EXPLORING EMOTION RECOGNITION IN PEOPLE WITH PARKINSON'S

By

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Abstract

Parkinson's disease (PD) is a neurodegenerative condition affecting the basal ganglia. Traditionally, PD was viewed as a motor condition, characterised by tremor, rigidity and bradykinesia. PD is now recognised to involve non-motor symptoms, including changes in social cognition. One key domain is facial emotion recognition (FER), which is critical for effective social interaction. This thesis examined FER abilities in people with Parkinson's (PwP) and controls, and explored physical, pharmacological, and psychological factors that may contribute to differences in FER abilities.

Previous research, has frequently observed reduced recognition of negative emotions in PwP, compared to controls. However, findings can still be mixed, largely due to reliance on static stimuli (e.g. photographs). In **Chapter 2**, FER abilities were assessed using dynamic point-light face stimuli, providing a more ecologically valid measure. PwP showed reduced emotion recognition accuracy (ERA) scores for happiness and sadness, compared to controls. Furthermore, increasing spatial distance between individual point-lights that made up the outline of the faces displayed, reduced ERA scores (across all emotions tested) in PwP, compared to controls. This suggests that increasing spatial distance of facial features may disrupt emotion processing in PwP.

Chapter 3 explored pharmacological factors by testing the same PwP ON and OFF dopaminergic medication. ERA scores improved when PwP were ON dopaminergic medication, across all emotions tested, indicating that dopaminergic therapy may enhance FER abilities, without altering how spatial and kinematic information is processed.

Chapter 4 assessed psychological factors contributing to differences in FER abilities in PwP. Measures of internal emotional experience did not explain differences in FER abilities. However, higher depression severity in PwP was associated with better FER abilities, whereas lower interoceptive self-regulation in controls was linked to improved FER abilities. These findings suggest distinct psychological influences on FER abilities in each group.

Overall, this thesis demonstrates that PwP show reduced FER abilities compared to controls, likely reflecting a complex interaction between physical, pharmacological, and psychological factors. These findings provide a new insight into how FER abilities may be affected in PwP, and highlight potential areas of interest for future interventions to support social communication and improve quality of life for PwP.

Lay Abstract

Parkinson's disease (PD) is a condition that affects movement. More recently it has been recognised that it can also impact thinking, emotions, and social interactions in people with Parkinson's (PwP). For example, the ability to recognise emotions on other people's faces. This is an important skill for day-to-day communication.

This research explored how well people with Parkinson's (PwP) recognise emotions from faces, compared to people who do not have Parkinson's (controls). The research also examined why there may be differences between PwP and controls in their ability to recognise facial emotions.

In the first study, participants watched short videos where faces were displayed as moving dots that outlined different facial expressions. PwP were less accurate at recognising happiness and sadness. When the distance between the dots that outlined the face was increased, PwP were less accurate in identifying the correct emotion, compared to controls.

The next study tested each PwP twice in the PLF task. Once when they had taken their daily medicine for Parkinson's (ON), and once when they had not yet taken their medicine (OFF). PwP recognised emotions more accurately when ON medication, than when they were OFF medication.

The final study explored how people's emotions and personal traits might relate to how they recognise emotions in others. In PwP, higher levels of depression were linked to improved accuracy at recognising emotions from faces. In controls, being less aware of body signals, such as breathing, was linked to improved recognition of emotions.

Together, these findings suggest that PwP may have reduced abilities in recognising emotions from faces for a number of reasons. Understanding these differences could help to explain how Parkinson's can affect communication and guide new ways to support emotional understanding and improve quality of life for PwP.

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List of Abbreviations

Analysis of Variance (ANOVA)

Autism Quotient (AQ)

Bayes Factor (BF)

Beck's Depression Inventory (BDI)

Blood-Brain Barrier (BBB)

Control (CTRL)

Emotion Recognition Accuracy (ERA)

Emotional Quotient (EQ)

Facial Affect Selection Task (FAST)

Facial Expression Recognition (FER)

Generalised Additive Model (GAM)

Generalised Additive Mixed Model (GAMM)

General Linear Mixed Model Power and Sample Size (GLIMMPSE)

Geriatric Depression Scale (GDS)

Intelligence Quotient (IQ)

Intraclass Correlation Coefficient (ICC)

L-Dihydroxyphenylalanine (L-DOPA)

Levodopa Equivalent Dose (LED)

Linear Mixed Effects Model (LME)

Major Depressive Disorder (MDD)

Matrix Reasoning Item Bank (MaRs-IB)

Mild Cognitive Impairment (MCI)

Mindful Awareness in Body-Oriented Therapy (MABT)

Monoamine Oxidase-B (MAO-B)

Movement Disorder Society (MDS)

Multidimensional Assessment of Interoceptive Awareness Version 2 (MAIA-2)

Multimodal Emotion Recognition Test (MERT)

Non-verbal reasoning (NVR)

Parkinson’s Disease (PD)

Parkinson’s Disease – Mild Cognitive Impairment (PD-MCI)

Parkinson’s Disease Questionnaire (PDQ)

Perth Alexithymia Questionnaire (PAQ)

Point Light Faces (PLF)

Point Light Walkers (PLW)

People with Parkinson’s (PwP)

Reading the Mind in the Eyes (RME)

Schutte Self-Report Emotional Intelligence Test (SSEIT)

Snaith-Hamilton Pleasure Scale (SHAPS)

Standard Deviation (SD)

Standard Error of the Mean (SEM)

Toronto Alexithymia Scale (TAS)

Unified Parkinson’s Disease Rating Scale (UPDRS)

United Kingdom (UK)

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Chapter 1 – Introduction

Parkinson's disease (PD) is a progressive neurodegenerative condition of the basal ganglia. There are approximately 137,000 people with Parkinson's (PwP) in the United Kingdom (UK) (Lamptey et al., 2022; Parkinson's UK, 2018). While PD was traditionally viewed as a 'motor condition characterised by tremor (shakiness), rigidity (stiffness), and bradykinesia (slowed movement) (Jankovic, 2008; Clarke, 2007; Parkinson, 2002), PD is now recognised as a much broader condition. Alongside motor symptoms, PwP may also experience a range of non-motor symptoms. This may include changes in mood, cognition, and social functioning, all of which can significantly reduce quality of life.

Researchers have made great efforts to understand the underlying causes of PD. It is believed that the loss of dopaminergic neurons in the substantia nigra disrupts the nigrostriatal pathway that supports voluntary motor control and connects the substantia nigra with the striatum (Sonne et al., 2025; Ureshino & Ramírez, 2021; Drui et al., 2014). This loss of dopamine may not only help to explain the characteristic motor symptoms PwP experience, but may also contribute to the explanation behind non-motor symptoms (Gupta & Shukla, 2021; Chaudhuri & Schapira, 2009).

The causes of neurodegeneration in PwP are complex and are likely to involve the role of genetics, the environment, or an interaction between these two factors. Approximately 10-15% of all PwP have monogenic PD, while the majority have idiopathic PD (PwP with no identifiable cause) (Bandres-Ciga et al., 2020). Genes

associated with monogenic PD include: PINK1, PRKN, PARK7, LRRK2, SNCA, VPS35 and GBA (Coukos & Krainc, 2024). However, this thesis focusses on idiopathic PD since this accounts for the vast majority of cases (Tran et al., 2020). Focussing on idiopathic PwP ensures that the findings are applicable to the largest proportion of individuals affected by the condition.

Environmental risk factors have also been speculated as potential causes of PD and may include, pesticide exposure in food, and head trauma (Bloem et al., 2021; Mackay et al., 2019). At the cellular level, these genetic and environmental factors may trigger disease mechanisms including neuroinflammation, aggregation of the protein α-synuclein, and dysfunction of cellular organelles (e.g. mitochondria). Together, these disease mechanisms are believed to contribute to neuronal loss (Bloem et al., 2021; Imbriani et al., 2018; Kalia & Lang, 2015). These findings may suggest that PD is not the result of a single cause, but due to complex, multiple interacting pathways.

The complexity of potential causes and underlying disease mechanisms makes diagnosis particularly challenging in PwP. In the UK, the current diagnostic standard requires the presence of bradykinesia, plus the presence of one (or more) of the following: tremor at rest, rigidity or postural instability (Clarke et al., 2016). However, as symptoms tend to develop gradually and may overlap with expected age-related cognitive decline, there is often an extended period of time before individuals present to healthcare professionals (Randhawa & Varghese, 2024). Clinical assessment of motor and non-motor symptoms, may be supported by rating scales such as the Movement Disorder Society Unified Parkinson's Disease Rating Scale (MDS-

UPDRS), or the Hoehn and Yahr Scale (Goetz et al., 2008; Hoehn & Yahr, 1967). In addition, the confirmation of a diagnosis may also be sought through response to dopaminergic medication (Martin et al., 2020). Occasionally where diagnostic uncertainty remains, a dopamine transport scan may be used to visualise dopamine activity in the brain. This can help to distinguish between PD and other movement conditions that may present in an individual (Gayed et al., 2015).

Although PwP are clinically diagnosed based on motor symptoms, there is increasing recognition of the importance of non-motor symptoms. Among these are changes in social cognition, which may include reduced abilities in interpreting social cues, or managing complex social situations (Siripurapu et al., 2023). Social cognition has been defined as psychological processes that help us to understand and navigate social interactions (Frith, 2008). Specific examples of these psychological processes include: theory of mind, empathy, and facial expression recognition (FER) (Doskas et al., 2024; Coundouris et al., 2020; Bodden et al., 2010; Kawamura & Koyama, 2007). Recent research suggests that around one-third of PwP experience changes in social cognition, even in the early stages of the condition (Czernecki et al., 2021).These changes are clinically relevant as they could contribute to feelings of social isolation experienced by many PwP (Subramanian et al., 2020).

One key domain of social cognition is FER, which is the ability that enables individuals to perceive other people's feelings and intentions. This helps to support effective social functioning (Horstmann, 2003). Difficulties with FER have been well-documented in PwP, particularly in emotions with negative valences such as anger,

sadness, and disgust (Shafiei et al., 2020; Lin et al., 2016; Clark et al., 2008; Lawrence et al., 2007; Sprengelmeyer et al., 2003). These difficulties with FER are not just trivial problems. Reduced FER abilities are associated with higher levels of interpersonal distress in PwP (Clark et al., 2008).

However, it is important to note that findings on FER abilities in PwP remain inconsistent. While many studies found that PwP have reduced FER abilities compared to controls, others suggested that there were no significant differences in abilities compared to controls (Coundouris et al., 2022; Bek et al., 2020; Adolphs et al., 1998). Differences in FER abilities may arise from contrasting methodological approaches used across different studies. For example, the type of stimuli used, or variations in the condition stage of the PwP recruited. For instance, static stimuli (e.g. images of facial expressions) are often presented at their most exaggerated point, which could simplify the tasks and make them less nuanced than real-world interactions. In contrast, dynamic displays (e.g. videos of facial expressions) provide more ecologically valid tests of FER abilities but have been used less frequently in FER research in PwP. Importantly, studies that have used dynamic displays in FER tasks have sometimes not found any differences in FER abilities between PwP and controls, perhaps due to being overly simplistic (Coundouris et al., 2022; Bek et al., 2020). This highlights the need to increase task difficulty, to enhance sensitivity in detecting subtle differences in FER abilities between PwP and controls. This approach would also have the additional benefit to better capture the subtle nature of emotion recognition in real-life contexts.

Beyond different methodological approaches, it is also essential to consider the role of dopamine (i.e. a key neurotransmitter in the brain) in FER abilities, in PwP. Pharmacological treatments aim to restore dopamine function in PwP. However, direct dopamine replacement is not feasible due to its inability to cross the blood-brain barrier (BBB). This means that pharmacological therapies focus on indirectly increasing dopamine. One of the most common dopaminergic medications prescribed to PwP is levodopa, a precursor molecule that can cross the BBB, which is subsequently converted to dopamine in the brain (Zahoor et al., 2018). Dopamine agonists, such as pramipexole and ropinirole bind to and activate dopamine receptors (specifically the dopamine D2-like receptors), stimulating dopamine activity in the brain (Luo et al., 2020). On the other hand, monoamine Oxidase-B (MAO-B) inhibitors such as selegiline and rasagiline prevent dopamine from being broken down in the synaptic cleft, increasing dopamine availability for PwP (Tan et al., 2022; Peretz et al., 2016).

As some studies focus on the use of levodopa only, research findings can be difficult to generalise across the wider population of PwP where multiple dopaminergic medications are typically used (Dan et al., 2019; McIntosh et al., 2015; Tessitore et al., 2002). To address this limitation, this thesis includes PwP taking any dopaminergic medication. Different dopaminergic medication doses were converted by the Levodopa Equivalent Dose Calculator, into the levodopa equivalent dose (LED) (Cervantes-Arriaga et al., 2009; Parkinson's Disease Measurement: PwP, Surveys, Trials, Analysis, n.d.). LED simply refers to how much levodopa would need to be administered to have the same effect as the alternative dopaminergic medication, enabling more direct comparisons to be made across treatments.

Previous research has explored the influence of dopamine on various functions.They described how dopamine is central in motor control, learning, and emotion recognition (Schuster et al., 2022; Wood, 2021; Bogacz, 2020). In an earlier study, it was suggested that dopaminergic loss in PwP may have a negative influence on FER abilities (Sprengelmeyer et al., 2003). For example, PwP who were OFF dopaminergic medication were found to have reduced FER abilities, particularly for negative emotions. This could indicate that dopamine may play an important role in emotion recognition.

While dopamine appears to be an important factor in FER abilities, there may be other physical and psychological factors that influence FER abilities in PwP. For example, manipulating spatial and/or kinematic features in dynamic displays of facial expressions has already been shown to influence FER abilities in controls (Sowden et al., 2021; Kamachi et al., 2013; Pollick et al., 2003) Spatial features refer to the distance between facial landmarks in a dynamic display, while kinematic features refer to the speed of the facial movements in dynamic displays. It is important to consider that PwP may rely differentially on these cues compared to controls. This is because one of the cardinal symptoms that PwP experience is bradykinesia (slowed movements) and one study previously uncovered that the perception of emotions can be influenced by our own relative speed that we move at (Edey et al., 2017).

While pharmacological factors (dopaminergic medication) and physical factors (spatial and kinematic cues) could impact FER abilities in PwP, it is also important to consider if psychological factors could impact FER. This is because FER abilities could be influenced by how PwP experience their own emotions. Research in this

area has used affective scenes. This includes images of scenes people may encounter in everyday life that evoke different emotional responses. Unlike FER tasks that require participants to identify facial expressions to infer emotions in others, affective scene tasks assess how viewing emotive images influences the participant's own emotional experience. One study compared how PwP (ON their dopaminergic medication) and controls rated affective scenes for valence (positive or negative feelings) and arousal (level of emotional activation) (Moonen et al., 2017). This study suggested that PwP and controls have similar ratings for emotional valence and arousal to controls. Other studies showed PwP experience reduced intensity of emotional experience, especially for complex emotions (e.g. amusement and tenderness) (Salfi et al., 2024; Naranjo et al., 2023). However, it is important to note that because PwP were ON their dopaminergic medication in these studies, the medication may have 'masked' any actual baseline differences in internal emotional experiences. Additionally, many studies investigating emotional experiences using affective scenes, did not include measures of alexithymia (difficulties in describing and identifying your own feelings) or interoceptive awareness within their questionnaire batteries (Salfi et al., 2024; Naranjo et al., 2023; Moonen et al., 2017; Taylor, 1984). This is a clear limitation in the current literature on internal emotional experiences in PwP because both alexithymia and interoceptive awareness are known to influence emotional processing and/or recognition (Culicetto et al., 2024; Bennett & Hacker, 2005).

Despite the breadth of existing research into emotion recognition in PwP, several general limitations within the existing literature demand consideration. Firstly, many studies have relied on static stimuli while researching FER (Salfi et al., 2024;

Czernecki et al., 2021; Lin et al., 2016; Clark et al., 2008; Lawrence et al., 2007; Sprengelmeyer et al., 2003; Adolphs et al., 1998; Borod et al., 1989). However, static stimuli (e.g. photographs) fail to capture the dynamic and complex nature of FER that occurs during social interactions in the real-world.

Secondly, whilst only a handful of papers use dynamic displays (e.g. videos) to assess FER abilities in PwP and controls, their findings have been inconsistent (Coundouris et al., 2022; Shafiei et al., 2020; Bek et al., 2020). As mentioned previously, future studies may need to consider the use of a more difficult task to assess emotion recognition, for example, by using point-light displays of faces. This is because point-light displays would reduce the amount of visual information of the face, by simply outlining key features of the face (e.g. eyes and mouth) with point-lights. This may be a better alternative suited to detecting subtle group differences in recognising emotions when comparing FER abilities in PwP and controls.

Thirdly, few studies have assessed the same PwP both ON and OFF dopaminergic medication. Sprengelmeyer and colleagues (2003) compared distinct groups of PwP who were assessed while either ON or OFF dopaminergic medication. Furthermore, other studies only considered emotion recognition abilities in PwP in one medication state (i.e. usually when PwP were ON their dopaminergic medication) (Salfi et al., 2024; Coundouris et al., 2022; Bellot et al., 2021; Bek et al., 2020; Shafiei et al., 2020; Clark et al., 2008). Testing PwP exclusively while they were ON their dopaminergic medication prevented researchers from establishing a true baseline measure of emotion recognition abilities, without any influence of dopaminergic medication.

Finally, many studies have demonstrated differences in FER between PwP and controls, but few have investigated why these differences may occur (Salfi et al., 2024; Czernecki et al., 2021; Shafiei et al., 2020; Lin et al., 2016; Clark et al., 2008; Lawrence et al., 2007; Adolphs et al., 1998; Borod et al., 1989). The few studies that have investigated potential factors that could contribute to differences in FER between PwP and controls, have mainly focussed on dopamine (i.e. a potential pharmacological factor). However, other physical (e.g. spatial and kinematic cues) and psychological (e.g. internal emotional experiences) factors that could contribute to differences in FER abilities in PwP, remain underexplored. Addressing these gaps is essential for building a more complete understanding of FER in PwP.

In response to these limitations, there are three overarching aims of the current thesis. The first aim is to directly compare FER abilities between PwP and controls using dynamic point-light displays. This has the advantage of providing a more ecologically valid way to measure FER abilities, as well as providing a convenient way to manipulate spatial and kinematic cues of facial movement. The second aim is to examine how dopamine influences FER abilities by testing the same PwP ON and OFF their dopaminergic medication. The third aim is to explore potential factors that could contribute to differences in FER abilities. These potential factors will span across three broad domains:

1. Physical factors – comparing FER abilities in PwP OFF their dopaminergic medication and controls in response to spatial and kinematic manipulations in dynamic point-light displays of facial expressions (see **Chapters 2 and 3** for further details).

2. Pharmacological factors – comparing FER abilities in PwP ON and OFF their dopaminergic medication (see **Chapter 3** for further details).
3. Psychological factors – examining internal emotional experiences and their possible links to FER, measured through the EmoMap task and questionnaires (see **Chapter 4** for further details).

Together, these three aims were shaped by limitations identified in the current literature. These aims provide a comprehensive approach to understand FER in PwP by integrating dynamic tasks, pharmacological comparisons, and assessments of internal emotional experiences. This thesis aims to clarify the extent of FER difficulties when using dynamic displays, in PwP compared to controls, and the factors that may contribute to these difficulties.

Chapter 2 – Comparing Facial Expression Recognition in People with Parkinson's OFF their Dopaminergic Medication and Controls

2.1 Introduction

Studies indicate that several disease processes, for example, neuroinflammation, the aggregation of α-synuclein, as well as mitochondrial dysfunction can contribute to the loss of mainly dopaminergic neurons, resulting in the cardinal motor symptoms PwP experience (Oliveira et al., 2024; Bloem et al., 2021; Imbriani et al., 2018; Reeve et al., 2018; Kalia & Lang, 2015). However, beyond these motor symptoms, PwP may also experience socio-cognitive challenges (Eddy & Cook, 2018). Specifically, FER may become difficult, which is an essential part of social interaction and communication (Foley et al., 2019; Ricciardi et al., 2017).

Challenges with FER for PwP leads to challenges in understanding the emotions of other people. This can have a negative impact on their social relationships and quality of life (Coundouris et al., 2020; Prenger et al., 2020). Despite diagnosis of PD being primarily based on motor symptoms (see **Chapter 1**), the presence of socio-cognitive challenges for PwP suggests that we also need to investigate non-motor symptoms of this condition and how these may impact daily lives for PwP (Marsili et al., 2018).

While non-motor symptoms, including sleep problems and fatigue, are gaining recognition in clinical assessment (e.g. the 'Non-Motor Aspects of Experiences of Daily Living' item was added into the UPDRS in 2008), there remains a need to understand FER abilities in PwP (Goetz et al., 2008). As mentioned previously, FER is a necessary skill required to understand others, and difficulties with FER can reduce quality of life for PwP (Coundouris et al., 2020; Prenger et al., 2020). This thesis aims to build upon

the existing literature by comparing FER abilities in PwP and controls. Furthermore, this thesis aims to identify individual factors that may contribute to differences (if any) in FER abilities between PwP and controls, with the long-term goal of improving overall quality of in PwP.

Although studies have noted differences with FER in PwP, compared to controls, it appears that not all emotions are equally challenging. Researchers have recorded differences in terms of FER in PwP for 40 years (Lin et al., 2016; Clark et al., 2008; Sprengelmeyer et al., 2003; Jacobs et al., 1995; Borod et al., 1990; Scott et al., 1984). A recent review notes that 64% of studies confirmed difficulties with FER in PwP (Argaud et al., 2018). Although studies have noted differences in the recognition of the six basic emotions (anger, happy, sad, disgust, fear and surprise) in PwP, they do not all appear to be equally challenging. For example, in a study by Lawrence and colleagues (2007), they recruited PwP (OFF their dopaminergic medication) and controls. Participants viewed photographs of models displaying six facial expressions (anger, disgust, fear, sadness, happiness and surprise) and then selected the emotion label that best represented the emotion displayed. They noted that PwP were less accurate when identifying anger, compared to controls. This suggests that although previous studies have confirmed that PwP struggle with FER, perhaps some expressions are more difficult to recognise than others.

Some studies suggest that there may be a particular difference in FER abilities between PwP and controls when comparing their ability to recognise negative emotions. A review by Argaud and colleagues (2018), gathered evidence from 59 papers and made 97 comparisons between PwP and controls to surmise whether FER differences were seen in PwP. The authors assessed numerous studies to quantify

difficulties in each of the six basic emotions. They found that the percentage of confirmed difficulties for negative emotions such as anger (44%), fear (54%) and sadness (51%) appears to be higher than the percentage of confirmed difficulties for positive emotions, such as happiness (27%). Together, this information may support the idea that negative emotions could be more difficult for PwP to recognise.

Whilst many studies have focussed on which emotions are more difficult for PwP to recognise, they often neglected investigating potential reasons for why there may be differences in FER abilities. One study investigated FER abilities between PwP and controls, as well as assessing if hypomimia (reduced facial expressions) in PwP could be a potential reason for differences seen in FER abilities (Gobbo et al., 2024). However, this study noted that reduced FER abilities in PwP (as stated in previous literature) may be due to difficulties in processing emotions, rather than interpretation of facial movements. This is because hypomimia scores did not seem to affect how PwP processed facial expressions. This highlights how future research should not only consider FER abilities in PwP and controls, but also why differences (if any) exist between these groups.

This chapter will consider FER abilities in PwP and controls, as well as potential reasons for differences, if any, exist. Previous research suggests that PwP experience challenges with biological motion processing (Jaywant et al., 2016). Biological motion processing refers to the immediate perception of complex movements (Cao et al., 2015). Point-light displays (see **Section 2.2.1** for details on point-light displays) are the most frequently used stimulus in biological motion processing (Vanrie & Verfaillie, 2004). In the study by Jaywant and colleagues (2016), PwP (ON their dopaminergic medication) and controls were recruited to view ‘point-light walkers’ (PLW) and

‘scrambled’ stimuli, ‘walking’ at a variety of kinematic (speed) levels. PLW are stimuli consisting of a human doing an activity (e.g. walking) which is depicted by the movement of white dots (point-lights) on a black background. The white dots, in this case, make up the outline of a human body. The scrambled stimuli randomised the location of the dots, from a PLW video. This meant that individual dots still had the same motion, but the location of the dots changed (i.e. the dots no longer represented the outline of a human). After watching each video participants stated whether they saw a human walking. Following on from this, the previous PLW and scrambled stimuli used were displayed as ‘visual noise masks’. These visual noise masks were made by duplicating and then randomising the starting point of each dot. For example, the dot for the head would be duplicated and then randomised, to be located near the dot for the right wrist. To perceive a human walking, participants would have to recognise the global structure of the human outline and not consider individual dots. Again, participants were asked to say whether they saw a human walking, but this time, the researchers explained that the human may be walking “in a cloud of extra dots”. This study concluded that PwP had reduced sensitivity to biological motion, compared to controls, regardless of the walking speed. However, it would also be interesting to investigate how PwP respond to point-light displays and changing speed when they are OFF their dopaminergic medication. This is because the study by Jaywant and colleagues (2016), only considered when PwP were ON their dopaminergic medication, which may have masked some of the potential problems PwP could have with interpreting speed in the stimulus. Future studies should also consider performing similar tasks in the same group of PwP when they are ON and OFF their dopaminergic medication to decipher if changes in dopamine levels affects abilities such as biological motion perception.

In this thesis, dynamic displays will be used in the Point-Light Faces (PLF) task. We manipulated kinematic and spatial features in the PLF task. A change in the kinematic levels of these displays, refers to a change in speed. In other words, how quickly the dots appear to move on the screen. Additionally, a change in spatial levels, refers to a change in the distance between point-lights in a point-light display. We chose to focus on changing kinematic features because previous studies have noted the contribution of kinematic levels in FER accuracy in dynamic displays (Keating et al., 2022; Sowden et al., 2021). In these studies, high speeds are associated with anger and to a lesser extent, happy emotions. Contrastingly, slower speeds are attributed to sadness. Therefore, it would be interesting to explore this general concept to see how it applies to PwP. We also investigated the role of changing spatial features on FER accuracy. Similarly to changing kinematic features, studies have noted the contribution of spatial levels in FER accuracy in dynamic displays (Keating et al., 2022; Sowden et al., 2021). In these studies, spatial exaggeration (i.e. increased distance between individual point-lights in the point-light displays, or in other words, an increased 'size' of movement seen), was associated with improved ERA scores for happiness and anger. Alternatively, decreasing spatial levels was associated with improved ERA scores for sadness. Again, it would be interesting to see if this concept remains true for PwP, or if PwP respond differently to a manipulation in spatial levels. Changing kinematic and spatial features of point-light displays, appears to generate specific changes in FER in previous studies, therefore we decided to focus on these features to see if they also affect FER abilities in PwP, similarly to what previous studies found.

One main hypothesis was constructed for this chapter, and one exploratory hypothesis. Based on the literature suggesting that FER is reduced in PwP for negative emotions, a group by emotion interaction was predicted (Lin et al., 2016;

Clark et al., 2008; Lawrence et al., 2007). It is anticipated that PwP and controls will differ in their ERA scores for anger and sadness, but have comparable scores for happiness. This is because, as stated in previous literature, the recognition of negative emotions appears to be particularly affected in PwP. The exploratory hypothesis aimed to uncover whether differences (if any), in FER abilities when comparing PwP and controls, was due to physical factors (i.e. do PwP have difficulties processing kinematic and/or spatial aspects of the face?).

2.2 Methods

2.2.1 Participants

34 PwP (15 female; M_{AGE} = 67.03 years) and 32 gender and age-matched controls (15 female; M_{AGE} = 66.33 years) took part in this study (**Table 2.1**). PwP were recruited for this study through an advertisement on the Parkinson's UK website, where they could express interest in participation, via email. Control participants were recruited through an email advertisement sent to individuals on the Older Adults Database at the Centre for Human Brain Health, University of Birmingham. All PwP were given a diagnosis of idiopathic Parkinson's, with a maximum of seven years since diagnosis. They were all taking dopaminergic medication for Parkinson's, as prescribed by their clinicians. Among the 32 PwP participants, 29 were taking levodopa-based therapies, including co-careldopa or co-beneldopa. 14 were taking dopamine agonists, including ropinirole and pramipexole. Lastly, 10 were taking monoamine oxidase inhibitors including rasagiline and selegiline (**Table 2.1**). It is important to note that these numbers reflect the total users of each drug class and are not mutually exclusive, as some participants were on combination therapies (involving more than one class of dopaminergic medication). Exclusion criteria included a diagnosis of co-occurring

motor problems or movement conditions such as Developmental coordination disorder, Huntington's disease and Tourette syndrome. Other exclusion criteria included the diagnosis of psychiatric clinical conditions such as schizophrenia, personality disorder, or a learning disability. All participants gave their full and informed consent. The study was approved by the Science, Technology, Engineering and Mathematics Ethical Review Committee at the University of Birmingham (ERN_18-1800D). Participants were reimbursed for their time at a rate of £10.00 per hour. Data from two participants had to be excluded as they did not complete the full task. Data from 32 PwP (14 female; M_{AGE} = 66.63 years) and 32 gender and age-matched controls (15 female; M_{AGE} = 66.33 years) were included in the final analyses (**Table 2.1**).

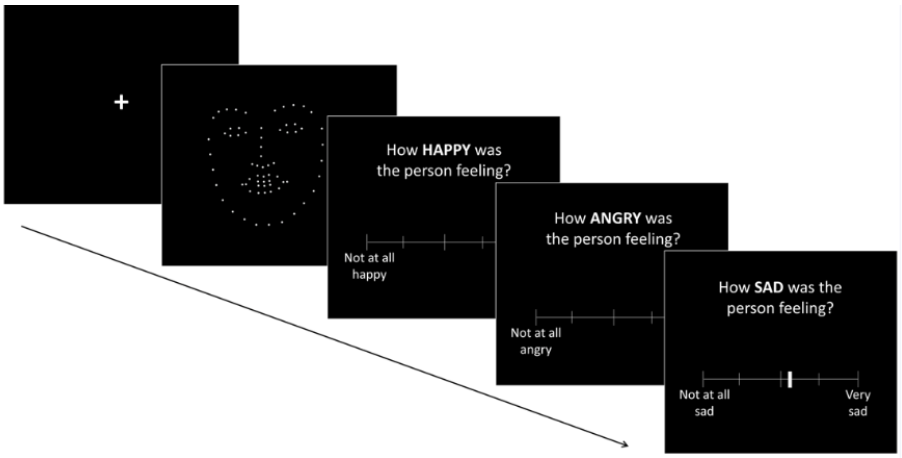
2.2.2 Stimuli

The PLF task was developed by Sowden et al., (2021) and further adapted by Keating et al., (2022). The videos displayed PLF stimuli (**Figure 2.1**). PLF stimuli are videos in which facial expressions are depicted by the movement of dots. Videos were recorded using four actors (two female, two male) who read a scripted sentence (e.g., "My name is John and I'm a scientist"). The actors were told to express the sentence using three different emotions (angry, happy and sad). The videos were modified to display three different spatial extents (S1 (50% of the spatial movement), S2 (100% of the spatial movement) and S3 (150% of the spatial movement) corresponding to spatially reduced, normal, and spatially exaggerated respectively) and three different speed levels (K1, K2 and K3) corresponding to slowed-down (50% of the recorded speed), normal, and sped-up (150% of the recorded speed) respectively. Therefore, in total there were 108 video stimuli. In terms of spatial manipulation, the movement of facial

features from one frame to the next was increased or decreased to give an increase or reduction in spatial exaggeration, respectively. Different speed levels were achieved by saving PLF frames at different frame rates. This made it appear as if there was varying facial movement speed.

