non-motor symptoms include neuropsychiatric disorders, cognitive impairments, sleep disorders, autonomic dysfunction, sensory disturbances, and other miscellaneous symptoms such as fatigue (Lèohle et al., 2009). Non-motor symptoms are commonly experienced by patients and are increasingly being researched the last years.

Cognitive decline is an important non-motor symptom and occurs already in the early stage of PD (Fang et al., 2020). The cognitive profile differs between patients. Various domains can be affected, and it differs in which domains impairments reveal first (Martinez-Horta & Kulisevsky, 2019). After neuropsychological assessment, patients can be diagnosed with mild cognitive impairment (PD-MCI) which is estimated to be present in a quarter of patients and is a harbinger of dementia (Cammisuli et al., 2019; Litvan et al., 2012). Importantly, non-motor symptoms including cognitive impairments have an impact on the reported quality of life of patients (Barone et al., 2009). Considering that mild cognitive impairment is often present and influences the well-being of patients, adding that non-motor symptoms follow a heterogeneous profile, it is essential to further explore cognitive dysfunctions in PD. The latest version of the Diagnostic and Statistical Manual for Mental Disorders (DSM-5) distinguishes six cognitive domains: complex attention, executive function, language, learning and memory, perceptual-motor function, and social cognition (American Psychiatric Association, 2013). However, the social cognition domain is often forgotten when assessing cognitive functions in PD patients.

Social cognition

Social cognition is introduced in the DSM-5 as one of the domains that can be affected by a neurocognitive disorder and was not included in previous DSM versions. It is now recognized as an independent cognitive domain (Alonso-Recio et al., 2021). Previously, it was thought that impairments in social cognition in PD are secondary to impairments in executive functions. However, social cognition impairments may appear without executive dysfunctions and vice versa (Palmeri et al., 2017; Alonso-Recio et al., 2021). Social cognition can be defined as 'the manner in which we interpret, analyze and remember information about the social world' (Baron and Byrne, 1997). Deficits in social cognition can be noticed when an individual has an impaired theory of mind (ToM), less emotional empathy, poor social perception, or when he or she may not behave normally in the social context (Henry et al., 2016). It goes without saying that if one is not able to understand the social world, this in turn can affect social relationships and daily living. This may also be the case for PD patients, who often suffer from impairments in social cognition (Palmeri et al., 2017). Social cognition should therefore be investigated in isolation, and with possible other cognitive domains which could be linked to deficits in social cognition.

A specific social cognitive deficit often found in PD is poor social perception (Coundouris et al., 2019; Alonso-Recio et al., 2021). Social perception is the ability to detect and identify social and emotional cues (Henry et al., 2016). This includes among other things the ability to recognize emotions of others through facial expressions. When looking at the brain, dopaminergic neurons and the basal ganglia (of which the substantia nigra is a part of) are involved in emotion processing. Dysfunction of basal ganglia-thalamocortical circuits in PD possibly play a role in recognition and processing of facial emotions (Ogden, 2005). The recent study of Alonso-Recio and colleagues (2021) studied the social cognition components and their relation to other cognitive domains. In the PD group, deficits were found in social

perception and ToM. Particularly, the impairments in FER were related to all the cognitive domains that were assessed in their study, which includes executive function, language, memory, processing speed and visuospatial ability. This implies that FER can be impaired in PD patients with overall cognitive decline. Patients with advanced PD often show overall cognitive decline, as well as impairments in FER (Alonso-Recio et al., 2021; Coundouris et al., 2019; Galtier et al. 2020). However, studies on the early stage of PD show mixed results concerning FER impairments. Some studies suggest that FER can already be impaired in the early stage of the disease, independent of overall cognitive impairment which is often found in advanced PD (Argaud et al., 2018; Mattavelli et al., 2021). Contrary to this, Hipp and colleagues (2014) found that particularly FER was intact in early stage PD patients. This shows that more research is needed on the ability to recognize facial emotions in the early stage of PD to determine if and how deficits appear.

