Journal of the International Neuropsychological Society (2023), **29**, 813–820
doi:10.1017/S1355617723000097

Research Article

Sex differences in Parkinson disease-associated episodic memory and processing speed deficits

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Abstract

Objectives: This study aims to address a gap in the data on cognitive sex differences in persons living with Parkinson disease (PD). There is some evidence that cognitive dysfunction is more severe in male PD, however data on episodic memory and processing speed is incomplete. **Methods:** One hundred and sixty-seven individuals with a diagnosis of PD were included in this study. Fifty-six of those individuals identified as female. The California Verbal Learning Test 1st edition and the Wechsler Memory Scale 3rd edition were used to evaluate verbal and visuospatial episodic memory and the Wechsler Adult Intelligence Scale 3rd edition was used to evaluate processing speed. Multivariate analysis of covariance was used to identify sex-specific differences across groups. **Results:** Our results show that males with PD performed significantly worse than females in verbal and visuospatial recall as well as a trend for the processing speed task of coding. **Conclusions:** Our finding of superior performance among females with PD in verbal episodic memory is consistent with reports in both healthy and PD individuals; however, females outperforming males in measures of visuospatial episodic memory is unique to PD. Cognitive deficits preferentially affecting males appear to be associated with frontal lobe-related function. Therefore, males may represent a disease subgroup more susceptible to disease mechanisms affecting frontal lobe deterioration and cognitive disturbances in PD.

Keywords: sex differences; cognitive dysfunction; Parkinson's disease; neuropsychological assessment; memory; processing speed

(Received 27 May 2022; final revision 21 October 2022; accepted 30 November 2022; First Published online 27 March 2023)

Introduction

Parkinson Disease (PD) disproportionately affects individuals by sex; the incidence is 1.5 times higher in males than in females (Elbaz et al., 2016). There is evidence that disease onset is earlier in males (Haaxma et al., 2007; Klebe et al., 2013), and that disease severity is greater in males (Picillo et al., 2017; Solla et al., 2012; Szewczyk-Krolikowski et al., 2014). For example, Lubomski et al. (2013) found that males had significantly higher scores on the UPDRS motor evaluation after adjustment for age and disease duration, and males required higher doses of pharmacological intervention, relied more heavily on caretakers, and reported lower quality of life scores regarding activities of daily living, communication, and cognition. In contrast, females reported fewer symptoms than males, although they did show higher levels of complications from symptoms (Scott et al., 2000). Male sex has been shown to be a predictor of cognitive decline (Cereda et al., 2016; Cholerton et al., 2018) and cognitively normal males with PD have been shown to progress at a steeper rate than females (Cholerton et al., 2018; Pigott et al., 2015) with an increased risk for dementia (Cereda et al., 2016). Conversely, females more often present with a tremor dominant phenotype, which is associated with less severe motor symptoms and cognitive difficulties (Haaxma et al., 2007; Twelves et al., 2003).

PD is known to affect an array of cognitive functions. Inhibition, switching, sequencing (Kudlicka et al., 2011; Litvan et al., 1991; Muslimovic et al., 2005; Shook et al., 2005), spatial working memory (Caballol et al., 2007; Emre, 2003), processing speed (Disbrow et al., 2014; Hansch et al., 1982; Lanni et al., 2014; Nguyen et al., 2017; Pal et al., 2016; Vriend et al., 2020; Zweig et al., 2016), and working and recognition memory (Dubois & Pillon, 1997; Higginson et al., 2005) have all been implicated. Therefore, the Movement Disorder Task Force (Litvan et al., 2012) suggest five cognitive domains relevant to the evaluation of cognitive impairment in PD: attention and working memory, executive function, language, memory (unspecified), and visuospatial function. Although deficits in all these domains have been reported in PD, and cognitive deficits are associated with motor symptom phenotypes that differentially impact males and females, the presence of cognitive sex differences has not been extensively studied. While there is accumulating evidence of sex differences in PD-associated cognitive dysfunction in domains such as executive

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Cite this article: Reekes T.H., Higginson C.I., Sigvardt K.A., King D.S., Levine D., Wheelock V.L., & Disbrow E.A. (2023) Sex differences in Parkinson disease-associated episodic memory and processing speed deficits. *Journal of the International Neuropsychological Society*, **29**: 813–820, https://doi.org/10.1017/S1355617723000097

function (Cholerton et al., 2018; Curtis et al., 2019; Reekes et al., 2020) and elements of visuospatial function (Bayram et al., 2020; Liu et al., 2015; Locascio et al., 2003; Riedel et al., 2008), there is scant or inconsistent data on sex differences in areas such as verbal and visuospatial episodic memory, and processing speed (Bayram et al., 2020; Cholerton et al., 2018; Reekes et al., 2020).