Figure 2.1

Point Light Faces Task Trial Structure



Note. Example of one trial in the Point Light Faces task (taken from Sowden et al., 2021).

2.2.3 Questionnaires and Tasks

Autism Quotient-50 (AQ-50): This 50-item questionnaire assesses autistic traits (Baron-Cohen et al., 2006). The AQ-50 uses a four-point Likert scale (definitely agree, slightly agree, slightly disagree and definitely disagree). This questionnaire is scored out of 50 and the higher the score, the greater the level of autistic traits present in the individual. In addition to this score out of 50, individual sub-scale scores can be calculated from this (attention switching, attention to detail, communication, social skill and imagination). Autistic traits were important to assess as autistic individuals and

those with higher levels of autistic traits are known to have difficulties with FER (Bothe et al., 2024). Therefore, it is important to account for autistic traits when analysing results to ensure that any differences in FER abilities are due to PD and not as a result of having higher levels of autistic traits. The AQ-50 was chosen as it can be self-administered, meaning participants were able to complete it independently, in their own time. In contrast, other questionnaires assessing autistic traits would have involved assessing behaviours and having structured conversations. One example is the Autism Diagnostic Observation Schedule, which requires formal training to administer. In addition, the AQ-50 has a good internal consistency score ($\alpha \geq 0.7$) and test-retest reliability ($r \geq 0.8$.) (Stevenson & Hart, 2017).

Toronto Alexithymia Scale-20 (TAS-20): This 20-item questionnaire assesses alexithymia traits (Bagby et al., 1994). The TAS-20 uses a five-point Likert scale (strongly disagree, disagree, neither agree nor disagree, agree and strongly agree). The scores can range from 20 to 100 and the higher the score, the greater the level of alexithymia. There are three individual sub-scale scores: difficulty describing feelings, difficulty identifying feelings and externally oriented thinking. TAS was included because it is the gold-standard alexithymia questionnaire that is adopted by most scientific studies that want to explore alexithymia traits in their participant population. TAS has been used extensively across different clinical populations including, the autistic population, people with eating disorders and, PwP (Ridout & Wallis, 2021; Kinnaird et al., 2019; Assogna et al., 2012). The TAS-20 has a good internal consistency score ($\alpha \geq 0.7$) and test-retest reliability ($r \geq 0.7$) (Bagby et al., 1994).

Perth Alexithymia Questionnaire (PAQ): This 24-item questionnaire assesses alexithymia traits (Preece et al., 2018). The PAQ uses a seven-point Likert scale

(ranging from strongly disagree to strongly agree). The scores can range from 24-168 and the higher the score, the greater the level of alexithymia. There are five individual sub-scale scores: negative – difficulty identifying feelings, positive – difficulty identifying feelings, negative – difficulty describing feelings, positive – difficulty describing feelings and general – externally oriented thinking. PAQ was included in the questionnaire battery because for someone with true alexithymia characteristics, the language used in the PAQ is more accessible than the TAS questionnaire. For example, in PAQ it is stated, “when I’m feeling bad, I can’t tell whether I am sad, angry or scared”. Additionally, “bad” is defined at the beginning of the PAQ. These definitions could help people with higher alexithymia traits understand what feelings the question is referring to. The PAQ has a good internal consistency subscale score ($\alpha \geq 0.8$) (Preece et al., 2018). Test-retest reliability was also measured as good (ICC = 0.70-0.79) (Cai et al., 2024).

Movement Disorder Society – Unified Parkinson’s Disease Rating Scale (MDS-UPDRS) Part II Motor Aspects of Experiences of Daily Living (M-EDL): This 13-item questionnaire assesses motor aspects of experiences of daily living (Goetz et al., 2008). The scores are out of a maximum of 52. The greater the scores, the greater the difficulties in motor aspects of experiences of daily living. This particular questionnaire was chosen as it could be self-administered, meaning participants could complete this in their own time. Additionally, the MDS-UPDRS Part II has strong psychometric properties. For example it has an excellent internal consistency score ($\alpha \geq 0.9$) and test-retest reliability (ICC = 0.85) (Siderowf et al., 2002; Martínez-Martín et al., 1994).

Matrix Reasoning Item Bank (MaRs-IB): This 80-item task assesses non-verbal reasoning (Chierchia et al., 2019). This task is eight minutes in total, regardless of

how many items you complete during those eight minutes. Participants do not have to complete all 80 items of the MaRs-IB. Each item is made up of a 3 x 3 matrix, making 9 cells in total. One of these cells in the bottom-right corner is empty and participants must choose the correct abstract shape out of four shapes provided to them. To choose the correct shape, participants must configure the relationship between the other shapes in the matrix. These shapes change in colour, size, shape and position. The MaRs-IB was selected because it measures non-verbal reasoning (NVR) and therefore, it can act as a proxy for cognition (Zorowitz et al., 2024). This provided an overview of cognitive abilities in PwP and controls. Another advantage is that participants could complete this in their own time, without the need for an experimenter having to conduct an interview on Zoom with them (e.g. the mini-mental state examination), to assess cognition (Folstein et al., 1975). The MaRs-IB-IB has a reasonable internal consistency value (Kuder-Richardson 20 ≥ 0.7) and test-retest reliability ($r = \geq 0.7$).

2.2.4 Procedure

Participants were asked to complete the PLF task online. This study was performed online for a number of reasons, such as for accessibility reasons and equal opportunities. This is because from an ethical perspective, it would not be advisable to take PwP OFF their medication and make them do an in-person study, especially in an unfamiliar environment. This could pose potential dangers including that PwP would be more likely to fall over and injure themselves. Therefore, the study was conducted online.

Participants were sent a link to the study in an email. The PLF task was conducted on Gorilla (Build-2022-10.25), allowing participants to complete the task remotely.

Participants received detailed written instructions via email on the testing day, outlining the study. A researcher was made available via email and phone during the session to provide assistance, if needed. The PLF task lasted approximately 45 minutes and was completed in one sitting. Instructions provided during the testing session were kept simple and in large-font formats. The task began with a silent PLF video and following this, participants rated how angry, happy and sad the person in the video was feeling. This visual analogue scale ranged from 'not at all angry/happy/sad' to 'very angry/happy/sad. It is important to note that the order of presentation of each emotion rating scale (angry, happy, and sad) was randomised on each trial. All participants performed the PLF task over two consecutive days, this was due to a drug manipulation for PwP (explained further in **Chapter 3**). For example, on the first day, if they were a participant with Parkinson's taking dopaminergic medication, we asked if they could complete the tasks before taking their first dose of medication. Following this, on the second day the participant was asked to complete the PLF task approximately one hour after taking their first dose of medication in the morning. The order of days on which they took their dopaminergic medication was counterbalanced. This is to ensure any effects of order were accounted and balanced for. Control participants also completed the PLF task twice, at similar times of the day, for two consecutive days. To reiterate, the results in this chapter, reflect when PwP were OFF their dopaminergic medication. For the control participants, half of the participants were taken from day one and half from day two (for justification of this technique see **Section 2.3.3**). This technique also ensured that practice effects were controlled for. Participants were also asked to complete a non-verbal reasoning task, The Matrix Reasoning Item Bank (MaRs-IB), on Gorilla (Build-2022-10.25). This was followed by a battery of questionnaires: AQ, TAS-20, PAQ and the UPDRS Part II (Motor

Experiences of Daily Living). These questionnaires were completed on an institutionally licensed version of Qualtrics. Together, these questionnaires and the MaRs-IB took no longer than one hour.

To ensure consistent stimulus presentation and control for variability in display size and resolution, participants' screen resolution and browser window dimensions were recorded using Gorilla's 'Browser Info' node. Participants were instructed to complete the study on a desktop computer or laptop (mobile phones and tablets were not permitted). Screen size data was reviewed and any participants using a screen resolution below the minimum threshold (1366 x 768) were excluded from the analysis.

2.2.5 Statistical Analyses

2.2.5.1 Group Matching

To check if the groups (PwP and controls) matched on age, non-verbal reasoning, alexithymia (TAS and PAQ) and autistic traits (AQ), independent-samples t-tests were conducted. To assess if the groups matched on gender, a chi-squared analysis was run.

2.2.5.2 Group Differences

Differences in parkinsonian traits (UPDRS) were assessed using an independent-samples t-test.

2.2.5.3 Emotion Recognition Accuracy Score

The emotion ratings for angry, happy and sad, on each trial were given a score from 0 to 10 (Keating et al., 2022). 0 represented a response of 'not at all angry/happy/sad

and 10 represented a response of ‘very angry/happy/sad. To calculate an emotion recognition accuracy (ERA) score, when a sad PLF is shown, the mean rating of the two incorrect emotions (angry and happy) were subtracted from the rating for the correct emotion (sad).

2.2.5.4 Analysis of Variance (ANOVA)

The main aim was to confirm if PwP had differences in terms of FER (seen as differences in the ERA scores), compared to controls when dynamic displays (PLF task) were used. The exploratory aim, was to manipulate speed and spatial levels in dynamic stimuli (PLF task) to reveal which factor (if any), contributed to the observed differences (if found, as part of the main aim) in ERA scores in PwP. These aims were achieved by participants performing the PLF task and calculating ERA scores. Following this a 2x3x3x3 Analysis of Variance (ANOVA) with the between-subjects factor, group (PwP, control) and the within-subjects factors emotion (angry, sad, happy), stimulus kinematic level (K1, K2 K3) and stimulus spatial level (S1, S2, S3) (Keating et al., 2022) was calculated. ERA score was the dependent variable.

2.2.6 Pre-Registration, Power Analysis, and Data Availability

The pre-registration for this study can be found online at https://osf.io/vzj2b. No changes or deviations were made in terms of study design, data collection procedures or the analysis plan since writing the pre-registration.

To estimate the required sample size, an a priori power analysis was conducted using General Linear Mixed Model Power and Sample Size (GLIMMPSE) (Kreidler et al., 2013). One study suggested that difficulties in FER were greater for unmedicated PwP (N=20) than medicated PwP (N=16), it should also be noted that this study used a

between-subjects design (Sprengelmeyer et al., 2003). In other words, different PwP were recruited for the ON and OFF dopaminergic medication groups. Whilst Chapter 2 focusses on comparing FER abilities in PwP OFF their dopaminergic medication versus controls, we chose to base our power calculation on Sprengelmeyer's study, due to the similar set-up to this study. This is because both studies are comparing differences in emotion recognition in PwP (ON and OFF their dopaminergic medication) and controls. Furthermore, in the Sprengelmeyer study, the differences in FER accuracy between PwP ON and OFF their dopaminergic medication, were less pronounced than those between PwP and controls. Therefore, there would be a larger effect size when comparing PwP and controls. This suggests that less people would be needed when comparing FER abilities in PwP and controls. Therefore, this power analysis (based on FER abilities from PwP ON and OFF their dopaminergic medication), gave us the maximum possible number of participants needed in this study. In addition, as this thesis planned two separate comparisons (PwP versus controls, Chapter 2 and PwP ON medication versus PwP OFF medication, Chapter 3), this one a priori power analysis allowed us to cover the participants needed for both chapters. This approach had the added benefit of ensuring sufficient power to detect effects in both comparisons, while maintaining consistency across these two studies. In order to have 80% power to detect a difference in FER between unmedicated and medicated PwP (Cohen's d = 0.62; (Sprengelmeyer et al., 2003)) at alpha-level 0.05, 32 participants were necessary per group. It was concluded that a minimum of 64 participants should be recruited for this study (at least 32 PwP and at least 32 controls).

Anonymised data will be made available on an open-access repository (e.g. OSF) following publication of the main findings, in accordance with GDPR and ethical guidelines approved by the Research Ethics Committee at the University of

Birmingham. All shared data will be fully anonymised and accompanied by documentation to support the reuse of these findings.

2.3 Results

2.3.1 Group Matching

Descriptive statistics for PwP and controls are listed in **Table 2.1,** in addition to tests of equivalence. PwP and controls did not significantly differ in terms of gender, age, alexithymia traits (TAS and PAQ) and autistic traits (AQ).

2.3.2 Group Differences

Parkinsonian traits were measured via the UPDRS. This score confirmed that PwP scored significantly higher than controls (UPDRS: $t(62) = -8.83$, $p < 0.001$). This confirms that parkinsonian traits were higher for PwP compared to controls. Non-verbal reasoning abilities were measured via the MaRs-IB. It was found that PwP scored significantly lower than controls (MaRs-IB: $t(62) = 2.22$, $p = 0.03$).

Table 2.1

Descriptive Statistics for People with Parkinson's (PwP) Versus Controls (CTRL)

	PwP (n = 32)	CTRL (n = 32)	Test of Equivalence
Gender	18 M, 14 F, 0 O	18 M, 14 F, 0 O	$X^2(1, N = 64) = 0.00, p = 1.00$
Age	66.66 [10.72]	65.91 [6.32]	$t(62) = -0.34, p = 0.73$
Dopaminergic Drug Class	Levodopa = 29 Dopamine Agonist = 14 Monoamine Oxidase-B Inhibitor = 10	-	-
Non-Verbal Reasoning	0.53 [0.13]	0.60 [0.14]	$t(62) = 2.22, p = 0.03$*
Alexithymia Traits (TAS)	42.28 [11.46]	40.06 [9.52]	$t(62) = -0.84, p = 0.40$
Alexithymia Traits (PAQ)	67.63 [31.91]	56.44 [20.66]	$t(62) = -1.67, p = 0.10$
Parkinsonian Traits (UPDRS)	10.50 [5.84]	0.97 [1.79]	$t(62) = -8.83, p < 0.001$***
Autistic Traits (AQ)	17.19 [6.82]	16.38 [7.23]	$t(62) = -0.46, p = 0.65$

Note. Descriptive statistics for people with Parkinson's (PwP) versus controls (CTRL). This table has the mean (M) and standard deviations (SD) for age (in years), non-verbal reasoning, TAS, PAQ, UPDRS and AQ (M[SD]). For the 'Dopaminergic Drug Class' row, numbers represent how many PwP take levodopa, dopamine agonists, or monoamine oxidase-B inhibitors. It is important to note that some PwP took a combination of drugs, across some (or all) of these drug classes. For tests of equivalence, significant p-values represent differences between groups. M = male, F = female, O = other, TAS = Toronto Alexithymia Scale, PAQ = Perth Alexithymia Questionnaire, UPDRS = Unified Parkinson's Disease Rating Scale, AQ = Autism Quotient. *** $p < 0.001$, * $p < 0.05$.

2.3.3 Comparison of Emotion Recognition Accuracy Scores Between People with Parkinson's and Controls

In this chapter, we compared ERA scores between PwP OFF their dopaminergic medication and controls (50% of controls from day one and 50% from day two). We chose to compare controls in this way because of how we designed the study. The order of days on which PwP took their medication (either one hour before

(representing the ‘ON’ state) or after (representing the ‘OFF’ state) performing the task), was counterbalanced. In other words, 50% of the PwP did the task before taking their medication on day one and the other 50% of the PwP did the task before taking their medication on day two of the study. We reflected this in our comparison control group by randomly selecting 50% of the controls from day one and 50% from day two.

Main Effect of Emotion, Spatial and Kinematic Levels on Emotion Recognition Accuracy Score

To compare these ERA scores, we used a 2x3x3x3 ANOVA, with the between-subjects factor, group (PwP, control) and the within-subjects factors, emotion (happy, angry, sad), kinematic (K1, K2, K3) and spatial (S1, S2, S3) level. This analysis showed a main effect of emotion ($F(2, 124) = 4.06$, $p = 0.025$, $\eta_P^2 = 0.061$), a main effect of spatial level ($F(2, 124) = 182.67$, $p < 0.001$, $\eta_P^2 = 0.747$) and a main effect of kinematic level ($F(2, 124) = 5.16$, $p = 0.007$, $\eta_P^2 = 0.077$). A main effect of emotion indicates there is an effect of emotion (happy, angry, sad) on ERA scores (happy: mean = 2.64, SEM = 0.122; angry: mean = 2.35, SEM = 0.127; sad: mean = 3.03, SEM = 0.110). A main effect of spatial level indicates there is an effect of spatial level on ERA scores, whereby increasing spatial level leads to improved ERA scores (S1: mean = 1.53, SEM = 0.119; S2: mean = 3.00, SEM = 0.105; S3: mean = 3.50, SEM = 0.121). A main effect of kinematic level indicates there is an effect of kinematic level on ERA scores, whereby increasing kinematic level leads to improved ERA scores (K1: mean = 2.50, SEM = 0.130; K2: mean = 2.74, SEM = 0.112; K3: mean = 2.77, SEM = 0.117). One interesting observation is that no kinematic by group ($F(2, 124) = 1.70$, $p = 0.186$, $\eta_P^2 = 0.027$) interaction was found.

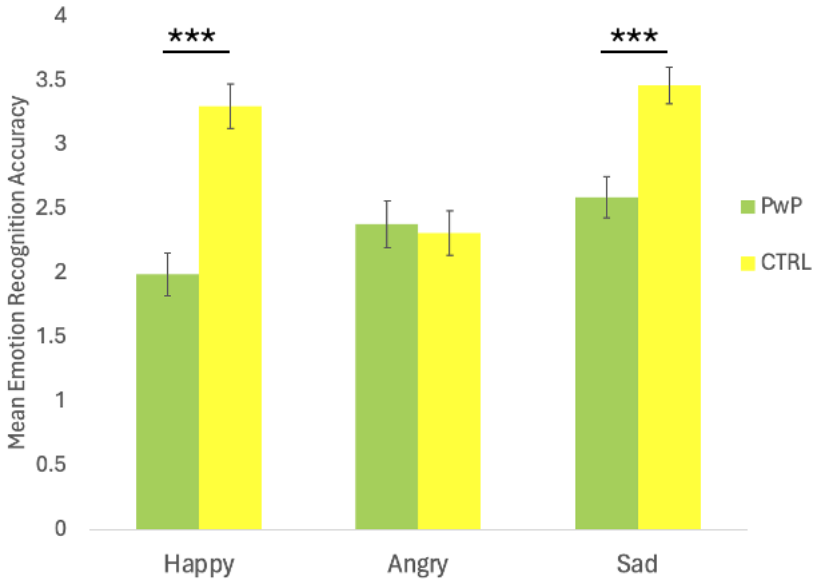
This suggests that PwP and control participants are similarly affected by kinematic manipulations.

Reduced Emotion Recognition Accuracy Scores for Happiness and Sadness in People with Parkinson's

When a 2x3x3x3 ANOVA, with the between-subjects factor, group (PwP, control) and the within-subjects factors, emotion (happy, angry, and sad), kinematic level (K1, K2, K3) and spatial level (S1, S2, S3) was applied to the data, an emotion by group interaction ($F(2, 124) = 4.34$, $p = 0.02$, $\eta_P^2 = 0.065$) was revealed (**Figure 2.2**). Two post-hoc 3x3x3 ANOVAs were performed for each group (PwP versus controls), with the within-subjects factors being emotion (happy, angry, sad) spatial (S1, S2, S3) and kinematic (K1, K2, K3) levels. It was concluded, from these two post-hoc ANOVAs that there was a main effect of emotion for controls but not for PwP. When Bonferroni-corrected independent t-tests were applied, significant differences were found between the groups (PwP and controls, respectively) for sad ($t(62) = 2.3$, $p_{bonf} = .027$, mean difference = -0.87) (PwP: mean = 2.59, SEM = 0.162; CTRL: mean = 3.46, SEM = 0.145) and happy ($t(62) = 2.9$, $p_{bonf} = .006$, mean difference = -1.31) (PwP: mean = 1.99, SEM = 0.166; CTRL: mean = 3.30, SEM = 0.170) emotions. This indicates that PwP have a lower mean ERA score for happiness and sadness.

Figure 2.2

Mean ERA Score for Happy, Angry and Sad Across Each Group



Note. Mean emotion recognition accuracy scores for PwP and controls, for the emotions happy, angry and sad in the PLF task. The data presented are from PwP OFF their dopaminergic medication and controls. 50% of the controls were from day 1 and 50% of the controls were from day 2, these were randomly selected. Error bars represent the standard error of the mean. Independent t-tests were applied to check for significant differences between the emotions. *** represents $p < 0.001$.

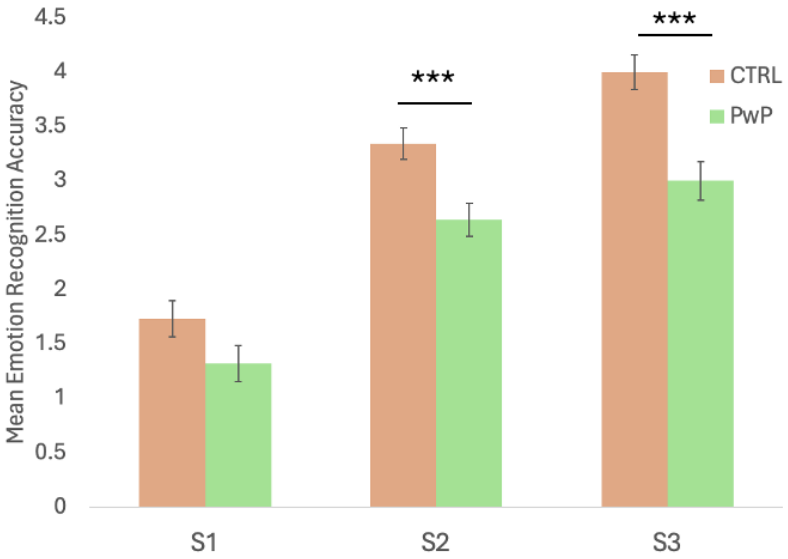
Reduced Emotion Recognition Accuracy Scores for S2 and S3 (Stimulus Spatial Levels) in People with Parkinson's

When a 2x3x3x3 ANOVA, with the between-subjects factor, group (PwP, control) and the within-subjects factors, emotion (happy, angry, and sad), kinematic level (K1, K2, K3) and spatial level (S1, S2, S3) was applied to the data, a spatial by group interaction ($F(2, 124) = 3.81$, $p = 0.025$, $\eta_P^2 = 0.058$) was revealed (**Figure 2.3**). When Bonferroni-corrected independent t-tests were applied, significant differences were found between the groups (PwP and controls, respectively) for S2 ($t(62) = 3.33$, $p_{bonf} = .030$, mean difference = -0.69) (CTRL: mean = 3.34, SEM =

0.142; PwP: mean = 2.64, SEM = 0.152) and S3 ($t(62) = 4.19$, $p_{bonf} = .005$, mean difference = -1.00) (CTRL: mean = 4.00, SEM = 0.160; PwP: mean = 3.00, SEM = 0.177) levels. This indicates that PwP have a lower mean ERA score for S2 and S3 spatial levels, compared to controls.

Figure 2.3

Mean ERA Score for S1, S2 and S3 Across Each Group



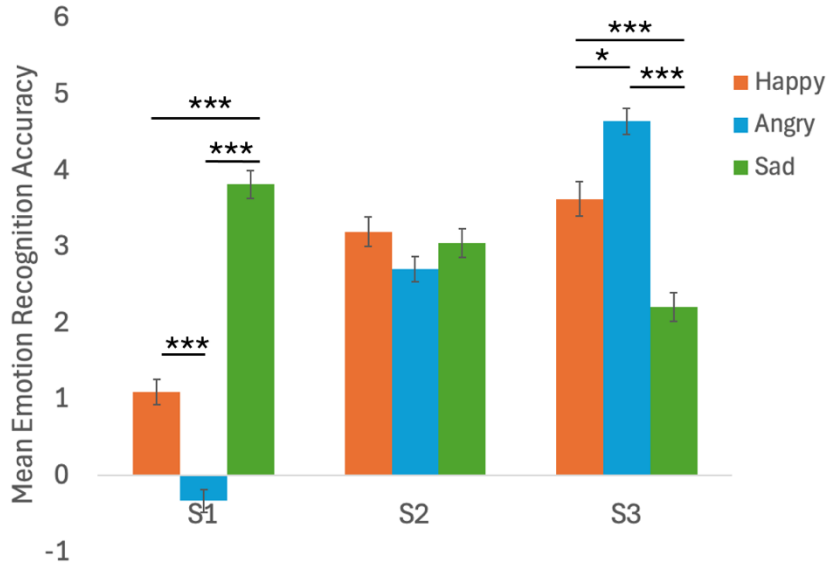
Note. Mean emotion recognition accuracy score for PwP and controls, for the spatial levels S1 (50% spatial level), S2 (100% spatial level) and S3 (150% spatial level) in the PLF task. The data presented are from PwP OFF their dopaminergic medication and controls. 50% of the controls were from day 1 and 50% of the controls were from day 2, these were randomly selected. Error bars represent the standard error of the mean. Independent t-tests were applied to check for significant differences between each spatial level. *** represents $p < 0.001$.

Differences in Emotion Recognition Abilities are Highlighted at S1 and S3 (Stimulus Spatial Levels)

When a 2x3x3x3 ANOVA, with the between-subjects factor, group (PwP, control) and the within-subjects factors, emotion (happy, angry, and sad), kinematic level (K1, K2, K3) and spatial level (S1, S2, S3) was applied to the data, an emotion by spatial interaction ($F(4, 248) = 117$, $p < 0.001$, $\eta_P^2 = 0.654$) was revealed (**Figure 2.4**). This was similar to what other studies found (Keating et al., 2022; Sowden et al., 2021). Three post-hoc 2x3x3 ANOVAs were performed, with the between-subjects factor, being group (PwP, controls) and the within-subject's factors being emotion (happy, angry, and sad) and kinematic level (50% speed, 100% speed, 150% speed). This showed a main effect of emotion at S1 ($F(2, 124) = 89.1$, $p < 0.001$, $\eta_P^2 = 0.590$) and S3 ($F(2,124) = 31.3$, $p < 0.001$, $\eta_P^2 = 0.336$) but not S2 ($F(2,124) = 1.69$, $p = 0.188$, $\eta_P^2 = 0.027$) as displayed in **Figure 2.4**. This was then followed up with Bonferroni-corrected paired t-tests to compare ERA scores achieved for different emotions within each spatial level. These results convey that the difference in emotions comes out when the spatial level is at 50% of the original stimulus spatial level (S1) or when the expression is at 150% of the original stimulus spatial level (S3). This provides one rationale for the emotion by spatial interaction seen when an ANOVA was applied to the data.

Figure 2.4

Mean ERA Score for S1, S2 and S3 Across Each Emotion



Note. Mean emotion recognition accuracy score for spatial levels, S1, S2, and S3, across the emotions. This graph represents the mean emotion recognition accuracy scores for PwP OFF their dopaminergic medication and controls. 50% of the controls were from day 1 and 50% of the controls were from day 2, these were randomly selected. Error bars represent the standard error of the mean. Paired t-tests were applied to check for significant differences between each emotion. *** represents $p < 0.001$ * represents $p < 0.05$.

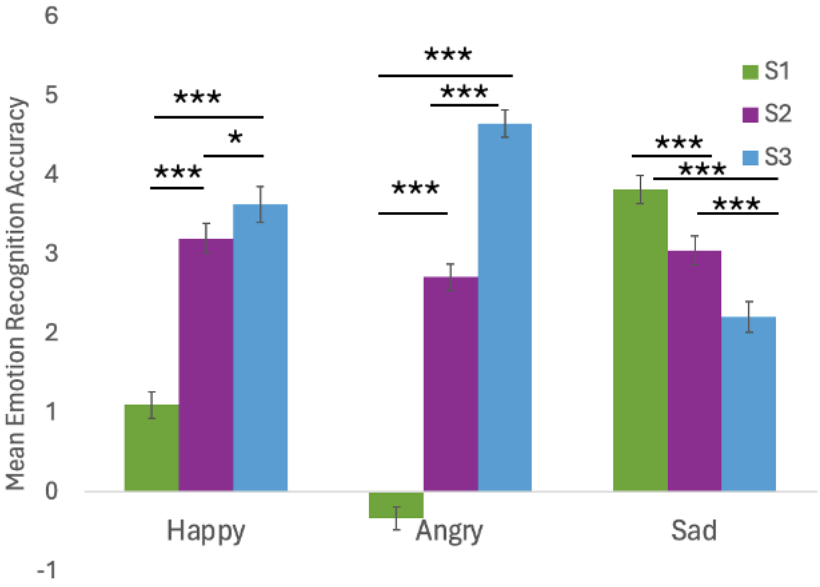
The Effect of Spatial Manipulations on Emotion Recognition Accuracy Scores is Not Significantly Different for Angry and Happy, but there are Opposing Effects for Sad

A further three post-hoc 2x3x3 ANOVAs were performed, with the between-subjects factor, being group (PwP, controls) and the within-subject's factors being spatial level (S1, S2, S3) and kinematic level (K1, K2, K3). Each ANOVA showed a main effect of spatial level across all emotions, happy ($F(2, 124) = 55.9$, $p < 0.001$, $\eta_P^2 = 0.474$), angry ($F(2, 124) = 418.5$, $p < 0.001$, $\eta_P^2 = 0.871$), and sad ($F(2, 124) = 37.0$, $p < 0.001$, $\eta_P^2 = 0.374$) (as displayed in **Figure 2.5**). This was then followed up with Bonferroni-corrected paired t-tests to compare ERA scores achieved at different

spatial levels within each emotion (**Figure 2.5**). Results highlight that there are no significant differences in ERA scores for angry and happy emotions during spatial manipulations, but there are opposing effects on ERA scores for sadness during spatial manipulations. For angry and happy emotions, ERA score increases as spatial level increases. However, the effect of the spatial manipulation is in the opposite direction for the low arousal emotion, sad. For sadness, ERA scores are higher as the spatial level decreases. These results may uncover another explanation for the emotion by spatial interaction found.