Facial emotion recognition and visual functions

Deficits in FER are related to several factors, such as overall cognitive decline (Alonso-Recio et al., 2021), disease duration and disease severity (Argaud et al., 2018). In addition, it is suggested that hypomimia can contribute to deficits in FER as PD patients do not mimic the emotions others' show in their faces (Argaud et al., 2016; Argaud et al., 2018; Livingstone et al., 2016). New insights suggest that deficits in FER can also be linked to visuospatial disturbances, as emotional and visual systems are connected in the brain (Argaud et al., 2018; Mattavelli et al., 2021). The loss of dopaminergic neurons in fronto-striatal systems can affect visual functioning as well as FER. In addition, the basal ganglia are involved in both emotion processing and eye movements (Clark et al., 2010). Impairments in visual functioning, such as defects in primary vision and problems with more complex visual functions are already common in early stage PD, and worsen with increasing disease

progression (Armstrong, 2015). Visual disturbances can be divided in lower- and higher-order visual functions.

Lower-order visual functioning arises from the primary vision and can be measured by ophthalmic examination. Lower-order visual functioning includes among other things contrast sensitivity, which is the ability to discriminate an object from its background (Weil et al., 2016). Contrast sensitivity seems to be reduced in PD patients compared to healthy controls (Clark et al., 2010; Hipp et al., 2014), and is related to disease severity (Guo et al., 2018). However, deficits can already be found in the prodromal phase and could be used as a biomarker in diagnosing PD (Armstrong, 2015; Guo et al., 2018). Interestingly, it is suggested that problems with contrast sensitivity correlates with cognitive impairments (Guo et al., 2018). Higher-order visual functioning involves higher cortical processing whereby cognitive strategies are used to use and interpretate visual information (Weil et al., 2016; Hart, 2015). It can be measured by more complex visual tasks in neuropsychological assessment, and both bottom-up and top-down processes can be responsible for visual problems in PD (Guo et al., 2018). Higher-order visual functioning includes abilities such as reading, visual recognition, imagery, attention, construction, perception and visuospatial functioning (Tranel, 1994). PD patients can experience a variety of visuospatial impairments in mild to moderate stages (Uc et al., 2005). Impairments are associated with various cognitive domains (Uc et al., 2005), level of motor functioning and problems with activities of daily living (Davidsdottir et al., 2005). Furthermore, visuospatial and perceptual problems have been found in patients with subjective cognitive impairments (Galtier et al., 2020). Regarding the early stage of the disease, specifically disturbances in visuospatial selective attention are found (Esposito et al., 2021).

Both lower- and higher-order visual functioning have been associated with the ability to recognize facial emotions. Impairments in FER in PD are suggested to be related to

problems with visual scanning, whereby visual scanning is driven by lower- and higher-order visual processes (Clark et al., 2010). Hipp and colleagues (2014) proposed two pathways to recognize emotions: the first uses lower-order visual function to subconsciously identify emotions by their physiological properties; the second uses higher-order visual function to consciously recognize emotions through cortical processing. The processes can interact with each other, but interaction is not necessary for emotion recognition. The study of Hipp and colleagues (2014) found that particularly FER was preserved in early stage PD. The authors suggest that patients use compensatory strategies for their difficulties with contrast sensitivity, and in this way correctly recognize emotions. Notably, although this study included early stage PD patients, included subjects were already using medication, which can be of influence on FER function (Palmeri et al., 2020).

In summary, FER can be impaired in advanced PD and is known to have an impact on quality of life of PD patients. However, it is unclear whether FER deficits can be found in the early stage of PD. In addition, it is unknown whether the ability to recognize facial emotional expressions can be linked to problems concerning visual functioning, which are common in (advanced) PD. This study will therefore investigate whether impairments in FER, and lower- and higher-order visual functions can be found in newly diagnosed, treatment naïve PD patients and whether these deficits are related to each other.

The first question was: Are FER ability and higher-order visual functions impaired in newly diagnosed, treatment-naïve PD compared to healthy controls?; The second question was: Is FER related to performance on lower- and higher-order visual functioning in newly diagnosed, treatment-naïve PD patients?; The third question was: Which of the lower- and higher-order visual tasks explains the most variance as a predictor for the outcomes on the FER task? Based on the existing literature, it can be hypothesized that both FER and higher-order visual functions are lower in PD patients compared to healthy controls. Second, it is

expected that a relationship can be found between FER and lower- and higher-order visual functions. The third expectation is that the scores on lower- and higher-order visual tasks are significant predictors of the outcome scores on the FER task.

Method

Participants

The dataset collected was the baseline data of the DUtch PARkinson Cohort (DUPARC) study (Boertien et al., 2020). The newly diagnosed PD patients were recruited through a network of PD treating neurologists, the Parkinson Platform Northern Netherlands. The patients were treatment naïve and included within three months after diagnosis. Participants willing to participate were then referred to the University Medical Center Groningen (UMCG). In total, 152 patients (72% male) with PD and 105 healthy controls (HC; 52% male) were included in this study. The PD patients had a mean age of 65.07 (sd = 9.23; range = 36 – 85). The level of education was classified with the Dutch Verhage scale (Verhage, 1964). The PD group had an educational level mean of 5 (sd = 1.27; range 1 – 7). The healthy controls were recruited through networks of family, friends, and acquaintances. The HC group had a mean age of 64.46 (sd = 8.71; range 41 – 84). The educational level had a mean of 5.48 (sd = 1.01; range 2 – 7). Inclusion criteria used for the PD group were diagnosis no longer than three months prior to testing and being treatment naïve. Exclusion criteria used for the PD group were those who did not finish the FEEST. Exclusion criteria used for the HC group was having a (history of) a neurological disease or not finishing the FEEST.

Procedure

PD patients visited UMCG two times for neuropsychological, ophthalmological and clinical assessment. The healthy controls underwent the same neuropsychological assessment in one or two sessions. The study was approved by the Medical Ethics Board of the

University Medical Centre of Groningen (MEtc UMCG). Both PD patients and healthy controls gave written informed consent.

Materials

Facial emotion recognition

The Ekman 60 faces test of the Facial Expressions of Emotion: Stimuli and Tests (FEEST) was used to assess social cognition, specifically the recognition of facial emotions (Ekman & Friesen, 1976). Black and white photographs were shown in which an individual expresses a basic emotion, which could be anger, disgust, fear, happiness, sadness, or surprise. The participant had to label the emotion that was displayed in the picture. Every emotion was shown 10 times, making the maximum test score 60. A higher score was indicative of a better performance. The test was taken on the computer and there was no time limit.

Higher-order visual function

Visuospatial perception. The Judgment of Line Orientation (JOLO) test was used to assess visuospatial perception (Benton, Varney & Hamsher, 1978). It consisted of 30 items in which the participant had to name which lines in the response-choice display had the same angles and were occupied in the same location as two stimulus lines. The test was in book form so that the stimulus lines were presented on the top page and the response-choice display was on the bottom page. The maximum score was 30 and a higher score was indicative of a better performance. The obtained score was corrected for age and gender (Benton et al., 1983). There was no time limit.

Visual selective attention and speed. The Test of Everyday Attention (TEA): Map Search was used to assess visual selective attention and speed (Robertson et al., 1996). The participant were given two minutes to circle as many restaurant-symbols (knife-and-fork sign) as possible on a colored map of Philadelphia. The number of symbols circled was the

obtained score. There were 80 restaurant-symbols on the map which is the maximum score. A higher score was indicative of a better performance.

Lower-order visual function

The Pelli-Robson chart was used to measure contrast sensitivity of the right and left eye separately. Large letters were displayed in lines on a chart with contrast varying across groups of letters. The contrast went from high to low. The participant had to read the letters on the chart, until they could not read two or three letters in a group. The score was based on the contrast of the last group and was a measure of the participants log contrast sensitivity. The total score of both eyes was used in this study. The maximum score is 4.5 (Mäntyjärvi & Laitinen, 2001). A score of 4.0 indicates normal contrast sensitivity. A score less than 4.0 indicates poor contrast sensitivity; less than 3.0 indicates visual impairment and less than 2.0 indicates visual disability (Parede et al., 2013). Only the PD patients were assessed with the Pelli-Robson chart.