Figure 2.5

Mean ERA Score for Happy, Angry and Sad Across Each Spatial Level



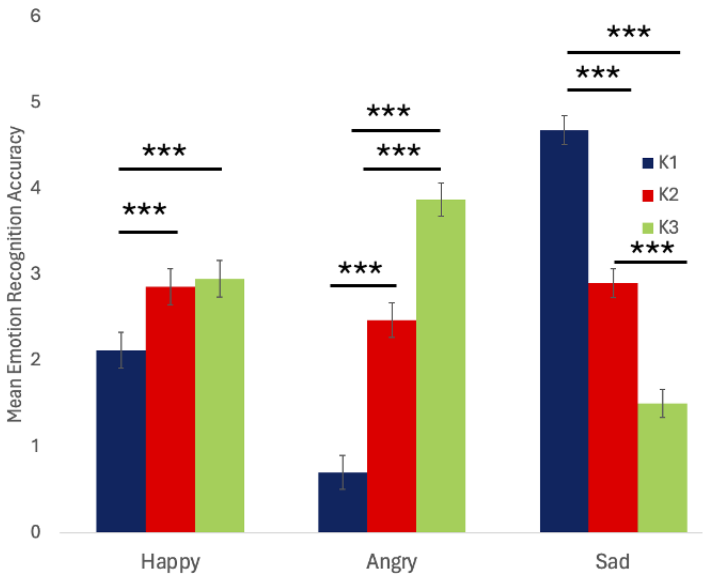
Note. Mean emotion recognition accuracy score for happy, angry and sad, across the spatial levels. This graph represents the mean emotion recognition accuracy scores for PwP OFF their dopaminergic medication and controls. 50% of the controls were from day 1 and 50% of the controls were from day 2, these were randomly selected. Error bars represent the standard error of the mean. Paired t-tests were applied to check for significant differences between each spatial level. *** represents $p < 0.001$ * represents $p < 0.05$.

The Effect of Kinematic Manipulations on Emotion Recognition Accuracy Scores is Not Significantly Different for Angry and Happy, but there are Opposing Effects for Sad

When a 2x3x3x3 ANOVA, with the between-subjects factor, group (PwP, control) and the within-subjects factors, emotion (happy, angry, and sad), kinematic level (K1, K2, K3) and spatial level (S1, S2, S3) was applied to the data, an emotion by kinematic interaction ($F(4, 248) = 121$, $p < 0.001$, $\eta_P^2 = 0.66$) was identified. This was similar to what was witnessed in another study (Keating et al., 2022). Three post-hoc 2x3x3 ANOVAs were performed with the between-subjects factor being group (PwP or controls) and the within subjects-factors being spatial level (50% spatial level, 100% spatial level and 150% spatial level) and kinematic level (50% speed, 100% speed and 150% speed). Each ANOVA showed a main effect of kinematic level for the emotions, happy ($F(2, 124) = 8.35$, $p = 0.001$, $\eta_P^2 = 0.12$), angry ($F(2, 124) = 195$, $p < 0.001$, $\eta_P^2 = 0.76$), and sad ($F(2, 124) = 136$, $p < 0.001$, $\eta_P^2 = 0.69$), as displayed in **Figure 2.6**. This was then followed up with Bonferroni-corrected paired t-tests to compare ERA scores achieved at different kinematic levels within each emotion. These results convey that the direction of the kinematic effect on ERA score was different for the high arousal (happy and angry) and low arousal (sad) emotions (**Figure 2.6**). This is the same pattern of results as seen in a study by Keating and colleagues (2022), as well as a previous study led by Sowden and colleagues (2021). These mean ERA scores for each emotion (happy, angry, and sad) across all kinematic levels (K1, K2 and K3) are displayed in **Figure 2.6.** This provides one rationale for the emotion by kinematic interaction seen when an ANOVA was applied to the data.

Figure 2.6

Mean ERA Score for Happy, Angry and Sad Across Each Kinematic Level



Note. Mean emotion recognition accuracy score for happy, angry, and sad, across the kinematic levels. This graph represents the mean emotion recognition accuracy scores for PwP OFF their dopaminergic medication and controls. 50% of the controls were from day 1 and 50% of the controls were from day 2, these were randomly selected. Error bars represent the standard error of the mean. Paired t-tests were applied to check for significant differences between each kinematic level. *** represents $p < 0.001$

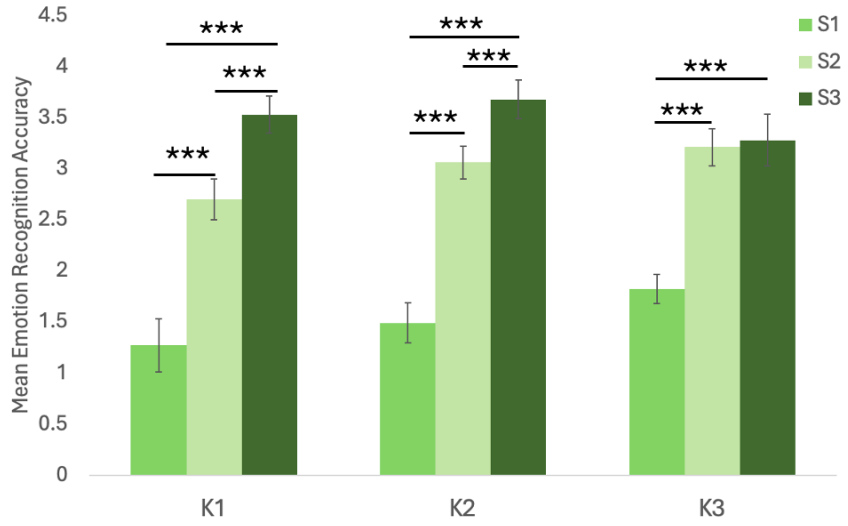
No Significant Difference in the Direction of the Effect on Emotion Recognition Accuracy Scores by Changing Spatial Level Across Each Kinematic Level

When a 2x3x3x3 ANOVA, with the between-subjects factor, group (PwP, control) and the within-subjects factors, emotion (happy, angry, and sad), kinematic level (K1, K2, K3) and spatial level (S1, S2, S3) was applied to the data, a spatial by kinematic interaction ($F(4, 248) = 6.42$, $p < 0.001$, $\eta_P^2 = 0.094$) was identified. Following this, three post-hoc 2x3x3 ANOVAs were performed, with the factors being group (PwP or controls), emotion (happy, angry, and sad) and spatial level (S1, S2 and S3). Each ANOVA showed a main effect of spatial level for each kinematic level (K1 ($F(2, 124) = 105.83$, $p < 0.001$, $\eta_P^2 = 0.63$), K2 ($F(2, 124) = 124.80$, $p < 0.001$, η_P

^{2} = 0.67), K3 ($F(2, 124) = 51.61$, $p < 0.001$, $\eta_P^2 = 0.45$)), as seen in **Figure 2.7**. This was then followed up with Bonferroni-corrected paired t-tests to compare ERA scores achieved at different spatial levels within each kinematic level. The results demonstrate that there is no significant difference in the direction of the effect (increasing spatial level, improves ERA), by changing spatial level across each kinematic level. Mean ERA scores across each kinematic level (which vary as a result of changing spatial level) are displayed in **Figure 2.7.**

Figure 2.7

Mean ERA Score for K1, K2 and K3 Across Each Spatial Level



Note. Mean emotion recognition accuracy score for speed (K1, K2 and K3), across the spatial levels (S1, S2 and S3). This graph represents the mean emotion recognition accuracy score for PwP OFF their dopaminergic medication and controls. 50% of the controls were from day 1 and 50% of the controls were from day 2, these were randomly selected. Error bars represent the standard error of the mean. Paired t-tests were applied to check for significant differences between each spatial level. *** represents $p < 0.001$.

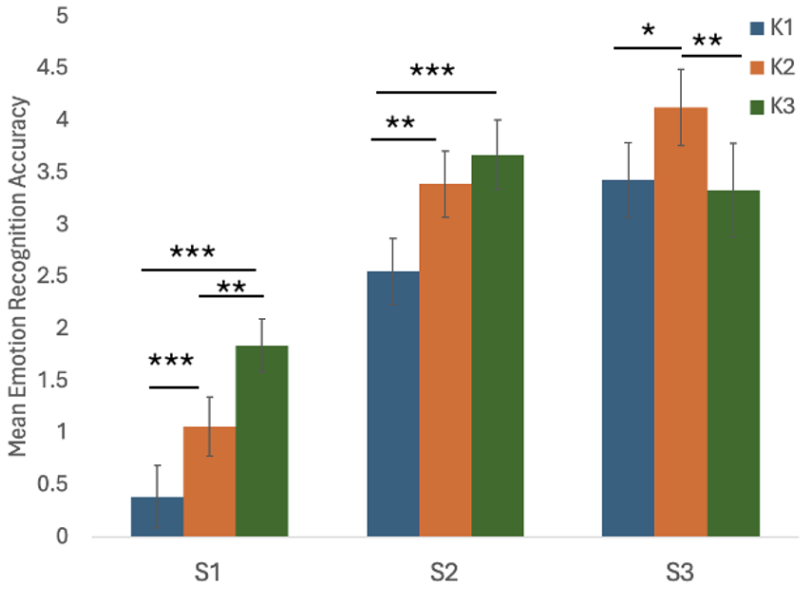
Increasing Kinematic Level for Each Spatial Level, Increases Emotion Recognition Accuracy Scores for Happiness and Anger, but Decreases Emotion Recognition Accuracy for Sad

When a 2x3x3x3 ANOVA, with the between-subjects factor, group (PwP, control) and the within-subjects factors, emotion (happy, angry, and sad), kinematic level (K1, K2, K3) and spatial level (S1, S2, S3) was applied to the data, an emotion by spatial by kinematic interaction ($F(8, 496) = 3.90$, $p < 0.001$, $\eta_P^2 = 0.06$) was identified. To unpack this significant three-way interaction, we conducted post-hoc 2x3x3 ANOVAs (group, spatial, and kinematic) for each emotion (happy, angry, and sad). In this case, all emotions had significant interactions for spatial by kinematic interactions (happy: $F(4, 248) = 6.35$, $p < 0.001$, $\eta_P^2 = 0.093$; angry: $F(4, 248) = 3.34$, $p = 0.016$, $\eta_P^2 = 0.051$; sad: $F(4, 248) = 3.87$, $p = 0.005$, $\eta_P^2 = 0.059$). When looking at the graphs for each emotion (happy, angry and sad), the pattern of results is similar for happiness and anger (**Figure 2.8**). However, this pattern is reversed for sadness. For sadness, participants became less accurate as the kinematic levels increased, for each spatial level. Thus, although an interaction between spatial and kinematic levels was noted for each emotion (happy, angry, and sad), the nature of the relationship is different (**Figure 2.8**). Finally, the post-hoc ANOVAs were followed up with Bonferroni-corrected paired t-tests to compare ERA scores for significant differences in ERA score achieved at different kinematic levels, within each spatial level (**Figure 2.8**). These results convey that the direction of the kinematic effect (within each spatial level), on ERA score was different for the high arousal emotions (happy and angry), compared to the low arousal emotion (sad).

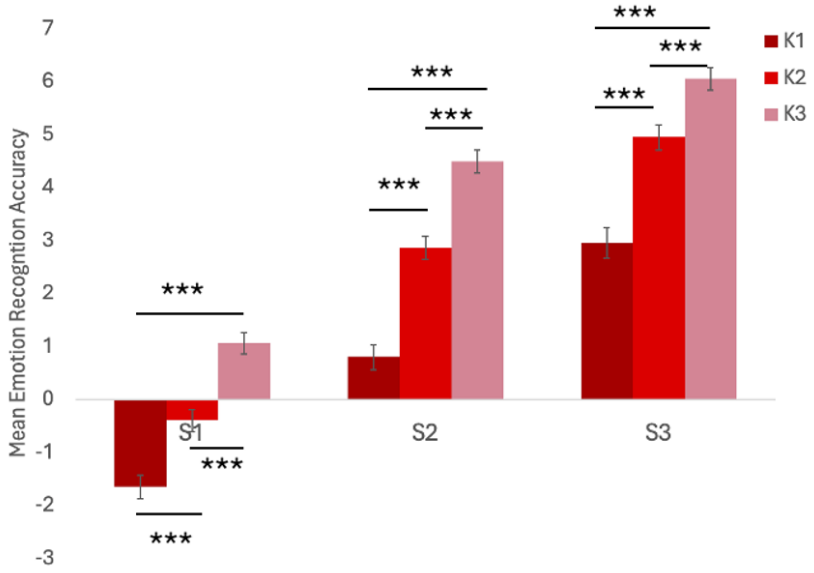
Figure 2.8

Mean ERA Score for S1, S2, and S3 Across Each Kinematic Level for Happy (A), Angry (B), and Sad (C)

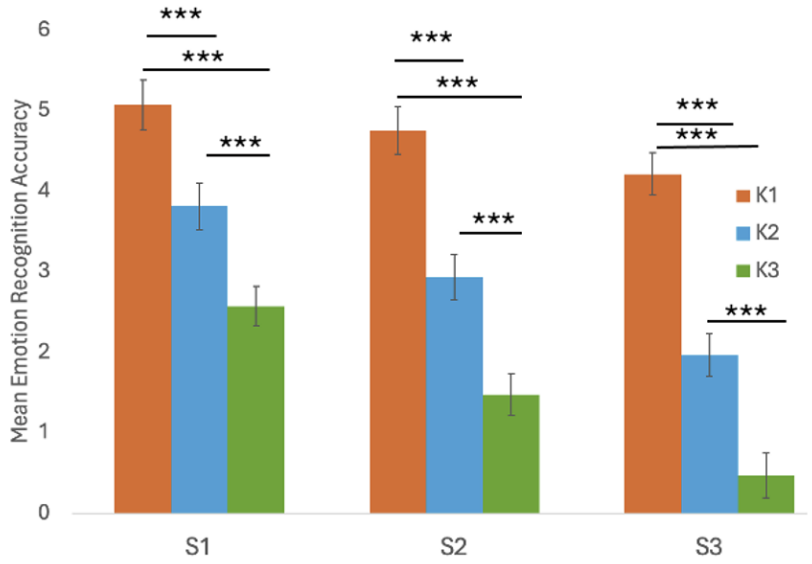
A



B



C



Note. Mean emotion recognition accuracy score for happy (A), angry (B), and sad (C). The scores were compared at different kinematic levels (K1, K2, and K3), within each spatial level (S1, S2, and S3). These graphs represent the mean emotion recognition accuracy score for PwP OFF their dopaminergic medication and controls. 50% of the controls were from day 1 and 50% of the controls were from day 2, these were randomly selected. Error bars represent the standard error of the mean. Paired t-tests were applied to check for significant differences in emotion recognition accuracy scores at different kinematic levels, within each spatial level. *** represents $p < 0.001$. ** represents $p < 0.01$. * represents $p < 0.05$.

2.4 Discussion

The current chapter compared FER abilities between PwP (OFF their dopaminergic medication) and controls and also explored potential factors that may contribute to any observed differences in FER abilities between these groups. This included physical factors, for example spatial and kinematic cues which were explored by manipulating both types of information.

To reiterate, a group by emotion interaction was predicted, whereby PwP and controls would differ in their ERA scores for anger and sadness, but not for happiness. This prediction was based on previous studies that suggested that FER abilities are

reduced in PwP for negative emotions (Lin et al., 2016; Clark et al., 2008; Lawrence et al., 2007). The exploratory hypothesis aimed to uncover whether differences in FER for PwP were due to difficulties processing kinematic and/or spatial aspects of the face by looking at potential interactions between group and kinematic level and/or group and spatial level.

Studies in the literature suggested that negative emotions, such as anger and sadness are more difficult for PwP to recognise compared to positive emotions. Therefore, it was predicted that PwP would have lower ERA scores in the PLF task for anger and sadness, compared to controls (Lawrence et al., 2007; Sprengelmeyer et al., 2003). This study investigated FER abilities in three of the six basic emotions (happy, angry, and sad) in PwP and controls. This was explored using dynamic displays (i.e. videos), rather than using static stimuli (i.e. photographs) which were more commonly used in previous studies (Waldthaler et al., 2019; Lin et al., 2016; Mioni et al., 2016; Clark et al., 2008; Lawrence et al., 2007; Sprengelmeyer et al., 2003). It has been suggested that negative emotions may have lower ERA scores due to a greater diversity of negative emotions (Argaud et al., 2018). Although a group by emotion interaction was found in this chapter, different emotions were driving this interaction than what was expected. The interaction was driven by PwP having reduced ERA scores for happiness and sadness relative to controls, whilst ERA scores for anger did not differ between these groups. To summarise, the interaction between group and emotion was driven by different emotions than those predicted from looking at results from previous literature.

According to the analyses, PwP experience reduced ERA scores for the emotions, happy and sad. These emotions are opposing in terms of valence, with happy being a

positive valence and sad being a negative valence. Reduced ERA scores for sadness in PwP was expected as similar findings were reported in previous studies. However, the reduction in ERA scores for happiness was unexpected (Lin et al., 2016; Sprengelmeyer et al., 2003). However, one study investigated FER abilities in PwP (OFF their dopaminergic medication) and controls (Lin et al., 2016). They also found that PwP had a reduced recognition accuracy for happy expressions. To measure FER abilities, they used the Fast Emotion Discrimination Task. Participants viewed images of individuals with different facial expressions. One positive emotion was investigated (happy) and three negative emotions (sad, angry and fear). Participants indicated whether the valence of the displayed face was positive or negative. Whilst this study noted that FER of negative emotions (sad and angry) was affected in PwP, they also noted that happiness was affected. However, this study detailed that happiness was more difficult to recognise for PwP who were classified as having 'high motor dysfunction'. Motor dysfunction was assessed via the Hoehn and Yahr's scale and UPDRS Part III. Perhaps one reason for differences in this thesis between PwP and controls in ERA scores for happiness was due to the PwP recruited. Perhaps this group had 'high motor dysfunction'. It is important to note that we did not assess participants using Hoehn and Yahr's scale or Part III of the UPDRS in our study. Although we did assess 'Motor Aspects of Experiences of Daily Living' using Part II of the UPDRS, this is different to the specific assessment of motor symptoms (e.g. rigidity and 'finger tapping' tests in Part III) because Part II of the UPDRS focusses on how motor symptoms may influence activities (e.g. getting out of bed and problems with getting dressed). It should also be noted that Hoehn and Yahr's scale and UPDRS Part III are assessed by clinicians which may be viewed as a more impartial report of motor symptoms experienced by PwP, rather than using self-report scales. Therefore,

perhaps it would be better to have motor symptoms assessed by a clinician, rather than solely relying on self-report scales. It would be interesting to investigate if the results found in **Chapter 2** (i.e. PwP having reduced ERA scores for happiness, compared to controls) were potentially associated with PwP having increased motor symptoms.

Anhedonia (reduced levels of pleasure in activities once enjoyed) is a core feature of major depressive disorder (MDD). It has also been associated with difficulty in identifying positive emotions, such as happiness. One possible suggestion for reduced ERA scores for happiness in PwP, compared to controls is that approximately 30-40% of PwP experience MDD (Loas et al., 2012). One cardinal symptom of MDD is anhedonia. One study looked at scores obtained in the Snaith-Hamilton Pleasure Scale 19 (SHAPS) in depressed adults, as a way of comparing levels of anhedonia in each participant (Light et al., 2019). Participants also completed a task assessing their abilities to recognise positive emotions expressed from images of faces which showed either a neutral face or faces with various intensities of happiness. Participants were asked whether they could detect any sign of a positive emotion in the faces shown and they selected either yes or no. It was found that greater levels of anhedonia were associated with increased difficulty in identifying positive emotions, particularly in the lower intensity happy faces. This may imply that a measure of anhedonia, such as SHAPS, in future studies could be helpful to check if there are any correlations between the levels of anhedonia experienced in participants and their ERA scores for happiness. This is an important consideration because if PwP are experiencing anhedonia, then they may struggle to recognise positive facial expressions as a result of anhedonia, rather than because of PD.

To reiterate, ERA scores for anger did not differ between PwP OFF their dopaminergic medication and controls. An alternative way to consider this, could be that control participants found anger more difficult to recognise accurately, compared to PwP. Perhaps anger is generally more difficult to recognise when the point-light displays are spatially manipulated. At lower spatial manipulation levels (S1), ERA scores declined extensively (compared to ERA scores for anger at S2 and S3). A lower spatial level simply refers to a decrease in the distance between the point lights that make up the outline of the face. Together, this information suggests that when the point-lights are closer together, anger is more difficult to recognise. One reason for this could be that anger characteristically has facial features or movements that are dynamic and expansive, as described by the facial action coding system (Ekman & Friesen, 1978). Anger is traditionally associated with furrowed brows and widened eyes. Perhaps, by decreasing the distance of the traditionally expansive movements of the face, anger could get confused with the only other negative valence emotion with overlapping cues that we tested in this study, sadness.

The exploratory hypothesis in this chapter aimed to uncover whether differences in FER abilities between PwP and controls were due to differences in processing kinematic and/or spatial aspects of the face. This exploratory hypothesis was investigated by examining potential interactions between kinematic level and group, as well as spatial level and group. In the current study, a spatial by group interaction was found, suggesting that PwP and controls differed in how they processed spatial information. However, no interaction was found between kinematic level and group. This indicates that PwP used kinematic information in a similar way to controls when

recognising facial emotions. This suggests that differences in FER abilities between PwP and controls may be more directly related to altered spatial processing, rather than due to differences in kinematic sensitivity between these groups. This supports the idea that understanding kinematic aspects of facial expressions may be intact in PwP.

This chapter concluded that PwP showed reduced FER abilities at higher spatial levels (S2 and S3) compared to controls, whereas changing kinematic cues did not appear to affect FER abilities differentially between the groups. This is in line with previous literature that implies that PwP do not necessarily experience challenges with speed but do exhibit challenges on tasks that involve integrating motion across space (Uc et al., 2005; Mosimann et al., 2004). In one study, a motion perception task was performed (Mosimann et al., 2004). Two black squares were presented side-by-side, each containing 12 white dots, moving in a random fashion, at the same velocity within each square. However, the dots moved at different velocities across the two squares. Participants had to indicate which square had the faster moving dots. This study found no differences between PwP and controls, reflecting how PwP may not experience challenges with processing speed. In a different study, they used a structure from motion task (Uc et al., 2005). This involved a computer generating either a sphere or a cube that rotates in the presence of random background noise, called ‘random dot cinematograms’. A signal level is measured, for example, a 30% signal level would represent that the sphere or the cube was represented by 300 dots moving amongst the 1000 dots in the background. PwP needed greater signal levels to accurately detect the sphere or the cube in at least 75% of trials. This conveys the challenges PwP have on tasks where motion must be integrated across space. Together, these

studies could help to explain why a spatial by group interaction was seen, but not a kinematic by group interaction. These studies looked at two different motion perception paradigms focussing on speed and spatial levels, and they uncovered that there were no differences in processing speed when comparing PwP and controls. However, integrated motion across space (spatial consideration) demonstrated differences in PwP.

One limitation of the current chapter is that our two groups (PwP and controls) were not matched for non-verbal reasoning scores. PwP had lower scores in non-verbal reasoning, compared to controls which may have affected performance in PwP in the PLF task. This is because non-verbal reasoning was used as a measure of the Intelligence Quotient (IQ). Numerous studies have noted that higher levels of intelligence may be associated with greater FER abilities (Walker et al., 2023; Schlegel et al., 2020). However, since PwP had lower non-verbal reasoning scores compared to controls, this finding may suggest that ERA scores in PwP may have been influenced by this difference, as the groups were not successfully matched on this variable.

It is also important to acknowledge that whilst the UPDRS Part II questionnaire is designed to assess activities of daily living in PwP, control participants may also score above zero. This can result from age-related changes, or unrelated health conditions that impact daily functioning. Controls that received scores above zero in the UPDRS Part II, may not reflect parkinsonian symptoms but general variability in health, in older adults. However, administering the same questionnaires to both PwP and control participants ensured methodological consistency. Furthermore, completion of the

UPDRS by controls helped to confirm that any differences in FER ability, were specific to PwP, rather than general age-related changes, or unrelated health conditions.

In summary, the current chapter investigated two hypotheses. First, an emotion by group interaction was predicted, whereby PwP and controls would differ in their ERA scores for anger and sadness, but not for happiness. Our predictions were only partially correct however, as an emotion by group interaction was found, but for the emotions, happy and sad. Secondly, we wanted to uncover potential reasons for differences seen in PwP. We investigated if spatial and kinematic manipulations had different effects on PwP versus controls. A spatial by group interaction was found but no kinematic by group interaction. The results from this chapter suggest that, for 'normal' (S2) and increased levels of spatial exaggeration (S3), PwP displayed reduced FER abilities, compared to controls. This may suggest that spatial manipulations play a role in explaining why PwP experience difficulties with FER.

Chapter 3 – Comparing Facial Expression Recognition in People with Parkinson's Both ON and OFF their Dopaminergic Medication

3.1 Introduction

Dopamine is a neurotransmitter and is involved in several different processes (e.g. movement, memory and motivation), this can lead to a variety of symptoms for PwP. (Ramesh & Arachchige, 2023). Lower levels of dopamine are present in PwP due to neurodegeneration of mainly the dopaminergic neurons in the substantia nigra and striatum (Zhou et al., 2023; Bloem et al., 2021). This neurodegeneration can lead to motor and non-motor symptoms (see **Chapter 1** for further details) (Ramesh & Arachchige, 2023). Motor symptoms may include, bradykinesia and rigidity, whereas non-motor symptoms can extend to mood disorders (e.g. depression) and cognitive changes.

Dopamine is implicated in mentalising abilities, which refers to the ability to understand emotions and mental states in other people, and within themselves (İnanç & Altıntaş, 2018). Recent research has confirmed that changes in dopamine levels can influence an individual's mentalising abilities (Schuster et al., 2024). In this study, controls were given haloperidol (a dopamine antagonist) on one of the study days and a placebo on another day. Participants viewed videos of two triangles interacting with each other. These triangles were programmed to show mental-state interactions (e.g. seducing or surprising). Participants then rated how accurately the video demonstrated different actions (e.g. seducing). This study demonstrated that when participants ingested haloperidol, they had a reduced ability to label mental-

state animations (e.g. surprising), showing that dopamine may be involved with mentalising abilities.

Dopamine has also been linked to emotion recognition. One study compared medicated PwP (this refers to the 'ON' state of dopaminergic drugs), unmedicated PwP (this refers to the 'OFF' state of dopaminergic drugs) and controls in a FER task (Sprengelmeyer et al., 2003). In this study, participants viewed photographs of faces expressing different emotions (happy, angry, sad, surprise, fear, and disgust). The six emotion labels were provided to participants during this study, and participants selected one label to best describe the emotion in each photograph. In addition, this study used morphed images to test FER in PwP and controls. These images were made by 'blending' two emotions together, in various proportions. The images of the facial expressions were adapted from Ekman and Friesen (1976). A 'correct response' represented if the participant selected the emotion 'happiness' when the majority of the morphed image represented happiness (Sprengelmeyer et al., 2003). Participants labelled these morphed images using one of the six basic emotion labels they thought the facial expression represented best. This study concluded that in general there was a reduction in FER accuracy for both groups of PwP, compared to the control group. This reduction in FER accuracy was particularly noted in PwP who were unmedicated. In the first part of the FER task, unmedicated PwP had reduced FER accuracy for the emotion, disgust, compared to medicated PwP. Furthermore, the recognition accuracy of anger and disgust in the morphed images, were reduced for the unmedicated PwP. Thus, highlighting, that PwP appear to find negative emotions such as anger and disgust more difficult to recognise than positive emotions, and this seems to be even more evident when PwP are unmedicated.

Currently, there are no known mechanisms that explain how dopaminergic signalling changes may influence emotional perception from faces. One recent paper by Schuster and colleagues (2024) showed that dopamine may play a role in emotion recognition in dynamic displays (displays with moving stimuli) of Point Light Walkers (whole-body motions) (Schuster et al., 2024). However, surprisingly, this has not been shown with faces. To explore how dopamine may affect FER in dynamic displays, the current chapter manipulated spatial and kinematic features (as outlined in **Chapter 2)** in PLF videos. ERA scores were then compared between PwP ON and OFF their dopaminergic medication, across different spatial and kinematic levels.

Preliminary evidence from Sprengelmeyer and colleagues (2003) suggests that when emotion recognition was assessed in distinct groups of PwP (i.e. when they were ON or OFF dopaminergic medication), difficulties in emotion recognition could be directly associated with dopaminergic signalling. However, it is difficult to find any evidence of studies that compared FER abilities in the same group of PwP (i.e. when they were ON and OFF dopaminergic medication). Furthermore, current FER literature has largely relied on static stimuli and therefore there is little evidence suggesting that FER in PwP typically relies upon the processing of dynamic cues, such as movement kinematics (Sowden et al., 2021). This chapter had two aims. The first aim was to confirm whether PwP OFF their dopaminergic medication had reduced FER abilities, compared to when they were ON their dopaminergic medication. The second (exploratory) aim was to uncover if differences processing kinematic and/or spatial aspects of the face, affected FER abilities in PwP. This aim was achieved by analysing potential interactions between drug and kinematic level and/or drug and spatial level.

3.2 Methods

The methods in this chapter are almost identical to **Chapter 2** and are repeated here, to be comprehensive. The only sections that have changed are **3.2.1 Participants**, **3.2.4 Procedure** and **3.2.5 Statistical Analysis,** as in this chapter it discusses the participants and procedure for PwP ON and OFF their dopaminergic medication, instead of PwP OFF their medication and controls.

3.2.1 Participants

34 PwP (15 female; M_{AGE} = 67.03 years) took part in this study (**Table 3.1**). PwP were recruited for this study through an advertisement on the Parkinson's UK website, where they could express interest in participation, via email. All PwP were given a diagnosis of idiopathic Parkinson's, with a maximum of seven years since diagnosis. All PwP were taking dopaminergic medication, as prescribed by their clinicians. Among the 32 PwP participants, 29 were taking levodopa-based therapies, including co-careldopa or co-beneldopa. 14 were taking dopamine agonists, including ropinirole and pramipexole. Lastly, 10 were taking monoamine oxidase inhibitors including rasagiline and selegiline (**Table 3.1**). It is important to note that these numbers reflect the total users of each drug class and are not mutually exclusive, as some participants were on combination therapies (involving more than one class of dopaminergic medication). Exclusion criteria included a diagnosis of co-occurring motor problems or movement conditions such as Developmental coordination disorder, Huntington's Disease and Tourette syndrome. Other exclusion criteria included the diagnosis of psychiatric clinical conditions such as schizophrenia, personality disorder, or a learning disability. All participants gave their full and informed consent. The study was approved by the Science, Technology, Engineering and Mathematics Ethical Review

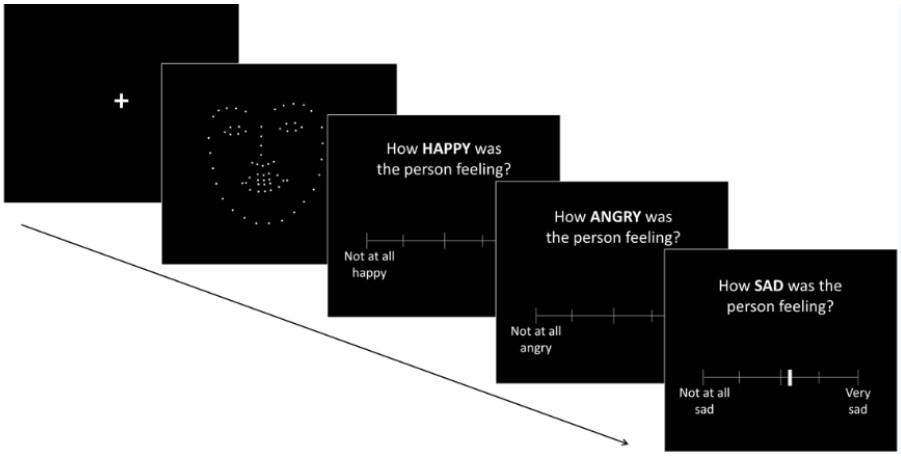
Committee at the University of Birmingham (ERN_18-1800D). Participants were reimbursed for their time at a rate of £10.00 per hour. Data from two participants had to be excluded as they did not complete the full task. Data from 32 PwP (14 female; M_{AGE} = 66.63 years) were included in the final analyses.

3.2.2 Stimuli

The Point Light Faces (PLF) task we used was developed by Sowden et al., (2021) and further adapted by Keating et al., (2022). The stimulus videos displayed PLF stimuli (**Figure 3.1**). PLF stimuli are videos in which facial expressions are depicted by the movement of dots. These videos were recorded using four actors (two female, two male) who read a scripted sentence (e.g., “My name is John and I’m a scientist”). The actors were told to express the sentence using three different emotions (angry, sad, and happy). The videos were modified to display three different spatial extents (S1 (50% of the spatial movement), S2 (100% of the spatial movement), and S3 (150% of the spatial movement) corresponding to spatially reduced, normal, and spatially exaggerated respectively) and three different speed levels (K1, K2, and K3 corresponding to slowed-down (50% of the recorded speed), normal, and sped-up (150% of the recorded speed) respectively). Therefore, in total there were 108 video stimuli. In terms of spatial manipulation, the movement of facial features from one frame to the next was increased or decreased to give an increase or reduction in spatial exaggeration. Different speed levels were achieved by saving PLF frames at different frame rates. This made it appear as if there was varying facial movement speed.

Figure 3.1

Point Light Faces Task Structure



Note. Example of one trial in the Point Light Faces task (taken from Sowden et al., 2021).

3.2.3 Questionnaires and Tasks

Autism Quotient-50 (AQ-50): This 50-item questionnaire assesses autistic traits (Baron-Cohen et al., 2006). The AQ-50 uses a four-point Likert scale (definitely agree, slightly agree, slightly disagree and definitely disagree). This questionnaire is scored out of 50 and the higher the score, the greater the level of autistic traits present in the individual. In addition to this score out of 50, individual sub-scale scores can be calculated from this (attention switching, attention to detail, communication, social skill and imagination). Autistic traits were important to assess as autistic individuals and those with higher levels of autistic traits are known to have difficulties with FER (Bothe et al., 2024). Therefore, it is important to account for autistic traits when analysing results so we can ensure that any differences in FER abilities are due to PD and not as a result of having higher levels of autistic traits. The AQ-50 was chosen as it can be self-administered, meaning participants were able to complete it independently, in

their own time. In contrast, other questionnaires assessing autistic traits would have involved assessing behaviours and having structured conversations. One example is the Autism Diagnostic Observation Schedule, which requires formal training to administer. In addition, the AQ-50 has a good internal consistency score ($\alpha \geq 0.7$) and test-retest reliability ($r \geq 0.8$.) (Stevenson & Hart, 2017).

Toronto Alexithymia Scale-20 (TAS-20): This 20-item questionnaire assesses alexithymia traits (Bagby et al., 1994). The TAS-20 uses a five-point Likert scale (strongly disagree, disagree, neither agree nor disagree, agree and strongly agree). The scores can range from 20 to 100 and the higher the score, the greater the level of alexithymia. There are three individual sub-scale scores: difficulty describing feelings, difficulty identifying feelings and externally oriented thinking. TAS was included because it is the gold-standard alexithymia questionnaire that is adopted by most scientific studies that want to explore alexithymia traits in their participant population. TAS has been used extensively across different clinical populations including, the autistic population, people with eating disorders and, PwP (Ridout & Wallis, 2021; Kinnaird et al., 2019; Assogna et al., 2012). The TAS-20 has a good internal consistency score ($\alpha \geq 0.7$) and test-retest reliability ($r \geq 0.7$) (Bagby et al., 1994).

Perth Alexithymia Questionnaire (PAQ): This 24-item questionnaire assesses alexithymia traits (Preece et al., 2018). The PAQ uses a seven-point Likert scale (ranging from strongly disagree to strongly agree). The scores can range from 24-168 and the higher the score, the greater the level of alexithymia. There are five individual sub-scale scores: negative – difficulty identifying feelings, positive – difficulty identifying feelings, negative – difficulty describing feelings, positive – difficulty describing feelings and general – externally oriented thinking. PAQ was included in

the questionnaire battery because for someone with true alexithymia characteristics, the language used in the PAQ is more accessible than the TAS questionnaire. For example, in PAQ it is stated, “when I’m feeling bad, I can’t tell whether I am sad, angry or scared”. Additionally, “bad” is defined at the beginning of the PAQ. These definitions could help people with higher alexithymia traits understand what feelings the question is referring to. The PAQ has a good internal consistency subscale score ($\alpha \geq 0.8$) (Preece et al., 2018). Test-retest reliability was also measured as good (ICC = 0.70-0.79) (Cai et al., 2024).

Matrix Reasoning Item Bank (MaRs-IB): This 80-item task assesses non-verbal reasoning (Chierchia et al., 2019). This task is eight minutes in total, regardless of how many items you complete during those eight minutes. Participants do not have to complete all 80 items of the MaRs-IB. Each item is made up of a 3 x 3 matrix, making 9 cells in total. One of these cells in the bottom-right corner is empty and participants must choose the correct abstract shape out of four shapes provided to them. To choose the correct shape, participants must configure the relationship between the other shapes in the matrix. These shapes change in colour, size, shape and position. The MaRs-IB was selected because it measures non-verbal reasoning (NVR) and therefore, it can act as a proxy for cognition (Zorowitz et al., 2024). This provided an overview of cognitive abilities in PwP and controls. Another advantage is that participants could complete this in their own time, without the need for an experimenter having to conduct an interview on Zoom with them (e.g. the mini-mental state examination), to assess cognition (Folstein et al., 1975). The MaRs-IB-IB has a reasonable internal consistency value (Kuder-Richardson 20 ≥ 0.7) and test-retest reliability ($r = \geq 0.7$).

3.2.4 Procedure

Participants were asked to complete the PLF task online. This study was performed online for a variety reasons, such as for accessibility and equal opportunities. This is because from an ethical perspective, it would not be advisable to take PwP OFF their medication and make them do an in-person study, especially in an unfamiliar environment. This could pose potential dangers including that PwP would be more likely to fall over and injure themselves. Therefore, I chose to run this study online.

Participants were sent a link to the study in an email. The PLF task was conducted on Gorilla (Build-2022-10.25), allowing participants to complete the task remotely. Participants received detailed written instructions via email on the testing day, outlining the study. A researcher was made available via email and phone during the session to provide assistance, if needed. The PLF task lasted approximately 45 minutes and was to be completed in one sitting. Instructions provided during the testing session were kept simple and in large-font formats. The task began with a silent PLF video and following this, participants rated how angry, sad and happy the person in the video was feeling (Keating et al., 2022). This visual analogue scale ranged from ‘not at all angry/sad/happy’ to ‘very angry/sad/happy’. This was done over two consecutive days. For example, on the first day, PwP taking dopaminergic medication, were asked if they could complete the tasks before taking their first dose of medication. On the second day they were asked to complete the PLF task approximately one hour after taking their first dose of medication in the morning. The order of days on which they took their dopaminergic medication was counterbalanced. This is to ensure any effects of order were accounted and balanced for. Next, participants were asked to complete a non-verbal reasoning task, The MaRs-IB on Gorilla (Build-2022-10.25). This was followed

by a series of questionnaires including the AQ, TAS, PAQ and MDS-UPDRS Part II (Motor Experiences of Daily Living). Together, these questionnaires and the MaRs-IB took no longer than 1 hour. These questionnaires were completed on an institutionally licensed version of Qualtrics. Together, the questionnaires and MaRs-IB, took no longer than 1 hour. The battery of questionnaires was performed on the second day of the study, in the afternoon, after PwP would have taken their morning medication. This was to try to minimise confusion when PwP were answering questionnaires about how they felt. This is because if they were answering questions and they were OFF their dopaminergic medication, they might be feeling slightly worse than normal, and this would bias their answers given in the questionnaires.

To ensure consistent stimulus presentation and control for variability in display size and resolution, participants' screen resolution and browser window dimensions were recorded using Gorilla's 'Browser Info' node. Participants were instructed to complete the study on a desktop computer or laptop (mobile phones and tablets were not permitted). Screen size data were reviewed and any participants using a screen resolution below the minimum threshold (1366 x 768) would be excluded from the analysis.

3.2.5 Statistical Analysis

3.2.5.1 Group Demographics

The number of PwP in each gender category was noted. Mean and Standard Deviation (SD) were calculated for age, non-verbal reasoning, alexithymia (TAS and PAQ) autistic traits (AQ) and parkinsonian traits (UPDRS).

3.2.5.2 Emotion Recognition Accuracy Score

The emotion ratings for angry/sad/happy on each trial were given a score from 0 to 10 (Keating et al., 2022). 0 represented a response of ‘not at all angry/sad/happy’ and 10 represented a response of ‘very angry/sad/happy’. To calculate an ERA score, for example, when a sad PLF is shown, the mean rating of the two incorrect emotions (angry and happy) was subtracted from the rating for the correct emotion (sad).

3.2.5.3 Analysis of Variance (ANOVA)

One aim was to confirm whether PwP OFF their dopaminergic medication had reduced accuracy for FER compared to when they were ON their dopaminergic medication. The other aim was to manipulate speed and spatial levels to reveal which factor (if any), contributes to the observed differences (if found, as part of the main aim) in ERA scores in PwP. This will be achieved by PwP performing the PLF task twice and calculating ERA scores. To compare the ERA score for PwP when they were ON and OFF their dopaminergic medication, a 2x3x3x3 repeated measures ANOVA was conducted, with the within-subjects factors drug (ON and OFF dopaminergic medication), emotion (angry, happy, sad), spatial (S1, S2, S3) and kinematic (K1, K2, K3) levels. ERA score was the dependent variable.

3.2.6 Pre-Registration, Power Analysis, and Data Availability

The pre-registration for this study can be found online at https://osf.io/vzj2b. No changes or deviations were made in terms of study design, data collection procedures or the analysis plan since writing the pre-registration.

To estimate the required sample size, an a priori power analysis was conducted using General Linear Mixed Model Power and Sample Size (GLIMMPSE) (Kreidler et al., 2013). One study compared medicated PwP (N=20), unmedicated PwP (N=16), and controls (N=40) (Sprengelmeyer et al., 2003). This research by Sprengelmeyer and colleagues (2003), reported that difficulties in FER were greater for unmedicated PwP than for medicated PwP. We chose to base our power calculation on this study because it had a similar set-up to the studies discussed in this chapter of the thesis. Importantly, in this chapter, differences in emotion recognition were compared in PwP when they were both ON and OFF their dopaminergic medication, forming a within-subjects design. Therefore, the power analysis performed (based on FER abilities from PwP ON and OFF their dopaminergic medication), gave us the maximum possible number of participants needed in this chapter, compared with a between-groups comparison used in the Sprengelmeyer and colleagues study (2003). This is because different people were recruited for the PwP ON medication group compared to the PwP OFF medication group. In addition, as this thesis planned two separate comparisons (PwP versus controls, **Chapter 2** and PwP ON medication versus PwP OFF medication, **Chapter 3**), this one a priori power analysis allowed us to cover the participants needed for both chapters. This approach had the added benefit of ensuring sufficient power to detect effects in both comparisons, while maintaining consistency across these two studies. Therefore, in order to have 80% power to detect a difference in FER between unmedicated and medicated PwP (Cohen's d = 0.62; (Sprengelmeyer et al., 2003)) at alpha-level 0.05, 32 PwP were necessary for this study in total.

Anonymised data will be made available on an open-access repository (e.g. OSF) following publication of the main findings, in line with GDPR and ethical guidelines

approved by the Research Ethics Committee at the University of Birmingham. All shared data will be fully anonymised and accompanied by documentation to support the reuse of these findings.

3.3 Results

3.3.1 Group Demographics

Descriptive statistics for PwP are listed in **Table 3.1.**

Table 3.1

Descriptive Statistics for People with Parkinson's (PwP)

	PwP (n = 32)
Gender	18 M, 14 F, 0 O
Age	66.66 [10.72]
Dopaminergic Drug Class	Levodopa = 29 Dopamine Agonist = 14 Monoamine Oxidase-B Inhibitor = 10
Non-Verbal Reasoning	0.53 [0.13]
Alexithymia Traits (TAS)	42.28 [11.46]
Alexithymia Traits (PAQ)	67.63 [31.91]
Parkinsonian Traits (UPDRS)	10.50 [5.84]
Autistic Traits (AQ)	17.19 [6.82]

Note. Descriptive statistics for people with Parkinson's (PwP). This table has the mean (M) and standard deviations (SD) for age (in years), non-verbal reasoning, TAS, PAQ, UPDRS and AQ. (M[SD]). For the "Dopaminergic Drug Class" row, numbers represent how many PwP take levodopa, dopamine agonists, or monoamine oxidase-B inhibitors. It is important to note that some PwP took a combination of drugs, across some (or all) of these drug classes. M = male, F = female, O = other, TAS = Toronto Alexithymia Scale, PAQ = Perth Alexithymia Questionnaire, UPDRS = Unified Parkinson's Disease Rating Scale, AQ = Autism Quotient.

3.3.2 Comparison of Emotion Recognition Accuracy Scores Between People with Parkinson's ON and OFF Dopaminergic Medication

The order of days on which PwP took their medication (either one hour before (representing the 'ON' state) or after (representing the 'OFF' state) performing the task), was counterbalanced. In other words, 50% of the PwP did the task before taking their medication on day one and the other 50% of the PwP did the task before taking their medication on day two of the study.

Main Effect of Drug, Spatial and Kinematic Levels on Emotion Recognition Accuracy Score

To compare ERA scores, we used a 2x3x3x3 repeated measures ANOVA, with the within-subjects factors drug (ON or OFF), emotion (happy, angry, sad), spatial (S1, S2, S3) and kinematic level (K1, K2, K3). This analysis showed a main effect of drug ($F(1,31) = 12.82$, $p = 0.001$, $\eta_P^2 = 0.29$). This indicates that when PwP were ON their dopaminergic medication (mean = 2.8, SEM = 0.3), they had significantly higher ERA scores, compared to when they were OFF their dopaminergic medication (mean = 2.3, SEM = 0.2). There was also a main effect of spatial ($F(2, 62) = 101.48$, $p < 0.001$, $\eta_P^2 = 0.77$), and kinematic ($F(2,62) = 4.62$, $p = 0.019$, $\eta_P^2 = 0.13$) levels. A main effect of spatial level indicates that ((S1: mean = 1.52, SEM = 0.1; S2: mean = 2.83, SEM = 0.1; S3: mean = 3.33, SEM = 0.125)), greater levels of spatial exaggeration increase ERA scores. When this main effect of spatial level was unpacked by using three Bonferroni-corrected paired t-tests, significant differences were seen when comparing S1 and S2 ($t(31) = -10.6$, $p_{bonf} < 0.001$, mean difference = -1.31) S1 and S3 ($t(31) = -10.8$, $p_{bonf} < 0.001$, mean difference = -1.81) and S2 and S3 ($t(31) = -4.8$, $p_{bonf} < 0.001$, mean difference = -0.50). A main effect of kinematic

level indicates that there is an effect of kinematic level (K1, K2, K3) on ERA score (K1: mean = 2.36, SEM = 0.1; K2: mean = 2.67, SEM = 0.1; K3: mean = 2.66, SEM = 0.1). When this main effect of kinematic level was unpacked by using three Bonferroni-corrected paired t-tests, no significant differences were seen when comparing K1 and K2 ($t(31) = -2.8$, $p_{bonf} = 0.064$, mean difference = -0.31) K1 and K3 ($t(31) = -2.0$, $p_{bonf} = 0.077$, mean difference = -0.30) and K2 and K3 ($t(31) = 0.1$, $p_{bonf} = 1.00$, mean difference = 0.011). As the Bonferroni-corrected paired t-tests indicated that there were no significant differences between the kinematic levels, this demonstrates that the overall effect (main effect of kinematic level) may be very subtle. An interesting point to note is that there was no drug by kinematic ($F(2,62) = 0.912$, $p = 0.407$, $\eta_P^2 = 0.03$) interaction and no drug by spatial ($F(2,62) = 1.44$, $p = 0.245$, $\eta_P^2 = 0.04$) interaction. This implies that the effect of spatial and kinematic manipulation does not vary as a function of drug state in PwP.

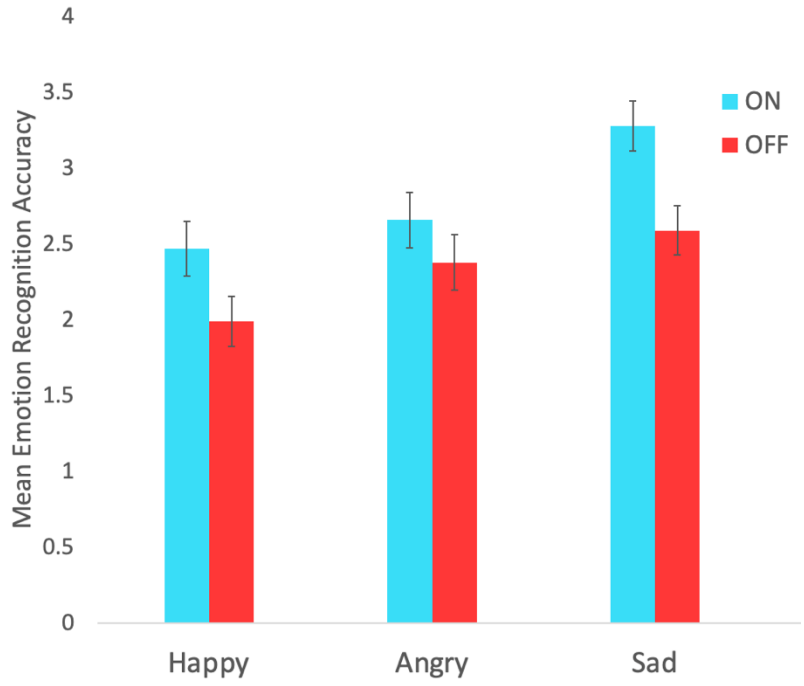
Main Effect of Drug, with No Significant Emotion by Drug Interaction

As discussed previously, a main effect of drug was observed. When PwP were ON their dopaminergic medication, they had higher ERA scores, compared to when they were OFF their dopaminergic medication. However, no significant drug by emotion interaction was found. This indicated that the effect of the dopaminergic medication was consistent across all emotions tested (happy, angry, and sad).

A visual representation of ERA scores across each emotion tested when PwP were ON and OFF their dopaminergic medication has been included for descriptive purposes only (**Figure 3.2**). It is important to note that no inference should be made by this graph, as there was no significant emotion by drug interaction ($p > 0.05$).

Figure 3.2

Mean ERA Score for Happy, Angry, and Sad When PwP Were ON and OFF Dopaminergic Medication



Note. Mean emotion recognition accuracy score for the emotions happy, angry and sad in the PLF task. The data presented are from PwP ON and OFF their dopaminergic medication. Error bars represent the standard error of the mean. Statistical analysis showed a significant main effect of drug ($F(1,31) = 12.82$, $p = 0.001$, $\eta_P^2 = 0.29$). However, no significant drug by emotion interaction ($p > 0.05$) was found. This figure has been presented for descriptive purposes only.

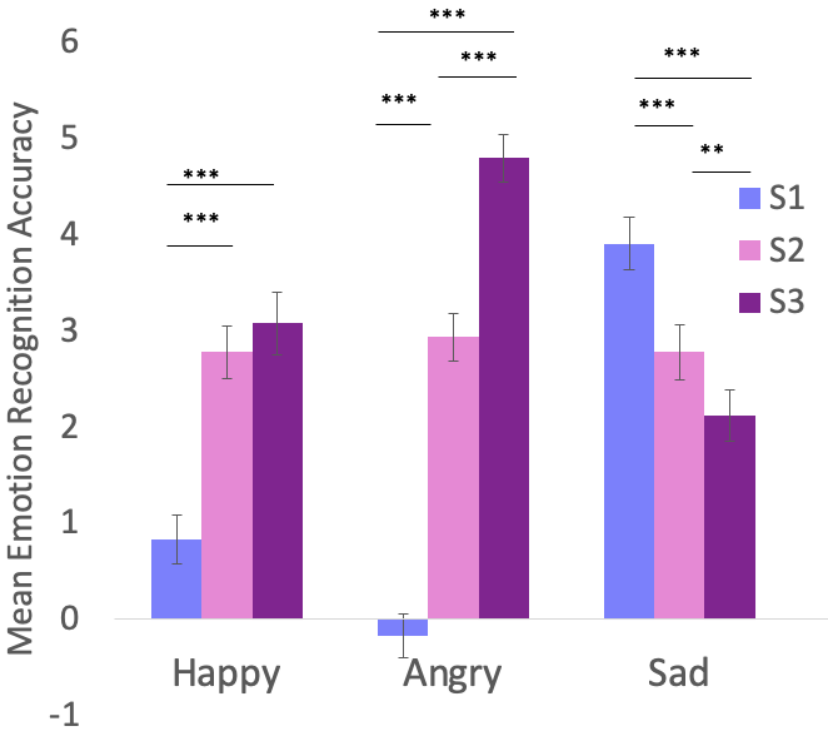
The Effect of Spatial Manipulations on Emotion Recognition Accuracy Scores is Not Significantly Different for Angry and Happy, but there are Opposing Effects for Sad

When a 2x3x3x3 repeated measures ANOVA was applied to the data, with the within-subjects factors drug (ON or OFF), emotion (happy, angry, and sad), spatial (S1, S2, S3) and kinematic level (K1, K2, K3) an emotion by spatial interaction ($F(4, 124) = 66.73$, $p < 0.001$, $\eta_P^2 = 0.68$) was found. This was similar to what other studies concluded (Keating et al., 2022; Sowden et al., 2021). Three post-hoc

repeated measure 2x3x3 ANOVAs were performed, with the within-subject's factors being with factors drug (ON or OFF), spatial level (S1, S2, S3) and kinematic level (K1, K2, K3). These ANOVAs uncovered a main effect of manipulating spatial level across all three emotions (happy ($F(2, 62) = 27.70$, $p < 0.001$, $\eta_P^2 = 0.47$), angry ($F(2, 62) = 187.95$, $p < 0.001$, $\eta_P^2 = 0.86$), and sad ($F(2, 62) = 28.92$, $p < 0.001$, $\eta_P^2 = 0.48$)). However, the direction of this effect was different for the high arousal emotions (angry and happy) compared to the low arousal emotion (sad). This was in line with what Keating et al., (2022) found. Finally, these ANOVAs were further unpacked using Bonferroni-corrected paired t-tests, to compare ERA scores achieved at different spatial levels within each emotion. Significant differences were seen when comparing angry S1 and S2 ($t(31) = -20.0$, $p_{bonf} < 0.001$), S1 and S3 ($t(31) = -26.7$, $p_{bonf} < 0.001$) and S2 and S3 ($t(31) = -13.4$, $p_{bonf} < 0.001$). Bonferroni-corrected paired t-tests also uncovered significant differences for happy S1 and S2 ($t(31) = -10.6$, $p_{bonf} < 0.001$) and S1 and S3 ($t(31) = -9.1$, $p_{bonf} < 0.001$). Significant differences were also found between the spatial levels for sadness. Differences were noted between S1 and S2 ($t(31) = 6.5$, $p_{bonf} < 0.001$), S1 and S3 ($t(31) = 9.7$, $p_{bonf} < 0.001$), and S2 and S3 ($t(31) = 4.2$, $p_{bonf} = 0.006$). These results highlight that the effect of the spatial manipulation is not significantly different for the high arousal emotions, happy and angry. For these emotions, ERA scores increase as spatial level increases. However, the effect of the spatial manipulation is in the opposite direction for the low arousal emotion, sad. In this case, ERA scores are higher as the spatial level decreases. Mean ERA scores for each emotion (happy, angry, and sad) across all the spatial levels are displayed in **Figure 3.3**.

Figure 3.3

Mean ERA Score for Happy, Angry, and Sad Across the Spatial Levels



Note. Mean emotion recognition accuracy score across the spatial levels (S1, S2, and S3) for the emotions happy, angry, and sad in the PLF task. The data presented are from PwP ON and OFF their dopaminergic medication. Spatial levels were as follows: S1 (50% of the original spatial stimulus level), S2 (100% of the original spatial stimulus level), and S3 (150% of the original spatial stimulus level). Error bars represent the standard error of the mean. Bonferroni-corrected paired t-tests were applied to check for significant differences between the spatial levels. *** Represents $p < 0.001$. ** represents $p < 0.01$.

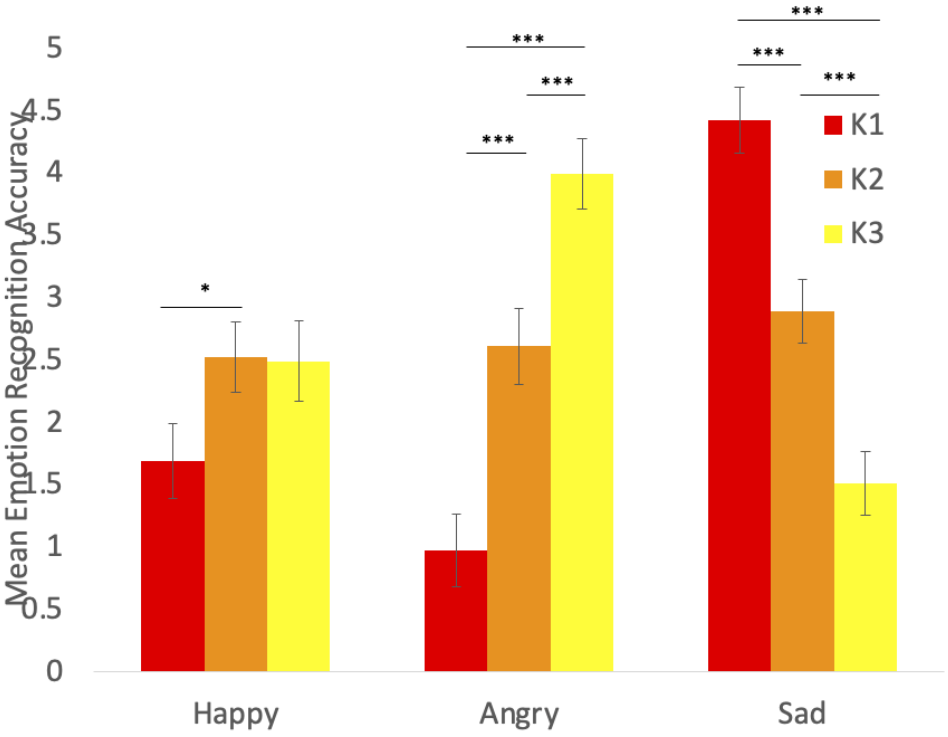
The Effect of Kinematic Manipulations on Emotion Recognition Accuracy Scores is Not Significantly Different for Angry and Happy, but there are Opposing Effects for Sad

When a 2x3x3x3 repeated measures ANOVA was applied to the data, with the within-subjects factors drug (ON or OFF), emotion (happy, angry, and sad), spatial (S1, S2, S3) and kinematic level (K1, K2, K3) an emotion by kinematic interaction

($F(4, 124) = 66.12$, $p < 0.001$, $\eta_P^2 = 0.68$) was seen. Three post-hoc repeated measure 2x3x3 ANOVAs were performed, with the within-subjects factors being drug (ON or OFF dopaminergic medication), spatial (S1, S2, S3), and kinematic (K1, K2, K3) levels. Each ANOVA showed a main effect of kinematic level for the emotions happy ($F(2, 62) = 6.49$, $p = 0.008$, $\eta_P^2 = 0.17$) , angry ($F(2,62) = 111.89$, $p < 0.001$, $\eta_P^2 = 0.78$) and sad ($F(2, 62) = 61.94$, $p < 0.001$, $\eta_P^2 = 0.67$), as displayed in **Figure 3.4**. This was followed up with Bonferroni-corrected paired t-tests to compare ERA scores achieved at different kinematic levels within each emotion. Significant differences were seen when comparing angry K1 and K2 ($t(31) = -11.5$, $p_{bonf} < 0.001$), K1 and K3 ($t(31) = -18.5$, $p_{bonf} < 0.001$) and K2 and K3 ($t(31) = 0.1$, $p_{bonf} < 0.001$). Bonferroni t-tests also uncovered significant differences for happy K1 and K2 ($t(31) = -4.3$, $p_{bonf} = 0.018$). Finally, Bonferroni-corrected paired t-tests were used to uncover significant differences between the kinematic levels for sadness. Significant differences were found between K1 and K2 ($t(31) = 8.9$, $p_{bonf} < 0.001$), K1 and K3 ($t(31) = 14.1$, $p_{bonf} < 0.001$) and K2 and K3 ($t(31) = 9.1$, $p_{bonf} < 0.001$). These results convey that the direction of the kinematic effect on ERA score was different for the high arousal (happy and angry), and low arousal (sad) emotions. These mean ERA scores for each emotion (happy, angry, and sad) across all the kinematic levels (K1, K2 and K3) are displayed in **Figure 3.4.** These results provide a rationale for the emotion by kinematic interaction seen when the ANOVA was applied to the data.

Figure 3.4

Mean ERA Score for Happy, Angry, and Sad Across the Kinematic Levels



Note. Mean emotion recognition accuracy score across the kinematic levels (K1, K2, and K3) for the emotions happy, angry, and sad in the PLF task. The data presented are from PwP ON and OFF their dopaminergic medication. Kinematic levels were as follows: K1 (50% of the original speed), K2 (100% of the original speed), and K3 (150% of the original speed). Error bars represent the standard error of the mean. Bonferroni-corrected paired t-tests were applied to check for significant differences between the spatial levels. *** Represents $p < 0.001$. * Represents $p < 0.05$.