Statistical analysis

Before the analyses were performed, the data was inspected by checking for striking values. The data was analyzed by using SPSS version 27 (IBM Corp., 2021), tests were two-tailed and a p-value of 0.05 or less was considered as statistically significant. Firstly, the demographics of the PD and HC group were looked at to examine whether the groups match in gender, age, and educational level. The data was checked for normality using the Shapiro-Wilk test. As the data was not normally distributed, non-parametric tests were used for further analyses. ANCOVA's were carried out to compare means between the PD and HC group on the FEEST, JOLO, and TEA Map Search, while controlling for gender. Using Cohen's guidelines, the partial eta squared effect sizes were interpreted as small (0.2), moderate (0.5) or large (0.8). Further analyses have been done on the scores of the PD group. Spearman rank correlations were calculated to examine the relationship between the Pelli-Robson chart,

JOLO, and TEA Map Search and the FEEST. Correlations coefficients were interpreted as very weak (.00-.19), weak (.20-.39), moderate (.40-.59), strong (.60-.79), or very strong (.80-1.0). The assumptions for a multiple regression analysis were checked and there were no violations. As a result, a multiple regression analysis has been carried out to investigate which of the lower- and higher-order visual tasks (Pelli-Robson chart, JOLO, TEA Map Search) could explain most of the variance of the scores on the FEEST. In addition, demographics (age, gender, educational level) of the PD group were included as predictors in the model. A 0.02 F-squared effect size for multiple regression indicates a small effect size; 0.15 medium; and 0.35 large (Cohen, 1988).

Hypotheses

Question 1: Are FER ability and higher-order visual functions impaired in newly diagnosed, treatment-naïve PD compared to healthy controls? We expected that the PD group scored lower on the FEEST, the JOLO, and the TEA Map Search compared to the HC group.

*Hypothesis 1a***.** H0: There is no difference in FEEST scores between the PD and HC group. Ha: The PD group has different scores on the FEEST compared to the scores of the HC group.

Hypothesis 1b. H0*:* There is no difference in JOLO scores between the PD and HC group. Ha: The PD group has different scores on the JOLO compared to the scores of the HC group.

Hypothesis 1c. H0: There is no difference in TEA Map Search scores between the PD and HC group. Ha: The PD group has different scores on the TEA Map Search compared to the scores of the HC group.

Question 2: Is FER in newly diagnosed, treatment-naïve PD patients related to performance on lower- and higher-order visual functioning? We expected that the Pelli-

Robson chart, JOLO, and TEA Map Search are significantly correlated to the FEEST scores in the PD group.

Hypothesis 2a. H0: No significant correlation is found between the Pelli-Robson chart scores and the FEEST scores. Ha: A significant correlation is found between scores on the Pelli-Robson chart and the FEEST scores.

Hypothesis 2b. H0: No significant correlation is found between the JOLO scores and the FEEST scores. Ha: A significant correlation is found between the scores on the JOLO and the FEEST scores.

Hypothesis 2c. H0: No significant correlation is found between the TEA Map Search scores and the FEEST scores. Ha: A significant correlation is found between the scores on the TEA Map Search and the FEEST scores.

Question 3: Which of the lower- and higher-order visual tasks explains the most variance as a predictor for the outcomes on the FEEST in the PD group? We expected that the Pelli-Robson chart, the JOLO, and the TEA Map Search could significantly predict the variance in the outcomes on the FEEST in the PD group.

Hypothesis 3: H0: The scores on the Pelli-Robson chart, JOLO, and TEA Map Search cannot predict the variance in outcomes on the FEEST. Ha: The scores on the Pelli-Robson chart, JOLO, and TEA Map Search can individually predict variance in outcomes on the FEEST.

Results

Demographic and clinical characteristics

The total sample consisted of 152 PD patients and 105 HC. The demographic features are described in table 1. A significant relationship was found between gender and group ($X^2(1, 257) = 10.05$, $p = .002$). The PD group had a significantly higher percentage of males than the HC group. The HC group had significantly higher educational levels than the PD

group. There was no significant difference in age between the groups. The PD group scored significantly lower on the Montreal Cognitive Assessment (MoCA) than the HC group.

Table 1

Demographical features of the PD and the HC group

	PD (*n* = 152)	HC (*n* = 105)	Mann-Whitney U	p
Sex: male (n (%))	109 (72)	55 (52)		
Age, M (SD)	65.1 (9.2)	64.5 (8.7)	7364	.293
Educational level, M (SD)	5 (1.3)	5.5 (1)	6131.5	<.001*
MoCA	25.0 (3.2)	26.2 (2.4)	6103	.002*
UPDRS III, M (SD)	31.2 (11.5)			
H&Y, stage (%)	1 (26); 2 (65); 3 (5); 4 (3)			

Note: PD = Parkinson's disease, HC = healthy controls, M = mean, SD = standard deviation, MoCA = Montreal Cognitive Assessment, MDS-UPDRS III = Movement Disorders Society – Unified Parkinson's Disease Rating Scale III, H&Y = Hoehn and Yahr scale.