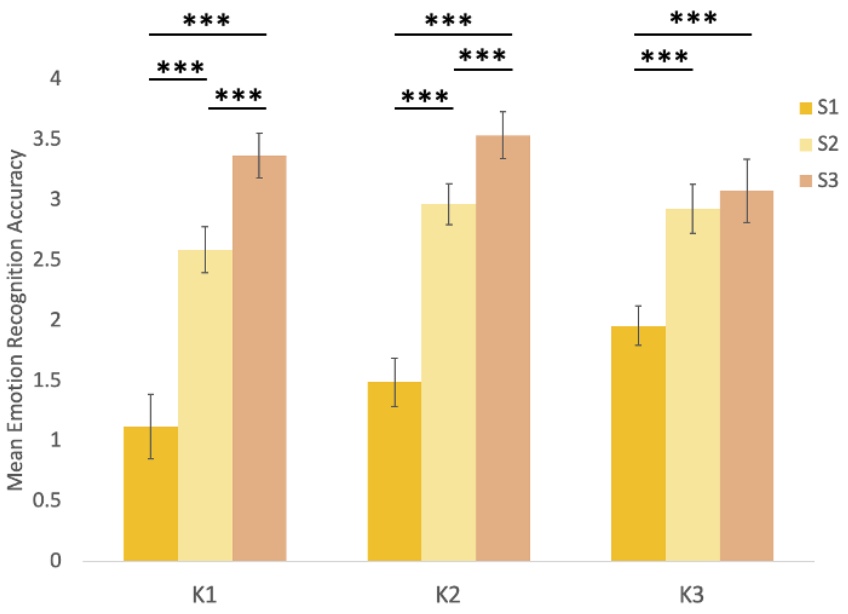
No Significant Difference in the Direction of the Effect on Emotion Recognition Accuracy Scores by Changing Spatial Level Across Each Kinematic Level

When a 2x3x3x3 repeated measures ANOVA was applied to the data, with the within-subjects factors drug (ON or OFF), emotion (happy, angry, and sad), spatial (S1, S2, S3), and kinematic level (K1, K2, K3) a spatial by kinematic interaction ($F(4,124) = 8.28$, $p < .001$, $\eta_P^2 = 0.21$). was seen. Three post-hoc repeated measure 2x3x3 ANOVAs were performed for each kinematic level, with the factors being drug (ON or OFF), emotion (happy, angry, and sad), and spatial level (S1, S2, S3). The

ANOVAs found a main effect of spatial level for each kinematic level (K1 ($F(2, 62) = 76.24$, $p < 0.001$, $\eta_P^2 = 0.71$), K2 ($F(2, 62) = 74.10$, $p < 0.001$, $\eta_P^2 = 0.71$), and K3 ($F(2,62) = 23.84$, $p < 0.001$ $\eta_P^2 = 0.44$)), as seen in **Figure 3.5**. This was then followed up with Bonferroni-corrected paired t-tests to compare ERA scores achieved at different spatial levels within each kinematic level. The results demonstrate that there is no significant difference in the direction of the effect (increasing spatial level, improves ERA), by changing spatial level across each kinematic level. Mean ERA scores across each kinematic level (which vary as a result of changing spatial level) are displayed in **Figure 3.5.**

Figure 3.5

Mean ERA Score for K1, K2, and K3 Across Each Spatial Level



Note. Mean emotion recognition accuracy score across the spatial levels (S1, S2, S3) for the kinematic levels (K1, K2, K3). The data presented are from PwP ON and OFF their dopaminergic medication. Kinematic levels were as follows: K1 (50% of the original speed), K2 (100% of the original speed), and K3 (150% of the original speed). Spatial levels were as follows: S1 (50% of the original spatial level), S2 (100% of the original spatial level), and S3 (150% of the original spatial level). Error bars represent the standard error of the mean. Bonferroni-corrected paired t-tests were applied to check for significant differences between the spatial levels. *** Represents $p < 0.001$.

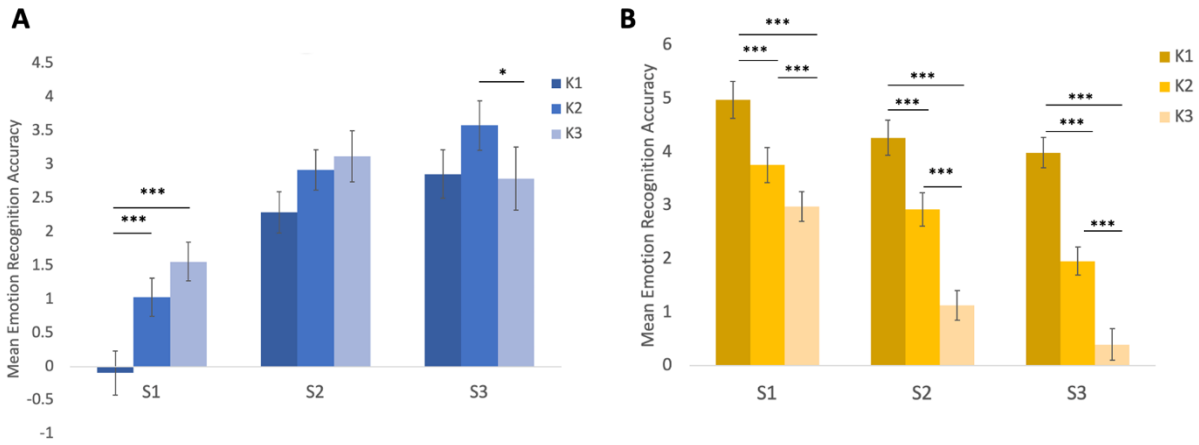
Increasing Kinematic Levels for Each Spatial Level Has Opposing Effects for Happy and Sad Emotions

When a 2x3x3x3 repeated measures ANOVA was applied to the data, with the within-subjects factors drug (ON or OFF), emotion (happy, angry, and sad), spatial (S1, S2, S3) and kinematic level (K1, K2, K3) an emotion by spatial by kinematic interaction ($F(8,248) = 2.42$, $p = .016$, $\eta_P^2 = 0.07$) was seen. To unpack this significant three-way interaction, we conducted post-hoc 2x3x3 ANOVAs (drug, spatial, and kinematic) for each emotion (happy, angry, and sad). This uncovered a significant interaction between spatial and kinematic levels for happy ($F(4,124) = 5.08$, $p < 0.001$, $\eta_P^2 = 0.14$) and sad ($F(4,124) = 4.79$, $p = 0.001$, $\eta_P^2 = 0.13$). This was not the case for angry ($p = 0.127$), however. When looking at the graphs for happy and sad, the pattern of results is observed to be different. For happiness, participants achieved higher ERA scores as kinematic levels increased for each spatial level (**Figure 3.6**). On the other hand, for sadness, participants obtained lower ERA scores as kinematic levels increased for each spatial level. These post-hoc ANOVAs were further unpacked using Bonferroni-corrected paired t-tests, to compare ERA scores for significant differences achieved at different kinematic levels, within each spatial level. These results convey that the direction of the kinematic effect (within each spatial level), on ERA score was different for happy and sad. When the ANOVA was further unpacked using Bonferroni-corrected paired t-tests, significant differences were also seen when comparing sad S1 K1 and K2 ($t(31) = 4.1$, $p_{bonf} = 0.001$), K1 and K3 ($t(31) = 6.4$, $p_{bonf} < 0.001$), and K2 and K3 ($t(31) = 3.0$, $p_{bonf} = 0.001$). Bonferroni t-tests also uncovered significant differences for sad S2 K1 and K2 ($t(31) = 4.6$, $p_{bonf} = 0.001$), K1 and K3 ($t(31) = 8.4$, $p_{bonf} < 0.001$) and K2 and K3 ($t(31) = 7.1$, $p_{bonf} < 0.001$). Finally, Bonferroni-corrected paired

t-tests were used to uncover significant differences between the kinematic levels for sad S3. Significant differences were found between sad S3 K1 and K2 ($t(31) = 6.9$, $p_{bonf} < 0.001$), K1 and K3 ($t(31) = 10.2$, $p_{bonf} < 0.001$) and K2 and K3 ($t(31) = 6.0$, $p_{bonf} < 0.001$).

Figure 3.6

Mean ERA Score for S1, S2, and S3 Across Each Kinematic Level for Happy (A) and Sad (B)



Note. Mean emotion recognition accuracy scores for happy (A) and sad (B) across the kinematic levels (K1, K2, K3) within each spatial level (S1, S2, S3). The data presented are from PwP ON and OFF their dopaminergic medication. Kinematic levels were as follows: K1 (50% of the original speed), K2 (100% of the original speed), and K3 (150% of the original speed). Spatial levels were as follows: S1 (50% of the original spatial level), S2 (100% of the original spatial level), and S3 (150% of the original spatial level). Error bars represent the standard error of the mean. Bonferroni-corrected paired t-tests were applied to check for significant differences between the spatial levels. ***Represents $p < 0.001$. * Represents $p < 0.05$.

3.4 Discussion

The current chapter investigated how accurate PwP were at FER when they were ON and OFF their dopaminergic medication. This helped to address the first aim of the study, which was to confirm if PwP OFF their dopaminergic medication had reduced accuracy for FER, compared to when they were ON their dopaminergic medication.

This chapter also aimed to uncover potential reasons behind FER differences, for PwP ON and OFF their dopaminergic medication, by manipulating spatial and kinematic features of dynamic displays. This aim was addressed by looking at potential interactions between drug and kinematic level and/or drug and spatial level.

This chapter addressed our first aim, by comparing PwP ON and OFF their dopaminergic medication to see if they had reduced FER abilities. A main effect of drug was seen in this chapter, meaning that PwP ON their dopaminergic medication had higher ERA scores compared to when they were OFF their dopaminergic medication. These results indicate that dopaminergic signalling may be involved in FER.

Perhaps dopamine influences FER in PwP by exerting general influences on perception and attention. Higher ERA scores when PwP were ON their dopaminergic medication could suggest that dopamine helps direct attention to socially relevant cues of the facial expressions (Nieoullon, 2002). This would improve FER abilities in PwP when they are ON dopaminergic medication. This pattern is also consistent with the "U-shaped dopamine curve", where excessively high or low levels of dopamine can negatively impact cognition (see **Chapter 5** for further information). (Cools & D'Esposito, 2011). Therefore, the findings from this chapter could highlight dopamine's potential role in FER, in PwP.

One study by Sprengelmeyer and colleagues (2003) also looked at FER in PwP ON and OFF their dopaminergic medication. In this study they found similar results, as discussed in this chapter when comparing PwP ON and OFF their dopaminergic medication (Sprengelmeyer et al., 2003). However, Sprengelmeyer and colleagues

(2003), found that PwP OFF their dopaminergic medication had specific difficulties with recognising negative emotions, namely anger and disgust, compared to PwP ON their dopaminergic medication. Arguably, these specific challenges with negative emotions may be due to the existence of a greater range of negative emotions (Argaud et al., 2018). Four out of six of the basic emotions are classed as negative emotions including, angry, sad, disgust, and fear. There is only one obvious positive emotion within the six basic emotions, happiness. Surprise is potentially a more controversial emotion, as it can have positive and negative connotations. Therefore, Argaud and colleagues (2018), suggested that PwP may be more likely to get negative emotions confused with each other. However, in this chapter, no drug by emotion interaction was found. Instead, PwP OFF their dopaminergic medication had reduced ERA scores across all emotions tested (happy, angry, and sad) compared to when they were ON their dopaminergic medication.

Perhaps this chapter did not find a specific difference in FER abilities for negative emotions, as stated by Argaud and colleagues (2018), because only three emotions were included in the PLF task. The PLF task used in this chapter only explored angry, happy, and sad emotions, meaning that there were not as many options that participants could get confused between. Instead, a main effect of drug was found, meaning all emotions (happy, angry, and sad) had lower ERA scores for PwP OFF their dopaminergic medication, compared to when they were ON their dopaminergic medication. This main effect of drug conveyed that the recognition of both positive and negative emotions were affected depending on drug state (ON versus OFF dopaminergic medication). This indicates that PwP may not necessarily confuse negative emotions with each other, and reduced ERA scores when PwP are OFF their

dopaminergic medication could be due to another factor. However, it is important to note that there is limited evidence of FER studies that directly compared the same PwP when they were ON and OFF dopaminergic medication (within-subjects design). Sprengelmeyer and colleagues (2003) used a between-subjects design meaning that different PwP were recruited for the ON and OFF dopaminergic medication groups. Perhaps this wider spread reduction in FER abilities seen in this chapter (reduction in FER abilities across all emotions tested) were due to the within-subjects design. This design could have increased sensitivity to pick up extra differences that previous studies using separate groups for PwP ON and OFF their dopaminergic medication, would not have detected.

Moving on to explore the second aim, we addressed potential reasons for differences in FER abilities between PwP ON and OFF their dopaminergic medication, by manipulating spatial features in the PLF task. We previously noted however, that there was no drug by spatial interaction. We observed an emotion by spatial interaction, which was in line with what has been seen in previous studies (Keating et al., 2022; Sowden et al., 2021). The level of spatial exaggeration led to variation in ERA scores depending on whether the emotion was high or low arousal. However, no emotion by spatial by drug interaction was observed. This suggests that the emotion by spatial interaction did not significantly vary depending on whether PwP were ON or OFF their dopaminergic medication. Further unpacking this emotion by spatial interaction revealed a main effect of manipulating spatial level for all three emotions, however, the direction of this effect was different for high arousal emotions (anger and happy) compared to the low arousal emotion (sad). Specifically, ERA scores for anger and happiness improved with increases in spatial levels. On the other hand, ERA scores

for sadness declined with increases in spatial levels. This pattern of findings was also confirmed in **Chapter 2** when comparing PwP OFF their dopaminergic medication and controls. These results suggest that PwP were still sensitive to the typical relationship between spatial levels and different facial expressions (also seen in controls in **Chapter 2**). Higher arousal emotions (anger and happiness) tend to be recognised more accurately by an increase in the spatial levels of the PLFs. On the other hand, sadness is recognised more accurately at reduced spatial levels.

In contrast to the emotion by spatial interaction found in this chapter, one study investigated FER of dynamic point-light displays, in controls and modified spatial properties of the face (after taking initial measurements of positions of different features of the faces), by exaggerating spatial distances (Pollick et al., 2003). By exaggerating distances, this can refer to positive exaggeration (or increasing distances of features) and negative exaggeration, (or decreasing distances of features). This study measured FER by exaggerating facial expressions including, anger, sadness, happiness, and surprise, to different extents. When the controls viewed these images, they selected one of the four emotions listed, that the image represented. This gave a measure of ERA. Following this, participants rated the intensity of this emotion. This research concluded that participants, in general, had better accuracy for happy, compared to anger. Furthermore, accuracy for happy expressions was better than the recognition of sad or surprise. They also noted that positive exaggeration of facial expressions improved ERA, compared to the natural “starting distances” and negatively exaggerated facial expressions. However, no significant interactions were found between expression and exaggeration. This contrasts the emotion by spatial interaction found in PwP, in this chapter. This is because this chapter found that

increasing the spatial level for happy and angry, related to improved ERA scores. Alternatively, decreasing the spatial level for sad, related to improved ERA scores. Perhaps the results from this chapter, combined with supporting knowledge from Pollick and colleagues (2003), suggests that PwP may utilise spatial manipulations in a different way to controls.

We continued to investigate the second aim, by addressing other potential reasons for FER differences between PwP ON and OFF their dopaminergic medication, by manipulating kinematic features in the PLF task. We previously noted however, that there was no drug by kinematic interaction. Different emotions are associated with different speeds, leading to differences in ERA scores when PLF videos were slowed down or sped up. An emotion by kinematic interaction was found, which was also in line with the current literature (Keating et al., 2022; Sowden et al., 2021). However, no emotion by kinematic by drug interaction was observed. This suggests that the emotion by kinematic interaction did not significantly vary depending on whether PwP were ON or OFF their dopaminergic medication. Further unpacking this emotion by kinematic interaction revealed a main effect of manipulating kinematic level for all three emotions, however, the direction of this effect was different for high arousal emotions (anger and happy) compared to the low arousal emotion (sad). The effect of manipulating kinematic level was significant for all three emotions. This general pattern of results was consistent with findings presented in **Chapter 2**, when comparing PwP OFF their dopaminergic medication and controls. In this current chapter, PwP became more accurate at identifying anger (i.e., ERA scores increased), and happiness (between K1 and K2), as the kinematic level increased. On the other hand, PwP became more accurate at identifying sadness, as the kinematic level decreased.

Again, this is what was found in two other studies who looked at FER abilities in the PLF task, in both autistic and non-autistic participants (Keating et al., 2022; Sowden et al., 2021). Importantly, considering the results across **Chapters 2 and 3**, these results suggest that PwP were still sensitive to the typical relationship between kinematic levels and different emotions. Higher arousal emotions (anger and happiness) tended to be recognised more accurately by an increase in the speed of the PLFs. On the other hand, sadness is recognised more accurately at slower speeds. Together, this indicates that PwP have a preserved sensitivity to typical kinematic features of emotional expressions.

One obvious reason for the differences in terms of ERA between our study and the current literature, is that we used dynamic displays as opposed to static stimuli (Sprengelmeyer et al., 2003). Kinematic and spatial levels were manipulated in the PLF videos to see if these factors contributed to FER differences seen in PwP ON and OFF their dopaminergic medication, in line with the second aim for this study. Interestingly, as there was no drug by kinematic and no drug by spatial interactions, this implies that accuracy patterns across the kinematic and spatial levels do not differ as a function of drug status (ON and OFF their dopaminergic medication). An important point to note is that PwP ON and OFF their dopaminergic medication, must be using the kinematic and spatial cues in the same way, otherwise you would not see significant main effects of spatial and kinematic manipulation. These main effects show that PwP ON and OFF their dopaminergic medication are processing this information and using it in the same way. This chapter had the advantage of using dynamic displays, however, the physical factors manipulated in the PLF task

(kinematic and spatial information), did not seem to be the reason for differences seen in ERA scores when comparing PwP ON and OFF their dopaminergic medication.

There are some limitations to this PLF study. For example, only facial expressions were tested and there was no non-social control stimulus. Therefore, it cannot be concluded whether dopaminergic medication would change the accuracy on any type of motion perception task, or if this is exclusively seen when perceiving facial motion.

Another limitation is that only three of the six basic emotions (happy, angry and sad) were used in the PLF task. It would be preferable to extend this to the full range of the six basic emotions (also include disgust, surprise, and fear). This would enable us to get a more complete picture of how FER is affected for PwP, as the studies that have used static stimuli (e.g. photographs) mostly included all six of the basic emotions in their analyses. However, we chose to look at the emotions happy, angry, and sad because this included a combination of positive (happy) and negative (angry and sad) valences, allowing us to further explore if only negative emotions are affected in PwP when dynamic displays are used. Additionally, these three emotions are quite distinct from one another, even though anger and sadness have the same negative valence, they are known to not correlate strongly with each other (Erbas et al., 2019). Providing PwP with three, very distinct emotions was a good starting point to check if they still had difficulties with the recognition of these very different expressions, before moving on to expressions that may be more difficult to distinguish from each other. This is important because emotions that are more similar to each other (e.g. anger and disgust), require finer-grained distinctions to be accurately recognised. Additionally,

presenting participants with happy, angry, and sad PLF stimuli ensured that both high (happy and angry) and low (sad) arousal emotions were covered.

In summary, **Chapter 3** had two aims. Firstly, to uncover whether PwP OFF their dopaminergic medication had reduced FER abilities compared to when they were ON their dopaminergic medication. This was confirmed by comparing ERA scores for PwP ON and OFF their dopaminergic medication. An overall main effect of drug was seen which indicated that PwP OFF their dopaminergic medication had lower ERA scores compared to when PwP were ON their dopaminergic medication. Secondly, we wanted to explore two potential physical factors (kinematic and spatial levels) to find out why FER differences may be seen for PwP. We investigated if spatial and kinematic levels had any effect on FER when comparing PwP ON and OFF their dopaminergic medication. However, this chapter concluded that PwP are processing these kinematic and spatial levels and using them in the same way as controls. Future research should try to uncover other reasons why dopaminergic signalling may affect FER in PwP ON and OFF their dopaminergic medication.

Chapter 4 – Comparing Emotion Processing in People with Parkinson's OFF their Dopaminergic Medication and Controls

4.1 Introduction

In this chapter, there will be a focus on comparing emotion processing in PwP and controls. For the purpose of this thesis, FER and emotion processing should not be used interchangeably. Instead, emotion processing can be regarded as an 'umbrella term' which includes FER. Emotion processing relies on the integration of numerous skills, including emotion identifying, facilitating and understanding various emotions. This chapter will investigate if differences in emotion processing are a potential reason for the differences witnessed in FER. So far, in **Chapters 2 and 3** emphasis has been placed on exploring differences in the recognition of facial expressions between PwP ON and OFF dopaminergic medication and controls. These chapters also began to explore potential factors that may contribute to differences in FER abilities between these groups. For example, speed and spatial cues in the PLF task were changed to see how this affected ERA scores in PwP and controls. This chapter will expand on this idea of identifying factors to explain why PwP have differences in FER abilities, compared to controls.

It is important to distinguish between FER and emotion processing. These concepts are closely related, and are sometimes used interchangeably, but they have key differences. In the simplest terms, FER is the ability to identify emotions in other people through their facial expressions. FER relies on the movement of the face such as, the mouth moving to smile, indicating happiness (Lindquist & Gendron,

2013). This is distinct from emotion processing because whilst FER is primarily a 'visual task', which considers movements of the face to represent different expressions, emotion processing is more complex than this. Emotion processing involves integrating various skills such as, identifying, facilitating, and understanding different emotions (McCleery et al., 2014). This suggests that emotion processing is not as straightforward as simply looking at facial expressions and immediately understanding the emotion of the other person. Instead, this conveys that identifying emotions (through FER), is just one contributing factor to processing emotions. One study looking at the interpretation of facial expressions, depending on the situational context, contributes to this idea of emotion processing being portrayed as a holistic process (Aviezer et al., 2008). In this study, young control participants were shown images of faces representing the emotion, disgust. These faces were placed in different situational contexts (contexts associated with fear, sadness, anger and disgust). Participants then clicked on one of the six basic emotion labels that they thought represented the image best. They found that despite participants viewing the same 'disgusted' facial expression, their perception of facial expressions changed, depending on the situational context. Therefore, a clear distinction can be made between FER and emotion processing because processing emotions involves the integration of multiple emotion-based skills.

As previously suggested, emotion processing has multiple areas of interest including emotion recognition, emotion understanding, and emotion awareness. These areas of interest have been studied using various tasks, questionnaires, and combinations of both. One particular aspect of emotion processing, emotion awareness has been studied extensively in PwP, because alexithymia (which is known to cause increased

difficulties with emotion awareness), is increasingly common in PwP, compared to the control population (Hogeveen & Grafman, 2021; Ricciardi et al., 2015). Alexithymia may be measured by questionnaires such as TAS and PAQ (Preece et al., 2018; Bagby et al., 1994). These questionnaires assess alexithymia traits, which are associated with numerous conditions including autism and PwP. A recent study suggested that alexithymia is responsible for FER differences in autism, and these differences are not due to autism itself (Ola & Gullon-Scott, 2020). Therefore, one potential suggestion for the differences in FER abilities between PwP and controls could be due to the presence of alexithymia, or how well participants identify their own emotions.

Alexithymia is recognised as a non-motor symptom in PwP (Culicetto et al., 2024; Assogna et al., 2012). Prevalence scores for the occurrence of alexithymia in PwP are estimated at around 20%, this is double to what is witnessed in the general population (Dafsari et al., 2019; Assogna et al., 2016; Ricciardi et al., 2015). Alexithymia can also have higher prevalence rates in other populations, for example in the autistic community, around 55% of autistic individuals have alexithymia (Milosavljevic et al., 2016). Autism is a neurodevelopmental condition, which is associated with differences in emotion recognition compared to non-autistic individuals (Keating & Cook, 2020; Lozier et al., 2014; Harms et al., 2010). One study recruited female autistic participants to take part in questionnaires and a task (Ola & Gullon-Scott, 2020). Autistic traits were measured using the AQ, alexithymia traits were measured using the TAS, and FER ability was measured using the Geneva Emotion Recognition Test. Participants watched videos of actors expressing different emotions through facial expressions and tone of voice. Participants were

then shown an emotion wheel and selected the emotion that they believed was being portrayed by the actor. This study exemplifies a multidimensional approach to emotion processing by examining emotion awareness and emotion recognition through a combination of experimental tasks and questionnaires. Considering multiple domains in emotion processing and seeing how they relate to one another, helps to create a more detailed picture of emotion processing in participants. The results suggested that FER abilities were determined by alexithymia in the participants, and not because of autism. To conclude, it would be an interesting idea to explore if emotion awareness (assessed by measuring alexithymia traits), is connected to emotion recognition.

Mapping out an individual's "internal emotional landscape" allows researchers to determine whether participants have very distinguished and consistent emotional experiences and recognition of emotions. Alternatively, the landscape could convey that they may experience confusion between different emotions, if the clusters of distinct emotions (happy, angry, and sad) are overlapping. The internal emotional landscape refers to how people experience and process their own emotions. A recent study investigated this idea, of an emotional landscape, by recruiting control adult participants, who completed the EmoMap task (Keating & Cook, 2023). The EmoMap task has two parts. In part one, pairs of images were shown to participants, and they were asked to rate how similar the feelings evoked from the two images were. From this part of the task, they calculated "similarity scores". These similarity scores represented either the distance within one emotion cluster (happy-happy, angry-angry or sad-sad) of the pairs of images, or the distance between emotion clusters (happy-angry, happy-sad, angry-sad). In part two of the task, three images

were shown to participants. There were three emotional experimental conditions (happy, angry, and sad). For example, in the happy experimental condition, participants were asked to identify which image made them feel the “most happy” (with two of the images being inducers of happiness and one image being an inducer of another emotion). Each image was shown multiple times, in different combinations, with other images, to investigate how participants rated the image, when compared to other images. This part of the task, enabled the researchers to calculate “emotional consistency scores”. These scores represented how logically consistent a participant was when selecting images in this task. For example, a logically consistent decision implies that if a participant selects image A over image B and image B over image C, then image A must be selected over image C. However, a logically inconsistent decision would be if the participant selected image C, over image A. Keating & Cook (2023) concluded that two main patterns could be seen in participants. Some participants had emotion clusters (angry, happy, and sad) which were very easily distinguishable from one another. This reflects that there are clear differences in how they experience different emotions, and this is very consistent. For example, anger is very distinguishable from sadness, and the participant is very consistent with how each image makes them feel. Alternatively, some participants had emotion clusters which were not easily distinguishable from one another. In this case, the results would suggest that there are no clear differences in how they experience different emotions. For example, happiness may not be easy to distinguish from sadness. In this case, participants may be very inconsistent with these emotional experiences and tend to get different emotions confused with each other. The EmoMap task, maps out internal emotional landscapes and generates an emotional similarity score and an emotional

consistency score for each participant, aiding researchers to identify how participants experience different emotions.

Understanding emotion processing could help to carve out a theory for differences in FER abilities between PwP and controls. In a subsequent study, the EmoMap and PLF (as described in Chapters 2 and 3) tasks were used in the autistic population (Keating et al., 2023). The EmoMap task, was performed, as described in the previous paragraph. The PLF task was administered to determine ERA scores in autistic and non-autistic participants. In this study, they revealed that there were no group differences in emotional consistency scores and emotion differentiation scores. When they investigated which variables influenced emotion recognition in non-autistic participants, they found that both the distance between emotion clusters and distance within emotion clusters, predicted performance on the emotion recognition task (PLF). Similarly, when they investigated what variables were important for emotion recognition in autistic participants, they found that distance between clusters and distance within emotion clusters, predicted how autistic participants performed in the PLF task. It would be interesting to explore if PwP and older adult control participants also have similar or different FER abilities and variables classed as important for FER abilities, compared to the autistic and non-autistic participants explored in the previous studies (Keating & Cook, 2023; Keating et al., 2023). There appears to be similar variables deemed as important in FER for autistic and non-autistic participants. In this case, emotional similarity scores (distance scores) seem to be important in emotion recognition for autistic and non-autistic individuals. It would be interesting to explore the use of the EmoMap task in PwP because this task has not been tested in PwP before. No studies to date have

even considered the idea of different emotional similarity and consistency scores affecting FER in PwP. This chapter will enable us to see if a different clinical population have similar, or different variables, important for FER.

To summarise what we know so far, there appears to be few studies exploring psychological factors which may contribute to differences in FER abilities. In previous literature, the main psychological factor focussed on so far, in relation to FER abilities seems to be alexithymia (Alvarado-Bolaños et al., 2023; Klietz et al., 2020; Assogna et al., 2012). As mentioned previously, numerous approaches have been used to investigate various aspects of emotion processing in PwP. For example, various FER tasks (using static stimuli and dynamic displays) have been used to investigate emotion recognition (Bek et al., 2020; Shafiei et al., 2020; Lin et al., 2016; Clark et al., 2008; Lawrence et al., 2007; Sprengelmeyer et al., 2003; Adolphs et al., 1998). In addition, questionnaires have been used to explore emotional awareness. For example, TAS which is used to measure alexithymia traits (Bagby et al., 1994). Sometimes studies combine one of these approaches to look at a specific area of emotion processing, and link it with another task, to focus on potential mechanisms for differences in emotion processing between PwP and controls. One example, as mentioned previously, includes the study that used a combination of pictures, sounds, and videos of various emotional states to examine emotion recognition in PwP and controls (Yuvaraj et al., 2014). This study combined an emotion recognition task with electroencephalography to attempt to explain why emotion recognition differences may be seen, using a physiological measure.

There are several advantages of using the EmoMap task to look in depth at emotion processing in PwP. For example, it does not simply rely on emotion recognition from traditional FER tasks, but looks at situational context and real-world scenarios, improving the ecological validity of the task. The EmoMap task uses images from the Nencki Affective Picture System (Marchewka et al., 2014). Images from the Nencki Affective Picture System are validated for the emotions they specifically evoke and include images of landscapes and objects. This is different to the traditional FER tasks, where emotions are detected through facial expressions. In the EmoMap task, participants must distinguish between opposing emotions they might feel when looking at the pictures. This highlights how the task applies emotion differentiation skills. The EmoMap task also indirectly examines emotional awareness. This is because participants must be conscious of their own feelings when looking at the pictures, to identify what emotions are evoked by each image, and the relative intensity of these emotions. The EmoMap task helps to create a more accurate reflection of the complexity of the many emotional skills that an individual must have when interpreting emotions in the real-world. Analysis of the data that the EmoMap task produces also has the advantage of enabling us to understand what is (or what is not) important for FER abilities for PwP and older adult controls.

In addition to the EmoMap task, PwP and controls completed a battery of questionnaires. This enabled us to investigate the influence (if any) of various psychological factors on FER abilities. The Multidimensional Assessment of Interoceptive Awareness Version 2 (MAIA-2) was included in the questionnaire battery based on recent evidence linking between poor interoceptive awareness skills to difficulties with emotional awareness (Price & Hooven, 2018). Given the

heterogeneity within PwP, some individuals may have more pronounced differences in interoceptive awareness than others. Including the MAIA-2 allowed us to identify potential subgroups of PwP who had lower interoceptive awareness abilities, providing a deeper understanding of the relationship between interoception and FER. Omitting the MAIA-2 might have overlooked a key mediator influencing the relationship between PwP and emotion recognition abilities.

Beck's Depression Inventory (BDI) was also included in the questionnaire battery for two reasons. Firstly, depression appears to be more prevalent in PwP than in the general population (Chendo et al., 2022; Chuquilín-Arista et al., 2020; McLean et al., 2017). Secondly, other research has demonstrated that individuals with depression tend to have reduced FER abilities, compared to controls (Krause et al., 2021; Liu et al., 2021). Together, these findings suggest that depression could partly explain the differences in FER abilities between PwP and controls (see **Chapters 2 and 3).**

Finally, the Parkinson's Disease Questionnaire – 39 (PDQ-39) was included in the battery of questionnaires as it provides a comprehensive measure of emotional and social well-being in PwP (Jenkinson et al., 1997). Therefore, the PDQ-39 provides a more holistic perspective on how PwP are affected by their condition compared to part II of the UPDRS, which primarily focuses on daily, motor-based functions. The PDQ-39 captures domains such as emotional well-being and social support, which have been suggested as factors that lead to differences in FER abilities, generally (Manierka et al., 2021; Tanzer et al., 2013). Including this questionnaire offered insight to explore whether variation in these areas might relate to FER performance in PwP. For this chapter, the PDQ-39 was administered to both PwP and control

participants. To ensure consistency in format and scoring across groups, controls received the original questionnaire wording (including items framed as “due to Parkinson’s”) and were instructed to respond based on their general experiences, over the past month.

The current study compares emotion processing in PwP OFF their dopaminergic medication and controls. We chose to only perform the EmoMap task in PwP OFF their dopaminergic medication because this would enable us to obtain a baseline value of how PwP perform in a task assessing emotion processing, without the influence of dopamine. This is because dopamine is known to affect FER abilities in PwP (see **Chapter 3** for further details). In **Chapter 2**, we used the PLF task in PwP and controls to understand emotion recognition abilities. Data from the PLF task will be combined with data from the EmoMap task, in an attempt to draw connections between potential psychological factors and FER abilities in PwP. One main aim and two exploratory aims were created for this chapter to investigate the varying internal emotional landscapes in PwP and controls, and how these may relate to recognising emotions in other people. In **Chapter 2**, which compared PwP OFF their dopaminergic medication and controls, an emotion by group interaction was found. Group differences were noted for happiness and sadness in the PLF task. This suggested that PwP had lower ERA scores for happiness and sadness than controls. The current study had one main aim. This aim was to determine if PwP have lower emotional differentiation scores (smaller distances between emotional clusters) for happiness and sadness compared to controls. This would be an interesting finding because in **Chapter 2** we explored how FER abilities for happiness and sadness were reduced in PwP, compared to controls. If PwP have lower emotional

differentiation scores (when considering distances between emotion clusters), it could suggest that PwP are obtaining lower ERA scores for these emotions because they get happiness and sadness confused. This is because if there are smaller distances between happy and sad emotion clusters, it reflects that their internal emotional experience of these emotions are not easy to distinguish from each other. This aim was addressed in Part 1 of the EmoMap task.

There were also two exploratory aims to investigate in this chapter. Firstly, to explore if the emotional consistency scores for happiness and sadness are different when comparing PwP and controls. A difference in emotional consistency scores for happiness and sadness would be an interesting finding because if PwP had lower emotional consistency scores for happiness and sadness, this would suggest that they are inconsistent when deciding the relative intensity for happy and sad images. In addition if lower emotional differentiation scores were found for happiness and sadness, this could reflect a smaller distance between these two emotion clusters, as suggested by Keating & Cook (2023). Therefore, as discussed previously, a smaller distance between happy and sad could reflect that the participant may be more likely to get these emotions confused. In sum, finding a difference in emotional consistency scores in PwP could reflect a potential factor for why PwP have reduced ERA scores for these emotions, compared to controls in the PLF task. This exploratory aim was addressed in Part 2 of the EmoMap task. Finally, the second exploratory aim was to investigate associations between different variables (e.g. distance within clusters and emotional consistency scores) and ERA scores collected previously in the PLF task (as discussed in **Chapters 2 and 3**), for both PwP and controls. This aim was addressed using data from **Chapter 2** and

corresponding results from the EmoMap task. This could help to provide suggestions of important factors for FER abilities in PwP and controls. Together, these aims may help to identify factors that differentially influence FER abilities in PwP, compared with controls.

4.2 Methods

4.2.1 Participants

24 PwP (13 female; M_{AGE} = 64.33 years) and 22 gender and age-matched controls (11 female; M_{AGE} = 66.77 years) took part in this study. All participants were re-recruited from the initial PLF study (see **Chapter 2**), meaning all previous inclusion and exclusion criteria were adhered to. All PwP were given a diagnosis of idiopathic Parkinson's, with a maximum of eight years since diagnosis. PwP were also taking dopaminergic medication for Parkinson's. However, when participating in this study, PwP were tested in their OFF dopaminergic medication state. Exclusion criteria included a diagnosis of co-occurring motor problems or movement conditions such as Developmental coordination disorder, Huntington's disease, Tourette syndrome. Other exclusion criteria included the diagnosis of psychiatric clinical conditions such as schizophrenia or personality disorder, or a learning disability. All participants gave their full and informed consent. The participants were contacted via email to ask if they were interested in participating in a follow-up study. The study was approved by the Science, Technology, Engineering and Mathematics Ethical Review Committee at the University of Birmingham (ERN_2183-May2024). Participants were reimbursed for their time at a rate of £10.00 per hour.

4.2.2 Stimuli

Participants (N=46) completed the EmoMap task, which is a two-part task. In part one of the task, pairs of images were viewed from the Nencki Affective Picture System (Marchewka, Żurawski, et al., 2014). Participants were asked to “think about what feelings arise when you look at each of these images. Now please rate how SIMILAR these two feelings are.” A visual analogue scale was used which ranged from 0, ‘Not at all similar’ to 10, ‘Very similar’. Each of these images were known to evoke feelings of happiness, anger or sadness (Riegel et al., 2016). There was a total of five images for each emotion (happy, anger, and sad), meaning there were a total of 15 images and 105 trials in total (as there were 105 unique image combinations). This consisted of 75 between emotion-category combinations (e.g. 25 angry-happy, 25 angry-sad and 25 happy-sad) and 30 within emotion-category combinations (10 happy, 10 angry, and 10 sad). To ensure that participants were thinking carefully about their answers before responding, a reaction time check was used. If participants responded before 1000 milliseconds, an error message would appear onscreen (“Too fast. Our algorithm has detected that you might need to take longer to think through your answer. You will now incur a 5 second penalty and then will be asked to do the trial again”).

In Part two of the EmoMap task, three images were viewed from the Nencki Affective Picture System (Marchewka, Żurawski, et al., 2014). In this part of the task, there were three emotional experimental conditions (happiness, anger and sadness) and one non-emotional control condition. The control condition was completed first and participants had to select which image they found to be the most colourful (one

image was in grayscale and two were in colour). The image in grayscale acted as an attention check. If participants picked the grayscale image as the ‘most colourful’ a five second penalty occurred, and the participant had to repeat the trial. It was important to include this control condition because as suggested by Huggins and colleagues (2021), judging colour could be viewed as similar to judging emotions, it is more of a personal decision rather than purely factual. Furthermore, this control condition enabled the confirmation that emotional consistency scores achieved were in fact, due to emotion and not as a result of any other decision-making mechanisms. In the emotional experimental conditions, the happy, angry and sad conditions were shown in a randomised order for each participant. Similarly to the non-emotional control condition, one of the images served as an attention check. For example, in the happy condition one image would strongly induce anger or sadness. If the participant selected the image which was there as an attention check, they would receive a five second penalty and then be asked to repeat that trial again. This is because each of these images were proven to evoke feelings of happiness, anger or sadness meaning that there was one incorrect response for every three images shown (Riegel et al., 2016).

4.2.3 Questionnaires

Parkinson’s Disease Questionnaire – 39 (PDQ-39): This 39-item questionnaire assesses how often PwP experience difficulties with different areas of life, for example, social situations (Jenkinson et al., 1997). The PDQ-39 uses a five-point Likert scale (never, occasionally, sometimes, often, always) The scores for each question range from 0-4, respectively. The total scores range from 0-100, and the

lower the score, the better the quality of life. The PDQ-39 consists of eight different dimensions: mobility, activities of daily living, emotional well-being, stigma, social support, cognition, communication and bodily discomfort. This means that there are eight different dimension scores calculated. For example, for the dimension, “cognition” the sum of each score in cognition is totalled. This total number is then divided by the maximum score for cognition and multiplied by 100. A PDQ-39 summary index is then calculated by adding all the dimension scores together and dividing this total number by eight. The internal consistency scores for the eight different dimensions of PDQ-39 ranged from 0.50-0.79. This has been deemed as an acceptable standard (L. C. S. Tan et al., 2004). Test-retest reliability was also measured as acceptable (ICC = 0.67-0.87).

Multidimensional Assessment of Interoceptive Awareness Version 2 (MAIA-2): This 37-item questionnaire assesses interoception. This is defined as, the sensation, interpretation and integration of internal biological signals (Eggart et al., 2021). MAIA-2 uses a six-point Likert scale (never, very rarely, rarely, occasionally, very frequently, always). The scores for each question range from 0-5, respectively. The exceptions are questions 5-12 and question 15, which are scored in reverse order. The scores can range from 0-185, and the higher the score, the greater the awareness of bodily sensation. The MAIA-2 consists of eight different scales: noticing, not-distracting, not-worrying, attention regulation, emotional awareness, self-regulation, body listening and trust. This means that there are eight different scale scores calculated. For example, for the scale, ‘noticing’ the sum of each score in noticing is totalled. Percentiles were also calculated for each scale score, by dividing the total number of participants (this was performed separately for PwP and

control groups) from the number of data points that were below mean values, as calculated in a validation study (Mehling et al., 2018). The internal consistency scores for the eight different scales ranged from 0.64-0.83. The only two scales below the standard (α = 0.70), were noticing (α = 0.64) and not-worrying (α = 0.67) (Mehling et al., 2018). Test-retest reliability was measured as moderate to good (ICC = 0.67-0.79) (Scheffers et al., 2024)

Beck's Depression Inventory (BDI): This 21-item questionnaire measures levels of depression in an individual (Wang & Gorenstein, 2021). BDI uses a four-point Likert-type scale. The scores for each question range from 0-3. The total scores range from 0-63, and the higher the score, the greater the level of depression. The levels of depression are as follows: 1-10 (these ups and downs are considered normal), 11-16 (mild mood disturbance), 17-20 (borderline clinical depression), 21-30 (moderate depression), 31-40 (severe depression), and over 40 (extreme depression). BDI has strong psychometric properties. For example, it has a good internal consistency score ($\alpha \geq 0.7$) and test-retest reliability ($r \geq 0.9$) (Jackson-Koku, 2016; Beck et al., 1988).

4.2.4 Procedure

All participants completed this study online. As stated in **Chapters 2 and 3,** this study was performed online for accessibility and equal opportunities reasons. It would not be advisable if PwP were OFF their medication to do an in-person study, especially in an unfamiliar environment. This could pose potential dangers including that these individuals would be more likely to fall over and injure themselves.

Therefore, this study was run online. Participants were sent a link to this study via email. The EmoMap task was conducted on Gorilla (Build-2024-05/06), allowing participants to complete the task remotely. Participants received detailed written instructions via email on the testing day, outlining the study. A researcher was made available over email and phone during the session to provide assistance, if needed. The EmoMap task (Parts 1 and 2) lasted no longer than 1 hour and 10 minutes and was completed in one sitting. Instructions provided during the testing session were kept simple and in large-font formats. Subsequently, participants completed a battery of questionnaires: PDQ-39, MAIA-2 and BDI. These surveys were completed on an institutionally licensed version of Qualtrics. Together, the questionnaires took no longer than 25 minutes.

4.2.5 Statistical Analyses

Parametric assumptions were met for all frequentist analyses, for example, independent-samples t-tests and linear mixed effects models. Non-parametric linear mixed effects models were performed when parametric assumptions were violated. Examples of checks performed to determine if the data was normally distributed or not, and hence whether to employ parametric or non-parametric analyses, respectively include Q-Q plots, histograms, Shapiro-Wilk test and density plots. These statistical checks were all conducted using R.

4.2.5.1 Group Matching

To check if the groups (PwP and controls) matched on age, non-verbal reasoning, alexithymia (TAS and PAQ), autistic traits (AQ), and depression (BDI), independent-samples t-tests were conducted. To assess if the groups matched on gender, a chi-squared analysis was performed.

4.2.5.2 Group Differences

Differences in parkinsonian traits (UPDRS and PDQ-39) and interoceptive awareness (MAIA-2) were assessed using independent-samples t-tests.

4.2.5.3 EmoMap Part 1 – Emotional Similarity Scores

Multidimensional scaling was used to create maps of participants' internal emotional landscapes (Keating & Cook, 2023). Similarity ratings, from part one of the EmoMap task were converted into Euclidean distance scores through multidimensional scaling. Multidimensional scaling allows you to model the emotional images seen in the task, as points in multidimensional space. If the emotional images are rated as very similar, they will have shorter distances in the multidimensional space. This distance can then be plotted on a graph. Mean distances within one particular emotion cluster (10 angry-angry, 10 happy-happy and 10 sad-sad) and between different clusters (25 angry-sad, 25 happy-sad and 25 angry-happy) were calculated. These distances were calculated by taking an average across emotions/emotion

pairs. When considering distances both between and within emotion clusters, larger distances represent greater emotion differentiation.

4.2.5.4 EmoMap Part 2 – Emotional Consistency Scores

In part two of the EmoMap task, consistency scores were computed based on how "logically consistent" a participant's decision was (Keating & Cook, 2023). A logically consistent decision can be represented as if a participant selects image A over image B and image B over image C, then image A must be selected over image C. However, a logically inconsistent decision would be if the participant selected image C, over image A. If a participant makes multiple inconsistent decisions, this may reflect that the participant has an imprecise way of experiencing a particular emotion across multiple instances (Huggins et al., 2021). We followed the procedures of Keating and Cook (2023) to calculate consistency scores. The number of times a participant selected a particular image was totalled. A participant with completely logically consistent decisions would have a linear relationship for their rank scores. For example, the image evoking most emotions (or the most colourful image) would be selected in all ten trials and hence would score ten. The image evoking the least emotions (or the least colourful image) should never be selected and hence would score zero. An item difference score was computed for each trial. This was calculated by subtracting the rank score for the unchosen item from the rank score for the chosen item. If a decision was classed as inconsistent, the item difference score would be zero, or less. Total consistency scores were calculated by adding together all the item difference scores, for each condition (e.g. happy/angry/sad). If

all the decisions made by a participant were consistent, they would receive the maximum score of 220.

4.2.5.5 Linear Mixed Effects Models

Data was processed and analysed using R (R Studio version 2024.04.2+764) and Python (Jupyter Notebook version 6.5.7). To conduct the linear mixed effects models (LME), the lmer (from the lme4 package) function in R Studio was used. Additionally, the Anova (from the car package) function was used. The Anova function enabled a Type III ANOVA with a Kenward-Roger approximation for degrees of freedom to be conducted (Luke, 2017).

Distance Within Emotion Clusters

To assess the contribution of various predictors to distances within emotion clusters, LME were employed, with group, emotion and their interaction as fixed effects. Furthermore, a separate LME was employed, with UPDRS, emotion and their interaction as fixed effects. The following were also included as fixed effects: TAS, age, gender, AQ, NVR, BDI, and MAIA-2. Subject number was included in both LME as a random intercept. The following models were used:

Distance within clusters ~ Emotion * Group + TAS + Age + Gender + AQ + NVR + BDI + MAIA-2 + (1|Subject)

Distance within clusters ~ Emotion * UPDRS + TAS + Age + Gender + AQ + NVR + BDI + MAIA-2 + (1|Subject)

Distance Between Emotion Clusters

To assess the contribution of various predictors to distances between emotion clusters, LME was employed, with group, emotion, and their interaction as fixed effects. TAS, age, gender, AQ, NVR, BDI, and MAIA-2 were also included in the LME as fixed effects. Finally, subject number was included as a random intercept. The following model was used:

Distance between clusters ~ Emotion * Group + TAS + Age + Gender + AQ + NVR + BDI + MAIA-2 + (1|Subject)

4.2.5.6 Generalised Additive Mixed Models

Non-parametric linear mixed effects models, otherwise known as generalised additive mixed models (GAMM) were also conducted. GAMM is a combination of a generalised additive model (GAM) and LME. To conduct GAMM, gamm (from the mgcv package) and lme (from the nlme package) functions were used in R Studio. In a GAMM model, smooth terms are used to model non-linear relationships between the response variable and the predictors. Fixed effects are used for linear terms in the model, and so they are not ‘smoothed’. Finally, random effects are used to account for variations that are not covered by smooth terms or fixed effects. The Anova function can check the significance of the various predictors in the model. For the smooth terms and fixed effects, Anova is applied directly to gam. For the random effects, Anova is applied to the ‘lme’ object.

Distance Between Emotion Clusters

To assess the contribution of various predictors to distances between emotion clusters, GAMM was employed, with UPDRS as a smooth term and emotion as a modulator. TAS, age, AQ, NVR, BDI and MAIA-2 were also included in the GAMM as smooth terms. Gender was included as a categorical fixed effect. Finally, subject number was included as a random intercept. The following model was used:

Distance between clusters ~ s(UPDRS, by = Emotion, k = 3) + s(TAS) + s(Age) + s(AQ) + s(NVR) + s(BDI) + s(MAIA-2) + Gender, random = list(Subject = ~1)

Emotional Consistency Scores

To assess the contribution of various predictors to emotional consistency, GAMM was employed, with group, emotion and their interaction as fixed effects. TAS, age, AQ, NVR, BDI, and MAIA-2 were included in the model as smooth terms. Gender was included as a categorical fixed effect. Finally, subject number was included as a random intercept. The following model was used:

Emotional consistency ~ Group * Emotion + s(TAS) + s(Age) + s(AQ) + s(NVR) + s(BDI) + s(MAIA-2) + Gender, random = list(Subject = ~1)

To assess the contribution of various predictors to emotional consistency, GAMM was employed, with UPDRS as a smooth term and emotion as a modulator. TAS, age, AQ, NVR, BDI, and MAIA-2 were also included in the model as smooth terms. Gender was included as a categorical fixed effect. Finally, subject number was included as a random intercept. The following model was used:

Emotional consistency ~ s(UPDRS, by = Emotion, k = 3) + s(TAS) + s(Age) + s(AQ) + s(NVR) + s(BDI) + s(MAIA-2) + Gender, random = list(Subject = ~1)

4.2.5.7 Bayesian Correlation

Bayesian analyses were conducted and the classification scheme in JASP (version 0.19) was used (Lee, MD. & Wagenmakers, EJ., 2014). A Bayesian correlation was performed to provide evidence for one theory over another. Bayes Factors (BF_{10}) were calculated, whereby a BF_{10} value of between one and three suggests weak evidence for the alternative hypothesis, between three and ten suggests moderate evidence, and greater than ten represents strong evidence.

4.2.5.8 Boruta Wrapper Algorithm

A random forest analysis using the Boruta wrapper algorithm (Boruta function from the Boruta package) was conducted. A random forest analysis technique was selected to analyse the data because this technique can help to determine important variables when making predictions (in this case, about FER). The Boruta wrapper algorithm was specifically selected because it is based on random forest analysis techniques and is particularly useful in determining variables of importance. The Boruta wrapper algorithm identifies important variables by comparing them to shadow features. Shadow features are produced by shuffling the variables. The Boruta wrapper algorithm considers the importance score of each variable and compares this score to the highest importance score (shadowMax) of the shadow features. If the variable always has a higher importance score than the shadow features, then the algorithm confirms the variable as important. However, if the variable never has a higher importance score (shadowMin) than the shadow

features, it is classed as unimportant. Sometimes, the importance score of the variable is comparable to the shadow features, in this case it is considered as tentatively important. For this analysis, the outcome variable was overall mean ERA, and the predictor variables were AQ score and AQ subscale scores (AQ Social Skills, AQ Attention Switching, AQ Attention to Detail, AQ Communication and AQ Imagination). TAS score and TAS subscale scores (TAS Difficulties Describing Feelings, TAS Difficulties Identifying Feelings and TAS Externally Oriented Thinking). Additionally, MAIA-2 and MAIA-2 subscale scores (MAIA-2 Noticing, MAIA-2 Not Distracting, MAIA-2 Not Worrying, MAIA-2 Attention Regulation, MAIA-2 Emotional Awareness, MAIA-2 Self-Regulation, MAIA-2 Body Listening and MAIA-2 Trust) were included as predictor variables. The final predictor variables included were NVR ability, age, UPDRS score, BDI score, emotional consistency score (total emotional precision), distance between clusters and distance within clusters (emotional similarity scores).

4.2.6 Pre-Registration, Power Analysis, and Data Availability

The pre-registration for this study can be found online at https://osf.io/zfgjs. No changes or deviations were made in terms of study design, data collection procedures, or the analysis plan since writing the pre-registration.

This sample size is based on an a priori power analysis which was performed using GLIMMPSE. This study was powered for a Cohen's d value of 0.5 and so it was concluded that 44 participants were required in total (22 PwP and 22 controls). This is the threshold for a moderate effect size. Reflecting on data from **Chapter 2**,

particularly the large effect size observed for the accuracy of happiness, (Cohen's d = 1.80), this suggests an indication of the magnitude of differences that might be expected in this sample. Bearing this in mind, we were more interested in moderate/large effect sizes, rather than very small differences. Therefore, a minimum of 44 participants were to be recruited for this study (at least 22 PwP and at least 22 controls).

Anonymised data will be made available on an open-access repository (e.g. OSF) following publication of the main findings, in accordance with GDPR and ethical guidelines approved by the Research Ethics Committee at the University of Birmingham. All shared data will be fully anonymised and accompanied by documentation to support the reuse of these findings.

4.3 Results

4.3.1 Group Matching

Descriptive statistics for PwP and controls are listed in **Table 4.1,** in addition to tests of equivalence. PwP and controls did not significantly differ in terms of gender, age, non-verbal reasoning, alexithymia traits (e.g. TAS, PAQ), autistic traits (e.g. AQ), and depression severity (BDI).

4.3.2 Group Differences

Parkinsonian traits were measured using UPDRS and PDQ-39 scores. These scores both confirmed that PwP scored significantly higher than controls (UPDRS: t(44) = -6.75, p < 0.001. PDQ-39: t(44) = -2.71, p = 0.01), confirming that parkinsonian traits were higher for PwP compared to controls. Interoceptive awareness was measured using MAIA-2. It was found that PwP scored significantly lower than controls (MAIA-2: t(44) = 2.07, p = 0.04).

Table 4.1:

Descriptive Statistics for People with Parkinson's (PwP) Versus Controls (CTRL)

	PwP (n = 24)	CTRL (n = 22)	Test of Equivalence
Gender	11 M, 13 F, 0 O	11 M, 11 F, 0 O	$X^2(1, N = 46) = 0.08, p = 0.78$
Age	64.33 [10.60]	66.77 [6.21]	$t(44) = 0.94, p = 0.35$
Non-verbal Reasoning	0.54 [0.14]	0.58 [0.12]	$t(44) = 0.95, p = 0.35$
Alexithymia Traits (TAS)	41.25 [12.55]	40.68 [10.02]	$t(44) = -0.17, p = 0.87$
Alexithymia Traits (PAQ)	64.63 [35.08]	58.55 [22.72]	$t(44) = -0.69, p = 0.25$
Parkinsonian Traits (UPDRS)	9.46 [5.24]	1.41 [2.02]	$t(44) = -6.75, p < 0.001$***
Parkinsonian Traits (PDQ-39)	21.70 [13.21]	12.47 [9.44]	$t(44) = -2.71, p = 0.01$*
Autistic traits (AQ)	16.63 [6.89]	16.64 [7.29]	$t(44) = 0.01, p = 1.00$
Depression Severity (BDI)	11.17 [8.41]	8.00 [5.85]	$t(44) = -1.47, p = 0.15$
Interoceptive Awareness (MAIA-2)	101.71 [17.96]	113.55 [20.77]	$t(44) = 2.07, p = 0.04$*

Note. Descriptive statistics for people with Parkinson's (PwP) versus controls (CTRL). This table has the mean (M) and standard deviations (SD) for age (in years), non-verbal reasoning, TAS, PAQ, UPDRS, PDQ-39, AQ, depression, and MAIA-2 (M[SD]). For tests of equivalence, significant p-values represent differences between groups. M = male, F = female, O = other, TAS = Toronto Alexithymia Scale, PAQ = Perth Alexithymia Questionnaire, UPDRS = Unified Parkinson's Disease Rating Scale, PDQ-39 = Parkinson's Disease Questionnaire – 39, AQ = Autism Quotient, BDI = Beck's Depression Inventory, MAIA-2 = Multidimensional Assessment of Interoceptive Awareness Version 2. *** p < 0.001, * p < 0.05.

4.3.3 EmoMap Part 1 – Emotional Similarity Scores

4.3.3.1 Testing for Normality – Distance Within Clusters

Emotion by Group Interaction as a Predictor

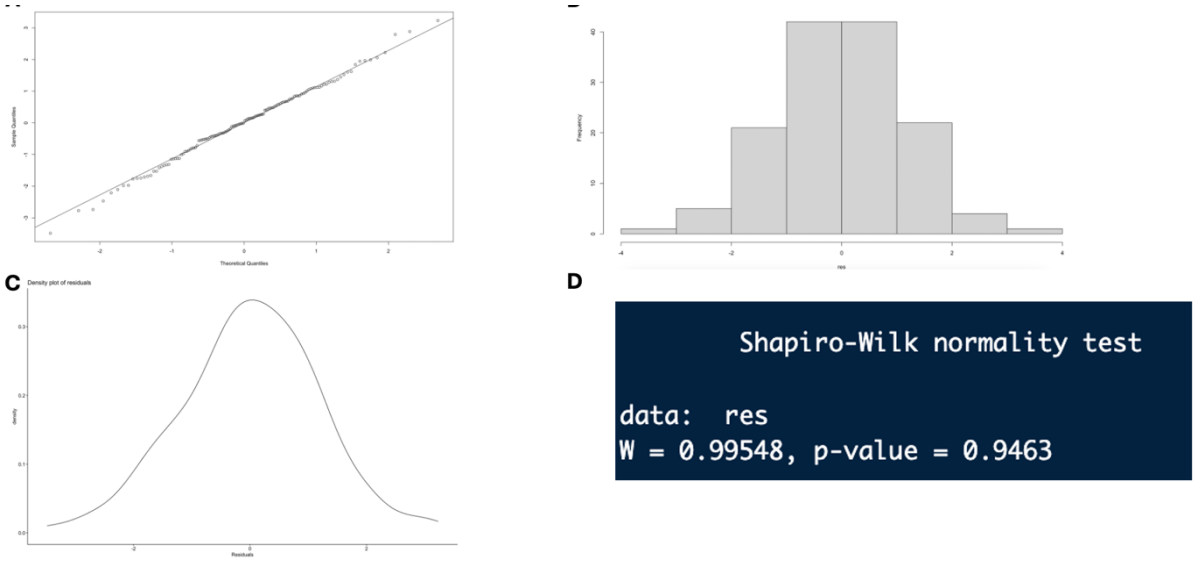
When building an LME for the response variable, distance within clusters, parametric assumptions were checked via a Q-Q plot, histogram, density plot, and a Shapiro-Wilk normality test. It was confirmed that the residuals from this model, were normally distributed and hence an LME was conducted.

Emotion by UPDRS Interaction as a Predictor

When building an LME for the response variable, distance within clusters, parametric assumptions were checked via a Q-Q plot, histogram, density plot, and a Shapiro-Wilk normality test (**Figure 4.1**). It was confirmed that the residuals from this model, were normally distributed and hence an LME was conducted.

Figure 4.1

Checking for Normality of the Residuals for the Model Looking at Distance Within Clusters



Note. Checking for normality of the residuals for the model looking at distance within clusters, with the interaction between emotion and UPDRS as a predictor. **Panel A** shows a Q-Q plot with points forming a straight line. **Panel B** shows a histogram with a normal distribution. **Panel C** shows a density plot which is bell-shaped and single peaked, reflecting a normal curve. **Panel D** shows the results from a Shapiro-Wilk normality test where $p > 0.05$, reflecting that the data is normal. Summarising these results together, the data reflects a normal distribution, and so parametric statistical analyses are appropriate to perform.

4.3.3.2 Linear Mixed Effects Model - Distance Within Clusters

To assess differences between groups (PwP versus controls) or UPDRS scores for their distances within emotion clusters, linear mixed effects models were used. These models predicted mean distance within clusters with emotion, group (or UPDRS score), and their interaction as fixed effects. The following control variables were also included as fixed effects: TAS score, age, gender, AQ score, NVR ability, BDI, and MAIA-2 (these questionnaires measure relevant demographic variables known to be associated with emotion perception) and with subject number as a random intercept (Cavieres et al., 2021; Hübner et al., 2021; Krause et al., 2021;

Colombarolli et al., 2019; Poljac et al., 2013; Isaacowitz et al., 2007). When emotion, group and their interaction were included as fixed effects, the linear mixed effects model showed that group does not contribute to distance within clusters ($F(1, 56.83) = 0.02$, $p = 0.88$). Additionally, when emotion, UPDRS score, and their interaction were included as fixed effects, the linear mixed effects models showed that UPDRS score does not contribute to distance within clusters ($F(1, 52.54) = 1.20$, $p = 0.28$).