*p <.05, two-tailed.

Comparison of study variables

The study variables of both groups are described in table 2 and the comparisons were controlled for gender. It was found that the PD group scored significantly lower on all tests in comparison to the HC group. The PD group had a mean contrast sensitivity of 3.11, which indicates poor contrast sensitivity based on the scoring of the Pelli-Robson chart (Parede et al., 2013).

Table 2

Study variables of the PD and the HC group

	PD Mdn (IQR)	PD n	HC Mdn (IQR)	HC n	F	p	η_p^2
FEEST	45 (9)	152	48 (9)	105	7.763	.006*	.030
JOLO	25 (7)	151	27 (6)	105	10.055	.002*	.038
TEA Map Search	46 (26)	152	58 (17)	104	27.751	<.001*	.099
Pelli-Robson chart	3.15 (.30)	106					

PD = Parkinson's disease, HC = healthy controls, FEEST = Ekman 60 faces test of the Facial Expressions of Emotion: Stimuli and Tests, JOLO = Judgment of Line Orientation, TEA = Test of Everyday Attention: Map search, Mdn = median, IQR = interquartile range, F = F-ratio used in ANCOVA, η_p^2 = partial eta squared.

*p <.05, two-tailed.

Relationship between the lower- and higher-order visual functions and the FEEST

A positive, weak correlation has been found between the FEEST and the Pelli-Robson chart ($r_s(106) = .35$, $p < .001$). There was a positive, weak correlation between the FEEST and the JOLO ($r_s(151) = .21$, $p = .009$). There was a positive, moderate correlation between the FEEST and the TEA Map Search ($r_s(152) = .42$, $p < .001$).

Predictors of the FEEST

A multiple regression analysis was carried out to investigate which of the lower- and higher-order visual tasks (Pelli-Robson chart, JOLO, TEA Map Search) could explain most of the variance of the FEEST scores. The demographic variables (age, gender, educational level) were also included. The results of the regression indicated that the model explained 31% of the variance ($R^2 = .307$, $R^2_{Adjusted} = .265$) and that the model was a significant predictor of the

FEEST scores ($F(6, 98) = 7.251$, $p < .001$). The effect size found ($f^2 = 0.44$) is a large effect size for a multiple regression.

Age and gender contributed significantly to the model (ß = -.339, $t(98) = -3.044$, $p < .003$ and ß = .172, $t(98) = 1.988$, $p = .050$, respectively). The Pelli-Robson chart, JOLO, TEA Map Search, and educational level, however, did not significantly contribute to the model.

Discussion

The aim of the current study was to create more insight into the ability of newly diagnosed, treatment-naïve PD patients to recognize the emotions of others through facial expressions, and whether visual functions are related to this emotion recognition. In order to learn more about this, the current study researched whether lower- and higher-order visual functions are related to FER, and whether these can act as predictors for the scores on a FER task. Most importantly, it has been found that FER can be impaired in newly diagnosed, treatment-naïve PD patients. Furthermore, lower- and higher order visual functions were related to impairments in FER.

First, the results showed that PD patients have more difficulties with FER than healthy controls. This is in accordance with earlier observations that FER can be impaired in the early stage of PD (Argaud et al., 2018; Mattavelli et al., 2021). However, literature lacks research on FER in newly diagnosed, treatment-naïve patients. The results of the current study contribute to the knowledge that FER indeed can be impaired in newly diagnosed, treatment-naïve PD patients. Worth noting, the PD group had a higher percentage of males than the HC group. It has been found in healthy controls that women perform better on the FEEST than men (Khosdelazad et al., 2020). It seems possible that this finding can be partly explained by the fact that the PD group consisted of more men than the HC group. In addition, the PD group showed more impairments in higher-order visual functions than healthy controls. This is in accordance with previous studies showing that higher-order visual functions can be

impaired in PD patients (Galtier et al., 2020; Uc et al., 2005). The lower-order visual scores of the PD group indicated poor contrast sensitivity, based on the scoring of the visual function task (Parede et al., 2013). Previous studies show that lower-order visual impairments can already be found in the prodromal phase of PD (Armstrong, 2015; Guo et al., 2018), and that PD patients have more impairments compared to healthy controls (Pieri et al., 2000). The findings are in line with the expectation that the PD group scores lower on the FER and higher-order visual tasks than the HC group.