4.3.3.3 Testing for Normality – Distance Between Clusters

Emotion by Group Interaction as a Predictor

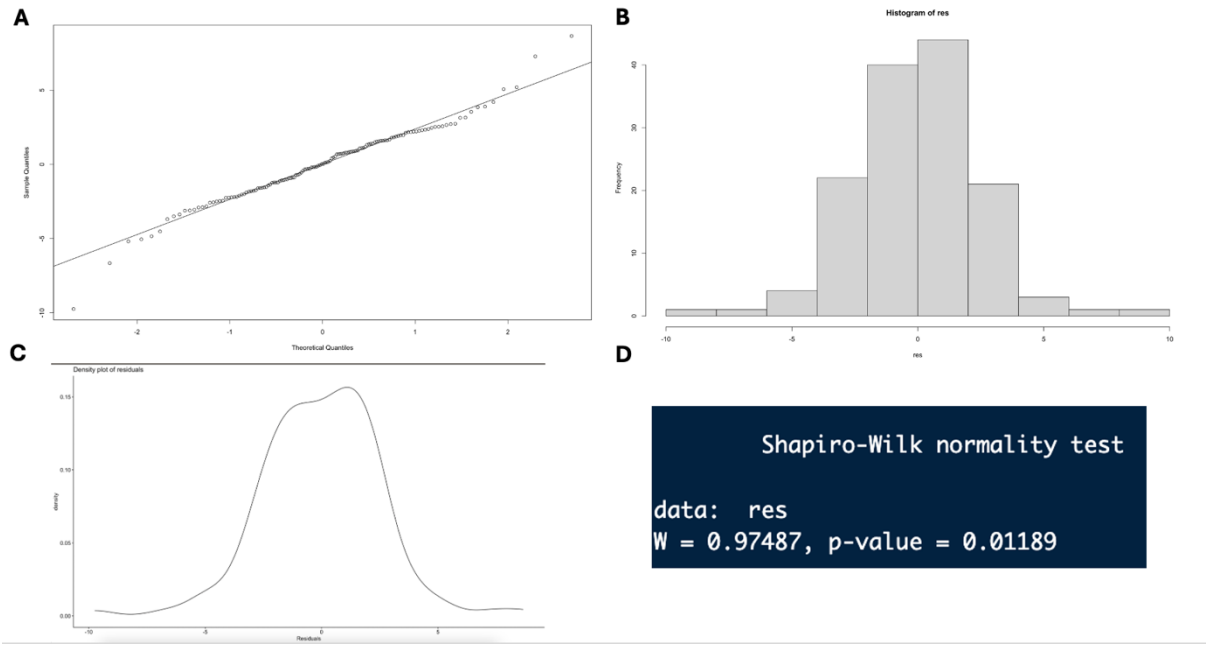
When building an LME for the response variable, distance between clusters, parametric assumptions were checked via a Q-Q plot, histogram, density plot, and a Shapiro-Wilk normality test. It was confirmed that the residuals from this model, were normally distributed and hence an LME was conducted.

Emotion by UPDRS Interaction as a Predictor

When building an LME for the response variable, distance between clusters, parametric assumptions were checked via a Q-Q plot, histogram, density plot, and a Shapiro-Wilk normality test (**Figure 4.2**). It was confirmed that the residuals from this model, were not normally distributed and hence a GAMM was conducted.

Figure 4.2

Checking for Normality of the Residuals for the Model Looking at Distance Between Clusters



Note. Checking for normality of the residuals for the model looking at distance between clusters, with the interaction between emotion and UPDRS as a predictor. **Panel A** shows a Q-Q plot with points deviating marginally from a straight line. **Panel B** shows a histogram with a slight deviation from normal distribution. **Panel C** shows a density plot which is beginning to indicate the presence of multiple peaks, reflecting a skewed curve. **Panel D** shows the results from a Shapiro-Wilk normality test where $p < 0.05$, reflecting that the data is not normal. Summarising these results together, the data does not reflect a normal distribution, and so non-parametric statistical analyses are appropriate to perform.

4.3.3.4 Linear Mixed Effects Model and Generalised Additive Mixed Model – Distance Between Clusters

To assess differences between groups (PwP versus controls) or UPDRS scores for their distances between emotion clusters, LME and non-parametric linear mixed effects models (GAMM) were used, respectively. LME predicted mean distance between clusters with emotion, group, and their interaction, as fixed effects. On the

other hand, GAMM predicted mean distance between clusters with emotion as a modulator and UPDRS score as a smooth term. The following control variables were also included as fixed effects in both models (LME and GAMM): TAS score, age, gender, AQ score, NVR ability, BDI, and MAIA-2 (these questionnaires measure relevant demographic variables known to be associated with emotion perception) and with subject number as a random intercept in both models (Cavieres et al., 2021; Hübner et al., 2021; Krause et al., 2021; Colombarolli et al., 2019; Poljac et al., 2013; Isaacowitz et al., 2007). When emotion, group, and their interaction were included in the LME, the model showed that group does not contribute to distance between clusters ($F(1, 64.37) = 1.12$, $p = 0.29$). However, when emotion, UPDRS score, and their interaction were included in the GAMM, the model showed an interaction between UPDRS score and emotion, whereby higher UPDRS scores are a significant predictor of distance between emotion clusters for anger and happiness ($F(1.00, 1.00) = 5.38$, $p = 0.02$) [mean distance (SEM) = 19.22 (0.89)]. This was not the case for distance between emotion clusters for angry and sad ($F(1.00, 1.00) = 1.03$, $p = 0.31$) [mean distance (SEM) = 14.10 (0.46)], or happy and sad ($F(1.00, 1.00) = 3.10$, $p = 0.08$) [mean distance (SEM) = 17.46 (0.88)]. These findings suggest that UPDRS scores contributes to distance between clusters, in an emotion-dependent manner.

4.3.3.5 Bayesian Correlation – Distance Between Clusters

To further assess the relationship between UPDRS score and distance between clusters, a Bayesian correlation was used. This statistical technique was chosen because Bayesian correlations are useful when the focus is on the interpretation of a

relationship between two variables (in this case, UPDRS score and distance between clusters). It provides a numerical output stating how likely the data belongs to one hypothesis, over the alternative hypothesis through calculation of Bayes Factors (BF). The Bayesian correlation provided only anecdotal evidence for a correlation between UPDRS score and the distance between a participant's angry and happy clusters ($r(44) = -0.31$, $BF_{10} = 1.49$). This was also the case when the Bayesian correlation was run between UPDRS score and the distance between a participant's happy and sad clusters ($r(44) = -0.23$, $BF_{10} = 0.58$). A final Bayesian correlation was performed between UPDRS score and the distance between a participant's angry and sad clusters ($r(44) = -0.24$, $BF_{10} = 0.64$), this concluded that there is anecdotal evidence for no correlation between UPDRS score and the distance between a participant's angry and sad clusters.

4.3.4 EmoMap Part 2 – Emotional Consistency Scores

4.3.4.1 Testing for Normality – Emotional Consistency Scores

Emotion by Group Interaction as a Predictor

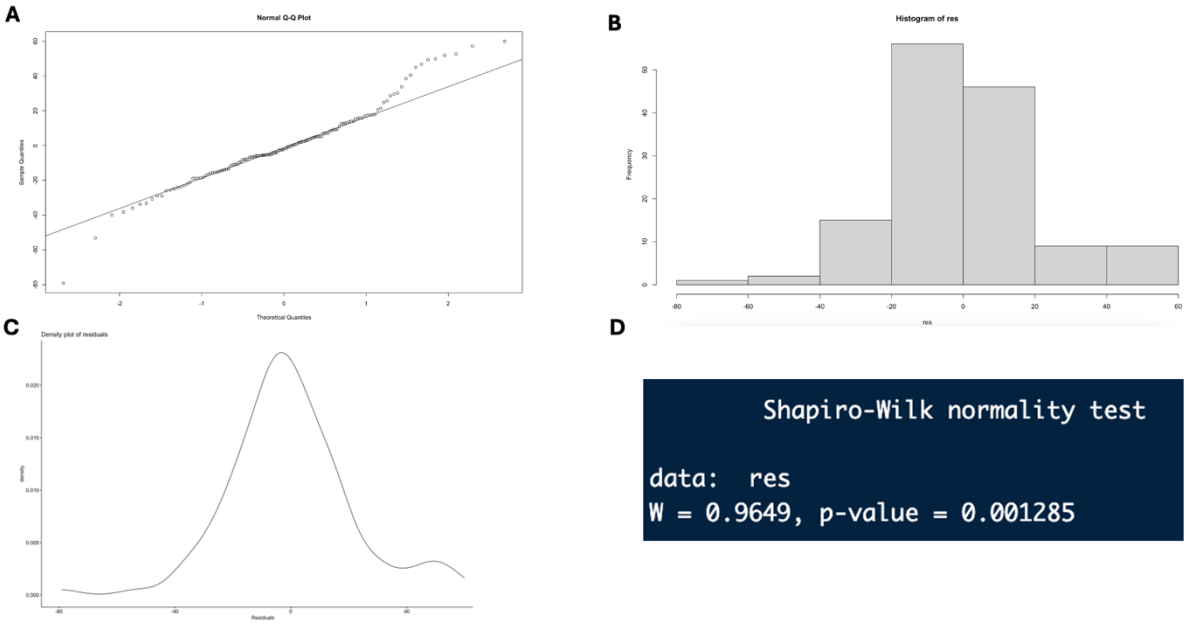
When building an LME for the response variable, emotional consistency scores, parametric assumptions were checked via a Q-Q plot, histogram, density plot and a Shapiro-Wilk normality test. It was confirmed that the residuals from this model, were not normally distributed and hence a GAMM was conducted.

Emotion by UPDRS Interaction as a Predictor

When building an LME for the response variable, emotional consistency scores, parametric assumptions were checked via a Q-Q plot, histogram, density plot, and a Shapiro-Wilk normality test (**Figure 4.3**). It was confirmed that the residuals from this model, were not normally distributed and hence a GAMM was conducted.

Figure 4.3

Checking for Normality of the Residuals for the Model Looking at Emotional Consistency



Note. Checking for normality of the residuals for the model looking at emotional consistency, with the interaction between emotion and UPDRS as a predictor. **Panel A** shows a Q-Q plot with points deviating away from a straight line, showing the formation of a ‘tail’. **Panel B** shows a skewed histogram. **Panel C** shows a density plot which indicates the presence of multiple peaks, reflecting a skewed curve. **Panel D** shows the results from a Shapiro-Wilk normality test where $p < 0.05$, reflecting that the data is not normal. Summarising these results together, the data does not reflect a normal distribution, and so non-parametric statistical analyses are appropriate to perform.

4.3.4.2 Generalised Additive Mixed Model – Emotional Consistency Scores

To assess differences between groups (PwP versus controls), (or UPDRS scores) and emotional consistency scores, non-parametric linear mixed effects models (GAMM) were used. For the model considering the interaction between UPDRS and emotion as a predictor for emotional consistency scores, UPDRS was modelled as a smooth term and emotion as a modulator. On the other hand, for the model considering the interaction between group and emotion as a predictor for emotional consistency scores, both group, emotion and their interaction were considered as fixed effects. The following control variables were included as fixed effects in both GAMM: TAS score, age, gender, AQ score, NVR ability, BDI, and MAIA-2 (again, these questionnaires measure relevant demographic variables known to be associated with emotion perception) and with subject number as a random intercept (Cavieres et al., 2021; Hübner et al., 2021; Krause et al., 2021; Stivaleti Colombarolli et al., 2019; Poljac et al., 2013; Isaacowitz et al., 2007). When emotion, group, and their interaction were included in the model, GAMM showed that group does not contribute to emotional consistency scores ($F(1, 32) = 0.21$, $p = 0.65$). Additionally, when emotion, UPDRS score, and their interaction were included in the model, GAMM showed that UPDRS score does not contribute to emotional consistency scores for angry ($F(1.00, 1.00) = 0.01$, $p = 0.95$), happy ($F(1.00, 1.00) = 0.13$, $p = 0.72$), or sad ($F(1.00, 1.00) = 0.03$, $p = 0.86$) emotions.

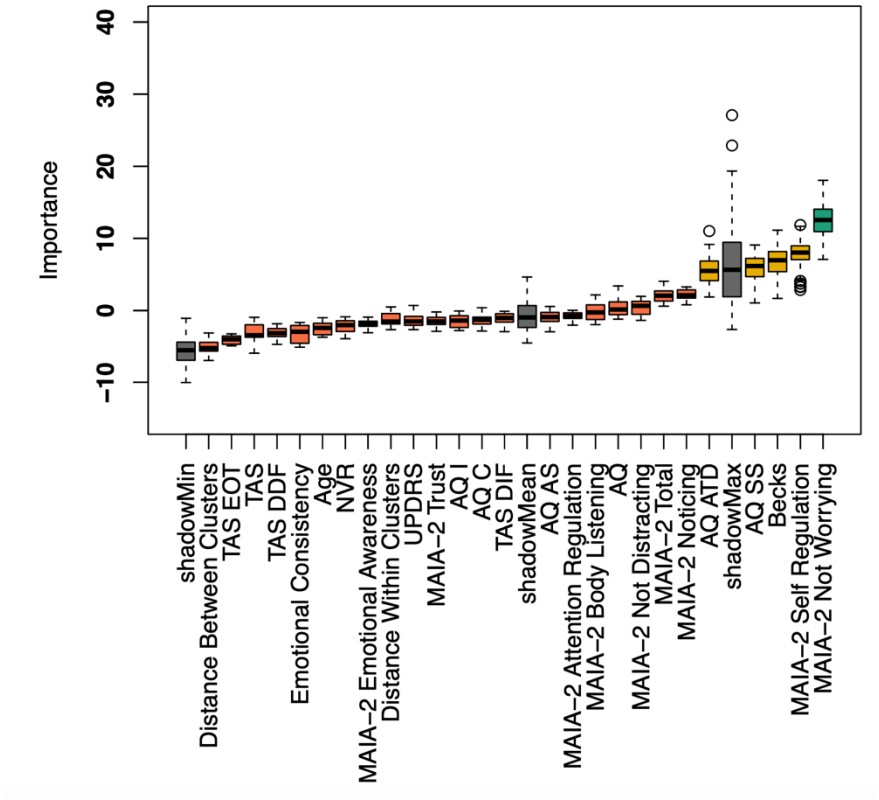
4.3.5 Assessing the Contribution of Various Factors to Emotion Recognition in Controls

To determine the importance of various factors for emotion recognition in control participants, a random forest analysis was conducted using the Boruta wrapper algorithm (version 8.0.0). In this random forest analysis, the outcome variable was overall mean ERA, and the predictor variables included: AQ score and each of the AQ subscale scores (AQ Social Skills, AQ Attention Switching, AQ Attention to Detail, AQ Communication, and AQ Imagination). TAS score and each of the TAS subscale scores (TAS Difficulties Describing Feelings, TAS Difficulties Identifying Feelings, and TAS Externally Oriented Thinking). MAIA-2 total score and each of the MAIA-2 subscale scores (MAIA-2 Noticing, MAIA-2 Not Distracting, MAIA-2 Not Worrying, MAIA-2 Attention Regulation, MAIA-2 Emotional Awareness, MAIA-2 Self-Regulation, MAIA-2 Body Listening, MAIA-2 Trust). Other predictor variables included: UPDRS score, BDI score, non-verbal reasoning ability, age, emotional consistency score (total emotional precision), distance between clusters, and distance within clusters (emotional similarity scores).

For control participants, of the 26 predictor variables tested, one was confirmed as important, four as tentative, and 21 as unimportant. **Figure 4.4** shows that MAIA-2 Not Worrying was classed as important for emotion recognition in control participants. MAIA-2 Not Worrying had a mean importance score of 12.40. AQ Social Skills, AQ Attention to Detail, MAIA-2 Self-Regulation, and BDI were classed as tentatively important with a mean importance score of 5.79, 5.58, 7.86, and 6.77, respectively. All other variables were classified as unimportant.

Figure 4.4

Predictor Variable Scores for 26 Variables Tested in the Boruta Random Forest Algorithm for Control Participants



Note. Predictor variable scores for 26 variables tested in the Boruta random forest algorithm for control participants. Each predictor variable is shown as a boxplot. Edges of each box represent the interquartile range (IQR). Whiskers represent 1.5 x IQR distance from box edges. Circles represent outliers. The colour of each box represents whether the algorithm deemed each predictor variable as important, or not. Green = confirmed important, yellow = tentatively important, orange = unimportant and grey = shadow features: shadowMin (minimum variable importance score), shadowMean (mean variable importance score), and shadowMax (maximum variable importance score).

4.3.6 Direction of Relationship for Statistically Significant Important and Tentative Predictor Variables of Emotion Recognition in Controls

In **Section 4.3.5** it was confirmed that MAIA-2 Not Worrying was an important predictor variable and MAIA-2 Self-Regulation, BDI, AQ Social Skills and AQ

Attention to Detail were tentative predictor variables of emotion recognition in controls. These results were also checked through the creation of an LME. After the Boruta wrapper algorithm, which is used to identify important predictor variables, an LME with all the important and tentatively important predictor variables was created. This LME concluded that the only predictor variable with statistical significance was MAIA-2 Self-Regulation ($F(1, 16) = 6.19$, $p = 0.02$). This LME also helped to confirm which direction the relationship between MAIA-2 Self-Regulation and ERA was in. A negative relationship ($b=-0.13$, $SE=0.05$, $t(16)=-2.49$, $p=.024$) was found between these variables, indicating that higher scores on MAIA-2 Self-Regulation (representing an increase in ability to regulate distress by paying attention to signals and sensations within the body), are associated with lower ERA scores.

4.3.7 Assessing the Contribution of Various Factors to Emotion Recognition in People with Parkinson's

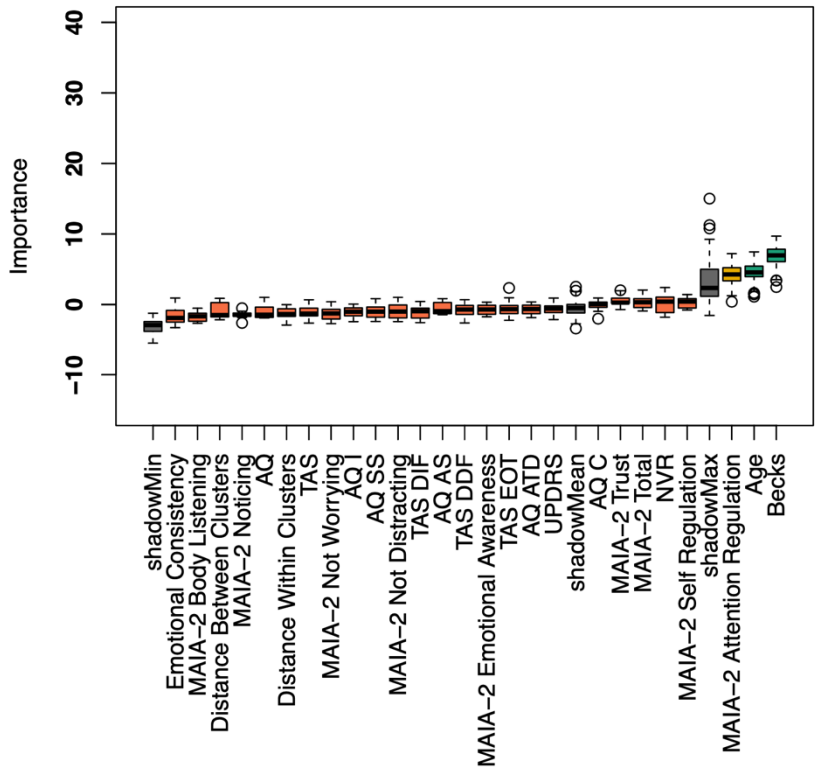
To determine the importance of various factors for emotion recognition in PwP, a random forest analysis was conducted using the Boruta wrapper algorithm (version 8.0.0). In this random forest analysis, the outcome variable was overall mean ERA, and the predictor variables included: AQ score and each of the AQ subscale scores (AQ Social Skills, AQ Attention Switching, AQ Attention to Detail, AQ Communication, and AQ Imagination). TAS score and each of the TAS subscale scores (TAS Difficulties Describing Feelings, TAS Difficulties Identifying Feelings, and TAS Externally Oriented Thinking). MAIA-2 total score and each of the MAIA-2 subscale scores (MAIA-2 Noticing, MAIA-2 Not Distracting, MAIA-2 Not Worrying, MAIA-2 Attention Regulation, MAIA-2 Emotional Awareness, MAIA-2 Self-

Regulation, MAIA-2 Body Listening, MAIA-2 Trust). Other predictor variables included: UPDRS score, BDI score, NVR ability, Age, Emotional Consistency score, Distance Between Clusters, and Distance Within Clusters.

For PwP, of the 26 predictor variables tested, two were confirmed as important, one as tentative, and 23 as unimportant. **Figure 4.5** shows that age and BDI were classed as important for emotion recognition in PwP. Age had a mean importance score of 4.54 and BDI had a mean importance score of 11.19. MAIA-2 Attention Regulation was classified as tentatively important and had a mean importance score of 4.21. All other variables were classified as unimportant.

Figure 4.5

Predictor Variable Scores for 26 Variables Tested in the Boruta Random Forest Algorithm for PwP



Note. Predictor variable scores for 26 variables tested in the Boruta random forest algorithm for PwP. Each predictor variable is shown as a boxplot. Edges of each box represent the interquartile range (IQR). Whiskers represent 1.5 x IQR distance from box edges. Circles represent outliers. The colour of each box represents whether the algorithm deemed each predictor variable as important, or not. Green = confirmed important, yellow = tentatively important, orange = unimportant and grey = shadow features: shadowMin (minimum variable importance score), shadowMean (mean variable importance score) and shadowMax (maximum variable importance score).

4.3.8 Direction of Relationship for Statistically Significant Important and Tentative Predictor Variables of Emotion Recognition in People with Parkinson's

In **Section 4.3.7** it was confirmed that age and BDI were important predictor variables and MAIA-2 Attention Regulation was a tentative predictor variable of

emotion recognition in PwP. These results were also checked through the creation of an LME. After the Boruta wrapper algorithm, which is used to identify important predictor variables, an LME with all the important and tentatively important predictor variables was created. This LME concluded that the only predictor variable with statistical significance was BDI ($F(1, 20) = 6.27$, $p = 0.02$). This LME also confirmed the direction of the relationship between BDI and ERA scores. A positive relationship ($b = 0.05$, $SE = 0.02$, $t(20) = 2.50$, $p = .021$) was found between these variables, indicating that higher scores on BDI (representing greater levels of depression severity) are associated with higher ERA scores. A second LME was generated which differed from the first LME by removing all other fixed-effects variables (except for the random effects variable, subjects) and only analysing the effect of the interaction between BDI and emotion. No interaction was found between emotion (happy, angry, and sad) and BDI score ($F(2, 620) = 1.56$, $p = 0.21$) when a second LME was generated, focussing on the potential interaction between these two variables.

4.4 Discussion

Although it was hypothesised that the emotions, happiness and sadness may have smaller distances between clusters for PwP compared to controls, this was not concluded from the results. The first aim of this study was to determine if PwP had lower emotional differentiation scores for happiness and sadness compared to controls. A smaller distance was predicted between the happy and sad emotion clusters for PwP, compared to controls because in **Chapter 2**, PwP had significantly lower ERA scores for happiness and sadness compared to controls. Therefore, it

was speculated that one reason for reduced ERA scores for these two emotions in PwP could be due to difficulty distinguishing between these emotions. In other words, their individual emotion clusters for happy and sad, may be quite overlapping, meaning that PwP may find these emotions difficult to differentiate when perceiving them from facial expressions in other people. However, when an LME was employed, the model showed that group (PwP versus controls) does not contribute to distance between clusters. This result is similar to what was found in a previous study, focussing on a different clinical population (autistic versus non-autistic participants), which also compared distances between emotion clusters using the EmoMap task (Keating et al., 2023). Although this chapter recruited a different clinical population (PwP versus controls), both autistic individuals and PwP have known differences with emotion recognition compared to non-autistic and control populations, respectively (for further information see **Section 5.2.4**) (Keating et al., 2022; Shafiei et al., 2020; Lin et al., 2016; Philip et al., 2010; Clark et al., 2008; Lawrence et al., 2007; Lindner & Rosén, 2006; Sprengelmeyer et al., 2003). In the study led by Keating and colleagues (2023), they found that group does not contribute to distance between clusters. This suggested that autistic and non-autistic participants in the study did not differ in differentiating emotions (angry, happy, and sad) from affective images. These results were comparable with the findings in the current chapter, when comparing PwP and controls.

Including UPDRS score, emotion, and their interaction in a GAMM uncovered a potential relationship between UPDRS score and distance between angry and happy clusters. However, a Bayesian correlation concluded that more evidence is required to confirm this. For exploratory purposes, and to gain a deeper understanding of how

the condition severity may affect emotional similarity scores in PwP, UPDRS score was included in a GAMM, instead of group. This model showed that higher UPDRS scores are a significant predictor of distance between emotion clusters for anger and happiness. This means that participants scoring higher on the UPDRS (which indicates greater difficulties in motor aspects of experiences of daily living in PwP), may result in larger distances between the emotion clusters, anger and happiness. Due to our relatively small sample size, a Bayesian correlation was used to assess the strength of evidence for the relationship between UPDRS score and distance between emotion clusters. However, only anecdotal evidence was found for a correlation between these two variables. Due to the limited evidence suggesting a correlation between the variables, more participants should be recruited in future studies to conclude if there really is a correlation between UPDRS score and distance between emotion clusters (e.g. between anger and happiness).

Differences in emotional consistency scores were considered as another potential reason for reduced ERA scores for happiness and sadness in PwP, compared to controls. However, emotional consistency scores did not differ between PwP and controls. The first exploratory aim was to investigate if emotional consistency scores for happiness and sadness were different when comparing PwP and controls. An exploratory aim was stated due to the very novel element of this study, looking at emotional consistency scores in PwP. It was considered that PwP may have lower emotional consistency scores for the emotions, happiness and sadness, compared to controls because in **Chapter 2** PwP had reduced ERA scores for happiness and sadness. Therefore, it could be hypothesised that PwP may make more inconsistent decisions in part 2 of the EmoMap task, leading to lower emotional consistency

scores (as explained in **4.2.5.4** EmoMap Part 2 – Emotional Consistency Scores). This would be reflected in the EmoMap task as making lots of inconsistent decisions for images representing happy and sad emotions. Therefore, PwP may struggle to interpret happy and sad facial expressions in other people. However, this idea has not been explored in the existing literature. When a GAMM was employed, the model showed that group does not contribute to emotional consistency scores. This was a different result to what was witnessed in a similar study looking at the EmoMap task in autistic and non-autistic participants (Keating et al., 2023). To reiterate what has been mentioned previously, it is useful to compare studies on autism with PwP, as individuals in both of these cases are known to experience differences in terms of emotion recognition (Keating et al., 2022; Shafiei et al., 2020; Lin et al., 2016; Philip et al., 2010; Clark et al., 2008; Lawrence et al., 2007; Lindner & Rosén, 2006; Sprengelmeyer et al., 2003). In the study by Keating and colleagues (2023), there was a main effect of group, suggesting that emotional consistency scores (referred to as 'precision scores' in Keating et al., 2023) are different for autistic and non-autistic participants. Autistic participants were found to have higher emotional consistency scores than the non-autistic participants. Emotional consistency scores do not seem to differ between PwP and controls, suggesting that lower ERA scores for happiness and sadness in PwP, is due to differences in emotional consistency scores.

The second exploratory aim was to investigate associations between different factors and ERA scores collected previously in the PLF task (as described in **Chapter 2**). These associations were investigated for controls and PwP, individually. When a random forest analysis was conducted using the Boruta wrapper algorithm for

controls, one of the important predictor variables for emotion recognition was MAIA-2 Not Worrying. Four tentatively important predictor variables were found including, MAIA-2 Self-Regulation, BDI, AQ Social Skills, and AQ Attention to Detail. When the important and tentatively important variables were added into an LME, only MAIA-2 Self-Regulation came out as statistically significant, with a negative relationship with ERA scores. Interoception is the ability to feel and interpret bodily sensations and signals. Interoceptive awareness is the ability to process these bodily sensations and signals so an individual can become consciously aware of these signals (Price & Hooven, 2018; Cameron, 2001). The MAIA-2 scale is a measure of interoceptive awareness, and the subscale, MAIA-2 Self-Regulation indicates how well participants can manage psychological distress by paying close attention to their body sensations (Mehling et al., 2018). MAIA-2 Self-Regulation relates to paying attention to bodily sensations and/or breathing to reduce levels of stress in the body (items 28-31). This relates to interoception because higher scores on MAIA-2 Self-Regulation reflects that participants can manage psychological distress better when they pay attention to their body sensations. This negative relationship suggests that higher scores on MAIA-2 Self-Regulation, are associated with lower ERA scores. This was unexpected because paying close attention to bodily sensations (such as heart rate and pain levels), also known as, ‘interoceptive awareness’ is thought to have intrinsic links to emotion awareness (Price & Hooven, 2018). For example, one study by Price and Hooven (2018) investigated the use of a therapeutic intervention termed ‘Mindful Awareness in Body-Oriented Therapy’ (MABT) in people as a technique of improving interoceptive awareness skills. Mindful body awareness simply refers to being aware of bodily sensations in the present moment. MABT comprises three stages: identifying sensations in the body, learning techniques to

improve interoceptive awareness and then utilising these techniques in ‘mindful body awareness’ (Price et al., 2019). Price and Hooven (2018) found that MABT developed these interoceptive awareness skills and as a result, this improved emotional awareness and regulation.

One potential explanation for the discrepancy between the current literature and the results from this chapter about interoceptive awareness and emotion recognition, is the relative levels of internal and external focus individuals may have. On one hand, internal focus is required for self-regulation, whereby focussing on (internal) bodily signals are used to manage psychological distress. On the other hand, external focus is required to accurately recognise emotions in other people. The control participants in the current study, as outlined in this chapter, were found to have a negative relationship between MAIA-2 Self-Regulation and ERA scores. This indicates that control participants with higher MAIA-2 Self-Regulation scores tended to have lower ERA scores. In other words, controls who focus more on their internal bodily signals to manage distress (more internal focus) have reduced FER abilities (less external focus). This implies there is a shift away from external focus, and more emphasis placed on internal focus. This theory is corroborated by one study, which focussed on interoceptive accuracy and how it relates to alexithymia in a non-clinical population (Ernst et al., 2014). The study by Ernst and colleagues (2014) used TAS to measure levels of alexithymia in participants and the Body Perception Questionnaire as a measure of interoceptive awareness. They found that higher levels of interoceptive awareness (greater internal focus) was closely associated with participants who had greater levels of alexithymia traits (reduced external focus). It has also been noted in a review of the alexithymia literature, that individuals with

externally oriented thinking styles, have reduced FER abilities (Grynberg et al., 2012). These studies suggest that being more aware of internal body signals (higher interoceptive awareness levels) may be associated with a reduced ability to recognise emotions in others (due to greater levels of alexithymia traits). In other words, participants with greater levels of internal focus, are associated with reduced levels of external focus.