Second, we analyzed whether FER ability is related to lower- and higher-order visual function. The performance on the lower-order visual task showed a weak relationship with the FER task. The performance on the higher-order visual tasks showed weak to moderate relationships with the FER task. This means that better visual functioning is associated with better FER functioning, and vice versa. This is in line with the expectation that visual functions may have a relationship with FER. A possible explanation for the weak to moderate relationships could be that PD patients compensate for their visual deficits in the beginning of the disease (Hipp et al., 2014), thus using compensatory strategies to maintain their FER ability. Nevertheless, significant weak to moderate relationships still suggest that visual functions are related to FER. This is in accordance with previous studies suggesting that FER impairments can be linked to visuospatial disturbances (Argaud et al., 2018; Mattavelli et al., 2021). The question arises whether the relationships between FER and visual functions get stronger as the disease progresses. It may be possible that the early stage PD patients were slightly affected in one domain and more affected in the other. The progression of the disease may cause more problems in the function that is now less affected, with as a result a higher relationship. However, if impairments in both FER and visual functions equally get worse over time, the relationship between the functions may stay the same.

The last question was whether lower- and higher-order visual tasks could predict the outcomes on the FER task. The whole model did significantly predict the FER task outcomes. It explained 31% of the variance and had a large effect size. Surprisingly, none of the visual function tasks was a significant predictor in the multivariate analysis. Only age and gender were significant predictors for the FER task outcomes. Older age was predictive of a lower score on the FER task. Meta-analysis has shown that older adults perform worse on FER tasks than younger adults (Gonçalves et al., 2018). Being male was predictive of a lower score on the FER task. Indeed, the PD group had a relative high percentage of males. Being male is a risk factor for developing PD and more men suffer from PD than women (Gillies et al,, 2014). As mentioned earlier, women seem to perform better on the FEEST than men (Khosdelazad et al., 2020). These findings are against the expectation that all visual function tasks could significantly predict the FER task outcome. It may be possible that a third factor such as age or gender plays a role in the relationships found between visual functions and FER in the previous section. However, it has previously been discussed that contrast sensitivity can be impaired in early stage PD patients, but that patients may compensate in the beginning for their lower-order visual losses by using higher-order cortical processing (Hipp et al., 2014). It is known that when the disease progresses, lower-order visual functions deteriorate. The higher-order mechanisms may no longer be sufficient to compensate for the lower contrast sensitivity. This raises the possibility that a stronger relationship can be found between lower-order visual function and FER in more advanced PD. The results of current study show that the visual functions are not significant predictors for the FER task scores. The FER impairments found in the early stage PD group could not be explained by the decreasing lower- and higher-order visual functions, which indicates that FER goes beyond visual functioning. FER is a component of the social cognition, and the social cognition domain has

recently been accepted as an independent cognitive domain, but should be studied more in relation to other cognitive domains (Alonso-Recio et al., 2021).

Implications

Studies show that deficits in social perception often occur in PD patients (Coundouris et al., 2019; Alonso-Recio et al., 2021). However, FER has not been extensively studied in newly diagnosed, treatment-naïve PD patients. The current study shows that FER can already be impaired in these patients. This finding has important implications for the family and friends of patients, and the multiple disciplines that work with PD patients, as problems in the social cognition domain can impact quality of life and communication with others (Carcone & Ruocco, 2017; Uem et al., 2016). Specifically, FER difficulties in PD are associated with increased interpersonal difficulties (Clark et al., 2008). When a patient is suffering from difficulties with FER, it can be made clear to relatives that the behavior of the patient can be a result of their disease and that this is not due to their personality. Psychologists should be more alert that FER difficulties can exist in early stage patients and possibly check this whenever these difficulties present.

When reviewing earlier studies suggesting factors related to FER, it stands out that these factors are other constructs rather than specific cognitive functions. Namely, studies show that FER is related to overall cognitive decline (Alonso-Recio et al., 2021), disease duration and disease severity (Argaud et al., 2018). The results of current study add that lower- and higher-order visual dysfunctions are associated with FER deficits. Therefore, when deficits in FER are demonstrated with the FEEST, it should be made clear whether the lower- and higher-order visual functions are affected and to which extent.