An unexpected result was also found when looking at what factors affect ERA in PwP. BDI scores were found to be positively associated with ERA scores. When a random forest analysis was conducted using the Boruta wrapper algorithm for PwP, two of the predictor variables were confirmed as important, age and BDI. One predictor variable was classed as tentatively important, MAIA-2 Attention Regulation. When these variables were all added into an LME, only BDI came out as statistically significant, with a positive relationship with ERA scores. This suggests that higher scores on BDI (greater depression severity), are associated with greater ERA scores in PwP. When another LME was generated looking at the potential interaction that could exist between emotion (happy, angry, and sad) and BDI score, no significant interaction was found between these two variables. This suggests that depression levels do not vary depending on emotion type (happy, angry, or sad). Depression does not seem to be associated with the recognition of one specific emotion.

One potential theory for understanding why greater depression severity may lead to improved FER abilities could be described by hypervigilance. Hypervigilance has been associated with clinical depression, with hypervigilant individuals showing heightened awareness of potential threats that may surround them (Kimble et al.,

2023). One study demonstrated that participants with post-traumatic stress disorder (PTSD), that became hypervigilant, use this behaviour when interpreting facial expressions (Masten et al., 2008). In particular, the authors described that participants with PTSD who were experiencing hypervigilance, responded quicker when identifying fearful facial expressions. These studies suggest that PwP who have greater levels of depression (according to BDI), may be more likely to experience hypervigilance, than those who were not classified as depressed, leading to greater ERA scores. This may be due to heightened emotional awareness, resulting in increased sensitivity when reading emotional signals in other people. Perhaps this is a coping mechanism for those who are hypervigilant, to navigate the social world more accurately. Future studies should consider the addition of hypervigilance measures, for example, the Brief Hypervigilance Scale (Bernstein et al., 2016). This could help to confirm if there is a positive correlation between BDI scores and/or ERA scores from the PLF task and the Brief Hypervigilance Scale scores. This would confirm if hypervigilance is related to depression and hence, FER abilities.

Although no significant group differences were found for emotional similarity or emotional consistency scores between PwP and controls, the finding that BDI and ERA scores are positively associated in PwP could have implications for psychological therapy. For example, PwP with greater levels of depression may be more hypervigilant, as explained previously. While this increased sensitivity may appear helpful in terms of ERA scores, it could also reflect underlying distress. From a therapeutic perspective, this suggests that psychological therapies for PwP should not only target mood-related symptoms such as depression and anxiety but also

address behavioural patterns such as hypervigilance or heightened emotional sensitivity that may interfere with emotion recognition abilities. Mindfulness-Based Cognitive Therapy (MBCT) may be particularly beneficial and is commonly used in individuals with depression and anxiety to help them observe emotions, without over-identifying them, helping to reduce hypervigilance levels (Seritan et al., 2022; Williams et al., 2021; Britton et al., 2012).

However, there are some limitations to this EmoMap study, such as the inclusion of BDI as a measure of depression in PwP, and in older adults generally. This is because BDI contains questions about somatic symptoms (distinct from psychological symptoms) such as, insomnia and loss of appetite (Torbey et al., 2015). These somatic symptoms can occur in both PwP and depression making it hard to isolate whether these symptoms are due to their condition, or because of depression. This may have over-inflated depression scores in PwP during the EmoMap study. This is because PwP would have chosen the appropriate statements that apply to them (e.g. 'I wake up several hours earlier than I used to and cannot get back to sleep'), but these symptoms (e.g. insomnia) they are experiencing may be a result of their condition, and not because of depression. Another questionnaire that could have been administered is the Geriatric Depression Scale (GDS). The GDS does not contain questions referring to any overlapping somatic symptoms in PwP. This questionnaire focuses on psychological symptoms of depression. Furthermore, the GDS has an excellent internal consistency score (α = 0.92) (Massai et al., 2018). Other studies have also noted that the GDS is a valid measure of depression in PwP (J. R. Williams et al., 2012; Mondolo et al., 2006).

Emotional intelligence (or emotional quotient, EQ), can be measured by several scales, including the Schutte Self-Report Emotional Intelligence Test (SSEIT). EQ has been demonstrated as an important factor in emotion recognition, but was not considered in this chapter (Schutte et al., 1998). The SSEIT is different to the emotion measure (EmoMap task) used in this chapter because it assesses three distinct domains of emotional intelligence: expression of emotions, emotion utilisation and emotion regulation (Schutte et al., 1998). This demonstrates the advantage of including the SSEIT in future studies, as it provides a comprehensive understanding of emotions in individuals, rather than solely focussing on only one aspect of EQ (e.g. emotion perception). In a recent study, they researched the role of EQ in FER by using the SSEIT (Boccaccio et al., 2023). This study assessed emotion recognition through a questionnaire based on images from the Radboud Faces Database. They noted that EQ has a significant role in FER, whereby individuals with a greater EQ perform better at emotion recognition. Therefore, in future studies building on from the findings in this chapter, it would be interesting to include EQ as one of the predictor variables in the LMEs, to verify if EQ is important in emotion recognition in PwP and control participants.

The current study had one main aim and two exploratory aims. The main aim of this study was to determine if PwP had lower emotional similarity scores, for happiness and sadness compared to controls. However, it was concluded that there were no significant differences between these groups for distances between emotion clusters. The first exploratory aim was to explore if emotional consistency scores for happiness and sadness are different when comparing PwP and controls. However, there were no significant differences between these groups for emotional

consistency scores. The second exploratory aim was to investigate associations between different factors and ERA scores collected previously in the PLF task for PwP and controls. For control participants both the Boruta wrapper algorithm and LME analysis identified MAIA-2 Self-Regulation as an important predictor variable for ERA scores, with a negative relationship. This relationship was explained by considering levels of internal and external focus. In this case, control participants may have higher levels of internal focus, relative to external focus. For PwP, the Boruta wrapper algorithm and LME analysis identified BDI as an important predictor variable for ERA scores, with a positive relationship. This relationship was explained by levels of hypervigilance in PwP. In this case, PwP may have greater levels of depression, and so may be more likely to experience hypervigilance, leading to increased sensitivity in recognising facial expressions. However, uture research should consider the inclusion of a more appropriate measure of clinical depression for PwP (e.g. GDS). Additionally, EQ should be measured and included as a predictor in LME/GAMM. This would determine if EQ is an important factor to consider in emotion recognition.

Chapter 5 - General Discussion

This chapter will provide an overview of the main findings of this thesis, and possible interpretations of these findings. Comparisons will be made with the current literature, as well as considerations of broader strengths and limitations of this project, in its entirety. More specific strengths and limitations can be found in each of the empirical chapters (**Chapters 2-4**). Finally, there are some suggestions made for future research, to carry this project forward.

5.1 Overview and Interpretation of Findings

5.1.1 Expression Perception in People with Parkinson's and Controls

One primary goal of this thesis was to compare expression perception in PwP and controls using dynamic displays, instead of static stimuli. **Chapter 2** examined differences in FER in PwP and controls using the PLF task. An emotion by group interaction was found for happiness and sadness, but not anger. This demonstrated that PwP had reduced ERA scores for happiness and sadness, compared to controls.

This information suggests that PwP have reduced FER abilities for particular emotions (happiness and sadness) when viewing dynamic displays of these emotions, compared to controls. On the other hand, FER abilities for anger seems to be around the same between PwP and controls. This thesis continued to investigate if these differences in FER abilities could be due to differences in how PwP use

physical cues (e.g. spatial and/or kinematic cues) when recognising facial expressions compared with controls (see **Chapter 2** for further details).

Differences in FER abilities between PwP and controls may be linked to spatial, but not kinematic cues. PwP had reduced FER abilities at the original (100%) and exaggerated (150%) spatial levels. However, no kinematic by group interaction was found. This aligns with evidence that controls rely on kinematic cues for FER, whereas PwP may depend more on spatial information (Sowden et al., 2021; Edey et al., 2017; Kamachi et al., 2013).

The absence of differences in FER abilities between PwP and controls in response to changes in kinematic cues appears to be consistent with evidence in the literature. The ability to perceive biological motion can remain at least relatively preserved in PwP. For example, PwP continue to show activation of the motor system during action observation (Poliakoff, 2013). They also may exhibit motor resonance when observing familiar, everyday actions that they are still able to perform, despite motor differences compared with controls (Bek et al., 2018). This preservation in perceiving biological motion, even in response to changing kinematic cues may reflect that regions implicated in motion processing (e.g. magnocellular pathways) do not directly overlap with regions of the brain most affected in PwP (e.g. the substantia nigra and striatum) (Chapman et al., 2004; Dauer & Przedborski, 2003). However, more recent evidence indicates that difficulties with velocity perception may emerge, particularly for PwP in later stages of the condition (Bernardinis et al., 2023). This could suggest that the preserved kinematic effects observed in this thesis reflect the fact that the PwP were in the earlier stages of their condition.

In contrast, spatial manipulations appeared to be more challenging for PwP. A reduction in ERA scores at higher spatial levels could reflect differences between PwP compared to controls in how they perceive displacement distances between key facial landmarks. These results are consistent with another study who concluded that middle and later-stage PwP, displayed differences in how they perceive larger displacement distances (Bernardinis et al., 2021). In our study, these perceptual differences may have contributed to the lower ERA scores noted at the higher spatial levels. This is because PwP may misjudge distances between key facial landmarks required for accurate FER.

5.1.2 Expression Perception in PwP ON versus OFF Dopaminergic Medication

Another aim of this thesis was to examine how dopaminergic medication influences FER abilities in PwP. In **Chapter 3**, participants completed the PLF task twice. Once when they were ON their dopaminergic medication and once when they were OFF their dopaminergic medication. The results demonstrated that ERA scores were reduced across all tested emotions (happiness, anger, and sadness) when PwP were OFF their dopaminergic medication, compared to when they were ON their dopaminergic medication. These findings suggested that dopamine may be a pharmacological factor underlying FER differences when PwP were ON versus OFF their dopaminergic medication, whereby increased dopamine levels through dopaminergic medication were associated with improved FER abilities.

The findings in **Chapter 3** are in line with what has been stated in previous literature. In another study, dopaminergic medication improved recognition of particular

emotions 27/10/2025 19:21:00. However, it is important to consider that only the recognition of anger and disgust were affected when comparing PwP ON and OFF dopaminergic medication, and this was obtained using static stimuli. Additionally, different individuals were used for the PwP ON dopaminergic medication group compared to those in the PwP OFF dopaminergic medication group. In a more recent study, it was also found that PwP OFF dopaminergic medication had reduced FER abilities compared to when they were ON medication (Dan et al., 2019). Therefore, they suggested that dopaminergic medication may rescue FER abilities in PwP, in other words, FER abilities were not significantly different between PwP OFF their dopaminergic medication and controls. Interestingly, as this study used the Emotional Face Matching Task (which presented all faces on screen at the same time), this indicated that improvements seen in FER abilities are unlikely to be explained by memory, or other broader cognitive differences. This could suggest that dopaminergic medication may enhance perceptual processing of facial emotion.

Not all studies have observed this effect. In one study looking at emotion recognition in PwP, no evidence of differences in FER abilities were detected in PwP ON and OFF treatment states (McIntosh et al., 2015). In this study early-stage PwP (receiving either deep brain stimulation and dopaminergic medication or dopaminergic medication only) were recruited. They completed three different emotion recognition tasks (in the ON and OFF state of their prescribed treatment regimen), including the Montreal Affective Voices task, the Baron-Cohen Reading the Mind in the Eyes (RME) task, and The Awareness of Social Inference Test (Baron-Cohen et al., 2001; Belin et al., 2008; McDonald et al., 2003). No significant differences were found between participants in the ON or OFF state, however, their

sample size was small (N = 16), and this small number may be insufficient to detect any effect of different states (ON or OFF dopaminergic medication) on emotion recognition abilities in PwP. In addition, there may have been differences in the way our study and McIntosh and colleagues (2015) defined early-stage PwP. However, they did not explicitly define early PwP, instead they stated that PwP would be excluded from their study if they were beyond Hoehn and Yahr stage II. This could help to explain why their findings contrast with our observations that dopaminergic medication can improve FER abilities in PwP.

The findings from this thesis (see **Chapter 3**), may support the idea that dopamine influences cognitive processes, relevant to FER abilities. Dopamine is a well-established neurotransmitter involved in motor and non-motor functions. Some of the non-motor functions include important cognition processes, for example, modulating attention (i.e. directing focus to socially relevant cues), and perception (i.e. detecting facial features relevant to emotional expressions) (Nieoullon, 2002). In PwP, degeneration of dopaminergic neurons within the basal ganglia disrupts both motor and non-motor functions (Weintraub et al., 2023; Lee & Koh, 2015; Park & Stacy, 2011; Lawrence et al., 2007; Sprengelmeyer et al., 2003). The results from this thesis are consistent with this account; PwP OFF their dopaminergic medication had reduced ERA scores in the PLF task, compared to when they were ON their dopaminergic medication. Together, this information could suggest that insufficient dopamine levels may disrupt attention and perception processes involved in FER. These findings may also align with the “U-shaped dopamine curve”, which proposes that insufficient or excessive dopamine can have negative consequences on cognitive processes (Cools & D’Esposito, 2011). Together, these findings and

theories suggest that, when PwP were ON their dopaminergic medication they were potentially closer to the “optimal” dopamine level required for the attentional and perceptual processes necessary for FER, leading to improved ERA scores. On the other hand, when PwP were OFF their dopaminergic medication this caused a reduction in ERA scores due to insufficient dopamine levels. It is important to note that although the U-shaped dopamine curve theory was not directly tested in this thesis, it may offer a useful framework for understanding the effects of dopamine on cognition in PwP.

Finally, in **Chapter 3**, the role of dopaminergic medication was considered in relation to the physical manipulations of the PLF stimuli. No drug by kinematic, or drug by spatial interactions were observed, indicating that dopaminergic medication did not differentially affect how PwP used speed or spatial cues. This thesis found that regardless of medication state, PwP showed the same general pattern of FER abilities as controls. For example, becoming more accurate at recognising angry and happy expressions with increased speed or spatial exaggeration, and more accurate at identifying sadness when speed or spatial levels were reduced. However, PwP were still achieving lower ERA scores than controls (see **Chapter 2** for further details), suggesting that a different factor must be responsible for the differences seen in FER when comparing PwP ON and OFF their dopaminergic medication. Together, these results suggest that while dopamine improves general FER abilities, it does not alter the way PwP process spatial or kinematic information from facial expressions.

5.1.3 Psychological Mechanisms in Emotion Recognition

As well as investigating physical and pharmacological factors that may impact FER abilities in PwP, this thesis also considered if psychological factors could contribute to the differences seen in FER abilities in PwP, compared to controls (see **Chapter 4** for further information). Using the EmoMap task, measures of internal emotional experience (e.g. emotional similarity and emotional consistency scores) were compared between PwP and controls. However, our results showed no differences for either of these measures between PwP and controls.

When comparing emotional similarity scores, PwP and controls did not differ in how they judged similarity between happy and sad emotions. In addition, these groups did not differ in their consistency of emotional responses, across repeated judgements. These results indicate that reduced FER abilities for happiness and sadness in PwP (as seen in **Chapter 2**) are unlikely to be influenced by differences in their internal emotional experiences. These findings also align with another study who reported that PwP did not have different emotional experiences (measured by ratings of induced emotions when watching affective video clips), compared to controls (Vicente et al., 2011).

Similarly, no group differences (PwP and controls) were observed in emotional consistency scores. Our results on emotional consistency scores build upon the work of a different study, who developed an emotional consistency task as an indicator of self-awareness of emotions in control participants (Huggins et al., 2021). Our results suggested that emotional consistency abilities appear to be similar for PwP and controls.

We also considered questionnaire measures as potential psychological factors that may affect FER abilities in PwP and controls. In controls, MAIA-2 Self-Regulation was found to be negatively associated with ERA scores. This indicates that as MAIA-2 Self-Regulation score increases, ERA scores in the PLF task decreases. In other words, control participants who are more able to manage their stress levels by paying closer attention to their bodily sensations and signals, tended to have lower ERA scores in the PLF task (for further insight into this relationship, see **Chapter 4**). However, this contrasts with the findings from one study who investigated interoceptive sensibility and emotion recognition in controls (Hübner et al., 2021). They concluded that higher interoceptive sensibility (measured using MAIA-2) enables faster recognition of changing emotions. However, it is important to note that their emotion recognition task measured reaction times for the recognition of happiness and fear. Additionally, in the PLF task, (see **Chapters 2 and 3** for descriptions of the PLF task), there was a broader range of emotions, including two emotions of the same valence (anger and sadness). Therefore, although both the PLF task and the task used by Hübner and colleagues (2021) were both testing emotion recognition, these studies seemed to address different aspects of this concept.

We also considered questionnaire measures as potential psychological factors that may affect FER abilities in PwP. A positive relationship was found between BDI and ERA scores, indicating that PwP who have greater depression severity levels, seemed to have improved emotion recognition abilities (for further insight into this relationship, see **Chapter 4**). This differs from another study who considered if there

was a link between FER abilities and depression severity (also measured using BDI), in PwP (Pietschnig et al., 2016). However, they concluded that depression scores were not a predictor of FER abilities in PwP. However, it could be speculated that the impact of depression severity on emotion recognition abilities depends on the different depression symptom profile each person experiences. For example, some individuals with depression experience apathy (Steffens et al., 2022). One study looking at apathy and emotion recognition noted that increased levels of apathy were associated with reduced emotion recognition abilities (Lockwood et al., 2017). On the other hand, dysphoria is linked with preserved, or even enhanced recognition of emotions (Harkness et al., 2005; Sloan et al., 2002). Combining this information together, it could be speculated that emotion recognition abilities may be influenced in different ways depending on how depression symptoms manifest in individuals.

Overall, these findings concluded that there may be distinct psychological factors that influence emotion recognition abilities in PwP and controls. While emotional similarity and consistency scores appear to be similar in PwP and controls, the differences in variables classed as important for FER abilities (e.g. the negative relationship between MAIA-2 self-regulation and ERA scores in controls and the positive relationship between BDI and ERA scores in PwP), suggests that there could be distinct contributing factors underlying FER abilities in each group.

5.1.4 Integration of Physical, Pharmacological, and Psychological Factors

Across **Chapters 2-4,** this thesis identified multiple influences on FER abilities in PwP. The physical factors indicated that manipulating spatial, but not kinematic,

levels of facial stimuli in the PLF task led to greater difficulty in recognising emotions for PwP, particularly at higher spatial levels. Pharmacological factors demonstrated that dopaminergic medication improved overall FER abilities in PwP. This suggested that dopamine may modulate perceptual and attentional mechanisms which are important in emotion recognition. Finally, psychological factors indicated that while internal emotional experiences (as measured by emotional similarity and consistency scores) appeared to be at a similar level between PwP and controls, different psychological factors (measured using questionnaires) affected FER abilities in PwP and controls (depression and interoception, respectively).

However, it is also important to consider that these factors (physical, pharmacological, and psychological) may not necessarily act independently. One suggestion could be that dopamine supports attentional focus needed to process spatial cues effectively in PwP, while different depressive symptom profiles in each individual may differentially affect emotion recognition abilities. The absence of a drug by spatial interaction, and drug by kinematic interaction could suggest that whilst dopamine improves FER abilities, this is not due to how PwP use spatial and kinematic information. Perhaps dopamine improves FER abilities in PwP due to the influence it has on psychological factors (e.g. BDI scores). Together, the results suggest that differences in FER abilities in PwP could be due to a combination of influences by physical, pharmacological and psychological factors, rather than due to one of these factors in isolation.

5.2 Strengths, Limitations, and Future Directions

General Strengths and Limitations

One key strength of this thesis was the use of online testing. From a practical perspective, this improved accessibility as it enabled participants to complete the tasks from the comfort of their own homes, making it easier for participants to participate from a physical perspective, as well as logistically (e.g. planning travel to a study site). This was an important consideration, particularly for PwP who may exhibit motor symptoms, as they completed the task on two separate days, once when they were ON their dopaminergic medication, and once when they were OFF their dopaminergic medication. In addition, online testing provided a lot of flexibility from a geographical perspective, meaning participants from all around the UK could participate. This potentially made any findings more generalisable, as well as enabling the studies in this thesis to meet power requirements to detect meaningful effects.

Another strength was the use of point-light displays to assess FER abilities in PwP and controls. Using the PLF task (as described in **Chapters 2 and 3**) also aided the exploration of potential physical factors (both spatial and kinematic) that may impact FER abilities in PwP and controls. The PLF task minimised any confounding variables (e.g. contextual cues) by removing them completely and provided a clear assessment of how motion cues (e.g. changes in spatial and/or kinematic levels) can affect FER abilities for different emotions (happy, angry, and sad).

The inclusion of both the TAS and PAQ, alexithymia questionnaires was a strength in this thesis. Some may question the relevance of including two questionnaires that measure alexithymia, however, it was decided that both questionnaires have unique

advantages. TAS was included because it is the “gold-standard” alexithymia questionnaire that is adopted by most scientific studies. TAS has been used extensively across various clinical populations. This includes the autistic population, people with eating disorders, and PwP (Ridout & Wallis, 2021; Kinnaird et al., 2019; Assogna et al., 2012). TAS has also been validated across numerous countries with different language versions (Ścigała et al., 2020; Colombarolli et al., 2019; Ling et al., 2016; Güleç et al., 2009; G. Taylor et al., 2003). This aided the comparison of studies in this thesis with other studies that also used TAS.

However, there are some concerns that TAS could be a measure of psychopathology symptoms, or levels of psychological distress (G. J. Taylor et al., 1997). Additionally, the language used in TAS (e.g. “when I am upset, I don’t know if I am sad, frightened, or angry”, compared to PAQ, “when I’m feeling bad, I can’t tell whether I am sad, angry or scared”) may be viewed as less accessible. In PAQ they define what “bad” means at the beginning of the questionnaire. Therefore, for someone with alexithymia, the language and definitions used in PAQ may be more understandable. Whilst **Chapters 2 and 4** confirmed that PwP and control groups were matched for alexithymia traits (using both TAS and PAQ), the inclusion of two different alexithymia measures helped to corroborate our findings. However, as the majority of the literature currently uses TAS, it was important to include this measure of alexithymia, for comparison purposes.

One limitation of this study was having no screening questionnaire for detecting mild cognitive impairment (MCI), which can be fairly common in PwP. In a recent meta-analysis, the authors concluded that the prevalence of MCI in PwP is around 40% (Baiano et al., 2020). Common screening questionnaires for MCI include the

Montreal Cognitive Assessment (MoCA) and the Mini-Mental State Examination (MMSE) (Y.-W. Yu et al., 2022; Nasreddine et al., 2005; Folstein et al., 1975). These questionnaires test cognitive skills. In the MMSE participants are asked basic orientation questions (e.g. what year it is/what country they are in), alongside questions involving language and recall skills (Folstein et al., 1975). The MoCA asks similar questions to the MMSE but is a newer version. The main objective of these questionnaires is to test for MCI, in older adults (including PwP). These questionnaires can help to distinguish between age-related cognitive decline and MCI, with MCI being a potential early warning sign of dementia (R.-L. Yu & Wu, 2022; Mamikonyan et al., 2009; Hoops et al., 2009).

One obvious question is why MCI should be assessed in FER studies? This can be answered by findings from a recent paper (Chiang et al., 2024). In this paper, the authors recruited PwP who had MCI, PwP without MCI, and controls. Participants were assessed on their FER abilities using the Multi-Modality Emotion Recognition test. In this task, participants looked at faces with different expressions (happy, angry, sad, surprise, disgust, fear, and neutral). Participants were instructed to choose a label that best represented the expression the face was showing. Following this, participants were provided with one label (e.g. surprise) and they chose one face from seven options which best represented the label. This study led by Chiang and colleagues (2024), concluded that PwP with MCI had reduced FER abilities, compared to PwP without MCI and the control group. This reduction in FER abilities was particularly for the emotion, disgust. To conclude, future studies should consider including either MoCA or MMSE questionnaires in FER studies with PwP to assess for MCI.

MCI was also considered in another neurodegenerative condition, Alzheimer's (Silva et al., 2020). In this study they looked at other non-verbal reasoning tasks which predicted who had MCI in people with Alzheimer's, and went on to develop dementia. The authors concluded that there appeared to be a relationship between low non-verbal reasoning scores in the Raven Coloured Progressive Matrices task and time taken to develop into dementia (Raven, 2000). Specifically, those who scored lower in the Raven Coloured Progressive Matrices task (i.e. indicating MCI), appeared to develop dementia quicker. These findings suggested that perhaps the Raven Coloured Progressive Matrices task should be included to assess non-verbal reasoning in PwP, going forward. This is because this task predicted not only those who may develop dementia (in people with Alzheimer's), but also how soon this may occur.

The use of point-light displays (see **Chapters 2 and 3** for further information) may be argued to be a limitation of this thesis. This is because in everyday life, emotion recognition does not solely rely on facial expressions but is a multimodal process. Tone of voice, body language, and contextual information, all contribute to our understanding of emotions in another person (Reed et al., 2020; Lausen & Hammerschmidt, 2020; Salido Ortega et al., 2020). Some people may argue that by stripping away these additional cues, may be oversimplifying FER and would therefore conclude that the PLF task is not ecologically valid. However, beginning with a reduced and highly controlled study, allowed the investigation of how motion-based cues affected FER abilities across different emotions in PwP and controls.

Therefore, this thesis presents a foundational understanding, which future research can build on, by reintroducing other cues (e.g. whole-body movements).

Online testing may also be viewed as a limitation of this thesis. This is because participants were using their own personal devices (e.g. laptops or desktop computers), which arguably could lead to a lack of experimental control, due to screen size variability and resolution. However, to maintain a relative level of consistency, participants were not able to complete these tasks on mobile phones or tablet devices. This was to prevent them from using devices with very small screen sizes, which would have resulted in individuals being unable to see the stimuli presented clearly. Only desktop computers and laptops were permitted. In addition, the PLF task was programmed to run in full-screen mode to minimise variability in display size. Finally, minimum resolution requirements were set for the PLF task using experimental builder tools (e.g. Gorilla), whereby participants below a certain threshold were blocked from participating. However, even with these interventions in place, it must be acknowledged that online experimentation could still have led to some variability, such as the participant's external environment and differences in devices used.

It is also important to consider that online testing may have introduced sample bias. Due to the nature of these studies, participants required internet access, a certain level of technological literacy, and access to a laptop or desktop computer to be able to participate. Therefore, participants from lower socioeconomic backgrounds, who may lack these resources, would be underrepresented in these studies. This is a clear limitation because it has been shown that those with a lower socioeconomic

status are at increased risk for depression (Lorant et al., 2003). As discussed in **Chapter 4**, depression severity appeared to affect emotion recognition abilities. Although the direction of the relationship between depression severity and emotion recognition abilities may vary between the findings presented in **Chapter 4,** and those reported in a recent meta-analysis, the evidence indicates that depression severity affects emotion recognition abilities (Krause et al., 2021). Therefore, any selection bias that reduced participation from people with lower socioeconomic statuses may have unintentionally influenced the results. In future studies, more efforts should be made to represent people from all backgrounds. Perhaps it would be advisable to collaborate with a charity, who could loan participants a laptop to enable individuals from all socioeconomic backgrounds to participate. This would also help to make results more inclusive and representative of the general population.

Finally, it is important to mention that it remains unclear whether improvement in FER abilities represents a complete return to emotion recognition ability levels seen in controls. This is because PwP ON their dopaminergic medication and controls were not directly compared, which is a limitation in this thesis. However, there was a comparison between PwP OFF dopaminergic medication and controls because this provided baseline levels of FER abilities in PwP. Future studies should compare PwP ON their dopaminergic medication and controls to confirm if dopaminergic medication in PwP rescues FER abilities to a comparable level to controls (i.e. no significant difference in FER abilities between these groups), or if the medication only partially improves FER abilities. If the latter is found to be true, this could

provide more evidence that dopamine may not be the only important factor in determining FER abilities in PwP.

Future Directions

The next natural step following the work in **Chapters 2 and 3** would be to use a more realistic human-like avatar in the PLF task. This would improve the ecological validity of the task. These digital human-like avatars could be created using tools such as Unreal Engine. This platform is widely used in the development of many popular video games in today's gaming market, and particularly its MetaHuman framework. MetaHuman would enable the creation of highly realistic human faces which could be manipulated to convey different facial expressions using the 'facial rig' system, by allowing different action units of the face to be moved. The use of advanced tools such as Unreal Engine would help to improve the ecological validity of the current findings presented in this thesis.

This thesis found that PwP were less accurate at FER when higher spatial levels were used in the PLF task. This also aligned with findings in a previous study suggesting that PwP have difficulties accurately judging distances, compared to controls, which may be due to a visual displacement perception impairment. Therefore, future studies could explore if difficulties in judging distances for PwP could be corrected using smart glasses. This idea of "wearable technology" has become increasingly popular in recent years. Smart glasses have been developed by leading brands such as Google Glass and Vuzix (Brusie et al., 2015). Similar ideas have already been utilised in the paediatric autistic population. For example, 'Superpower Glass' was used to help autistic children with emotion recognition (Voss

et al., 2019). In this clinical trial, autistic children were placed into one of two groups, either using the wearable Superpower Glass intervention or receiving standard behavioural therapy. It was concluded that children wearing the Superpower Glass intervention, had improved social skills and reinforced emotion recognition skills. In the future, similar technology could be developed for PwP using wearable technologies that adjust perceived distances between key facial landmarks. This would help PwP to better understand facial expressions in other people, which could also result in improved wellbeing and quality of life for PwP.

5.3 General Conclusion

The current thesis examined whether there were differences between PwP and controls in FER abilities, when dynamic displays were used. After concluding that there were differences in FER abilities between these groups for happiness and sadness, this thesis explored potential factors for why these differences may exist. The factors explored were divided up into categories; physical, pharmacological, and psychological factors. Several factors may play a role in FER abilities in PwP, for example, spatial levels were identified as a potential physical factor. Larger distances between individual point-lights in the PLF task caused a reduction in ERA scores for PwP, compared to controls. Secondly, dopaminergic medication may be a pharmacological factor influencing FER abilities in PwP. For example, PwP OFF their dopaminergic medication had reduced FER abilities, compared to when they were ON their dopaminergic medication. Finally, several psychological factors were explored, and the findings suggest that the psychological factors underlying differences in FER abilities, differ between PwP and controls. This is because when

we explored identical factors which can contribute to differences in FER such as, measures of alexithymia traits, depression severity, and interoceptive awareness, different factors were classified as important for PwP, compared to controls. For PwP, BDI scores were an important factor for FER. Alternatively, in control participants, interoceptive awareness levels as measured by MAIA-2, specifically in terms of self-regulation were important in FER. By identifying several factors that may influence FER abilities in PwP, this thesis has highlighted new areas of interest which could be explored further to better understand differences in FER abilities for PwP, compared to controls. Furthermore, interventions targeting these factors could help to improve FER abilities and overall social functioning in PwP. Hopefully, one day, this research could contribute to improving quality of life in PwP.

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