Limitations and strengths

The main limitation of this study is that the HC group did not have an ophthalmic examination. Therefore, the scores on the lower-order visual task of the PD group could not

be compared with the HC group. Indeed, the PD group had poor contrast sensitivity. However, this still raises the question whether this PD group had significant impairments in lower-order visual functions in comparison to the HC group. An additional limitation is that only one task of lower-order visual function was assessed. This may have contributed to the finding that the lower-order visual task had a weak relationship with FER and could not predict the FER scores. Perhaps other lower-order visual functions play a role in FER. Another limitation is the tasks used for measuring higher-order visual function. The TEA Map Search assesses visual selective attention and had a moderate relationship with FER. Notably, selective attention can be impaired in PD (Dujardin et al., 2013). It may be possible that problems in selective attention are partly responsible for lower scores on the TEA Map Search, and that the visual component is not as impaired as it is thought to be. Moreover, the JOLO assesses visuospatial perception and had a weaker relationship with FER. It has been found that PD-MCI patients score worse on the JOLO than PD patients without cognitive impairments (Galtier et al., 2020). Thus, it is possible that the visual component does not play a substantial role in FER. Furthermore, the PD and HC group differed in gender and educational level. This makes it difficult to interpret comparisons between the groups, especially because gender was a significant predictor for the FER task outcomes.

When looking at the way in which FER was measured, this could have had an influence on the outcomes. The test used in this study consists of black and white photographs that express a basic emotion, which is a static task. The photographs shown do not move which is not similar to the way in which emotions are shown in real life. A more dynamic approach to measuring FER could have given different results and should be considered in future research. Another theory to keep in mind is that hypomimia can contribute to deficits in FER (Livingstone et al., 2016; Argaud et al., 2016). Healthy individuals shortly mimic someone's emotion with their facial muscles, which activates a little of the emotion

(Livingstone et al., 2016). This can cause recognition of the given emotion. Since PD patients can have a masked face, it is suggested this contributes to deficits in FER. An emotion on a photograph could potentially be even harder to mimic than for instance a video of someone showing an emotion.

The strength of current study is that newly diagnosed, treatment-naïve PD patients were examined, which is a group of patients that has not been extensively studied yet. In this way, FER could be studied without the interfering effect of dopaminergic medication. Another strength is that the PD group was compared to an age-matched HC group to determine whether FER can be impaired in early stage PD, since it has been found that older adults above 60 years perform poorer than younger adults on FER tasks (Murray et al., 2022).

Future research

Since it is suggested that early stage PD patients compensate for their visual deficits, it would be beneficial to investigate whether lower-order visual dysfunctions in later stages of the disease have a stronger relationship with deficits in FER. As only one task of lower-order visual function was used, more lower-order visual functions should be investigated. In a similar manner, the current study used two higher-order visual tasks. This should be expanded by including more higher-order visual tasks. However, with our cross-sectional data we cannot demonstrate a causal relationship and the visual functions could not predict the FER task scores. Age and gender however turned out to be predictors of the FER task outcomes in the current study. Therefore, future research should consider studying other factors in relationship to FER.

It is essential to know that the group researched was treatment naïve, as most PD patients get prescribed dopaminergic medication sooner or later. Recent research has found that dopaminergic medication used by PD patients may reduce FER difficulties, however, patients still show greater FER deficits than healthy controls (Palmeri et al., 2020). This raises

the question how FER function can be improved by medication and is a considerable topic for future research.

Conclusion

The results of this study show that FER can already be impaired in newly diagnosed, treatment-naïve PD patients compared to healthy controls. This is an important finding, as the literature on FER in early stage PD patients is scarce and inconsistent. The lower- and higher-visual functions showed weak to moderate relationships with FER. These relationships are of interest and imply that visual functions are associated with FER. However, the visual tasks could not predict the FER task scores. Moreover, age and gender could predict the FER task scores. The current study highlights the importance of acknowledging that FER can already be impaired in newly diagnosed, treatment-naïve PD patients, as FER difficulties could have an impact on quality of life and relationships.

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