Existing data on sex differences in verbal episodic memory in PD is limited to simple list learning tasks including the Hopkin's Verbal Learning Test-Revised (HVLT-R; Bayram et al., 2020; Liu et al., 2015), and the Auditory Verbal Learning Test-Long (AVLT; Yang et al., 2018) and show that males perform worse than females. Episodic memory of visuospatial material has yet to be evaluated. There is existing data showing sex differences in visuospatial processing that does not involve memory in PD though findings are mixed. Studies have shown that males performed significantly better on the Benton Judgement of Line Orientation test (Bayram et al., 2020; Liu et al., 2015). Males have also shown superior visuo-construction and spatial reasoning on a clock drawing task (Riedel et al., 2008). Interestingly, Locascio et al. (2003) found that while males performed better on the Money Road Map test of visuospatial processing and mental rotation, over time male performance declined at a faster rate than female performance. Others have found similar performance between males and females with PD on visuospatial functions. Amick et al. (2007) found no sex differences using a mental rotation test. Similarly, a recent meta-analysis found no difference in visuospatial ability by sex in PD (Curtis et al., 2019).

Complicating the comparison of cognitive dysfunction across sex is the fact that, in healthy control populations (including adult and aging adult populations), studies show that females outperform males on tasks of verbal memory, but not on spatial memory tasks (A. Herlitz & Yonker, 2002; Lundervold et al., 2014; Sundararaman et al., 2016).

It is well-established that persons with PD perform significantly worse on measures of processing speed compared to healthy controls. However, reports of sex differences in processing speed in PD are mixed. Some studies have shown that females with PD outperform males on digit symbol substitution tasks such as the SDMT (Reekes et al., 2020) and coding (Cholerton et al., 2018). Recently, a report of data from the Parkinson's Progression Markers Initiative found that while females outperformed males on the SDMT, decline over time did not differ by sex (Bayram et al., 2020). However, others reported no significant sex differences on the SDMT (Liu et al., 2015).

Thus, while there is accumulating evidence that cognitive dysfunction in PD disproportionately affects males (Cereda et al., 2016; Liu et al., 2015; Lubomski et al., 2013; Reekes et al., 2020) reports of sex differences across various cognitive domains remain inconsistent and incomplete. Therefore, we evaluated sex-specific cognitive differences in verbal and visuospatial episodic memory as well as processing speed. Extending previous work on cognitive sex differences will improve our understanding of disease subgroups, which is critical for clinical intervention.

Methods

The sample consisted of 167 individuals with idiopathic PD [56 female, consistent with increased incidence in males (Dorsey et al., 2018)] who were recruited as potential candidates for deep brain stimulation (DBS) surgical intervention. All individuals with PD were diagnosed by a board-certified neurologist based on DSM-IV-TR criteria. Individuals included in the current analysis were between the ages of 50 and 82 years. Sex was determined by self-report and only those entered as male or female were included. Exclusion criteria were history of functional neurosurgical intervention, diagnosis of other neurological illness or any other medical illness that could impact cognitive function. Individuals receiving a diagnosis of dementia by DSM-IV criteria were excluded, as were participants with an MMSE score < 20. This study was approved by an Institutional Review Board at University of California, Davis and was completed in accordance with the Helsinki Declaration.

Demographic information was collected from each individual including: age, years of education, disease duration, and pertinent personal and family history. In addition to demographic information, a large battery of neuropsychological measures was administered to each individual as part of his/her presurgical assessment. This battery included tests of global cognitive function, attention and working memory, executive function, language, memory, visuospatial function, and processing speed. We focused on verbal and visuospatial episodic memory because results from these domains are spare or contradictory. We do not report results from other domains because they have been reported previously by multiple investigators. There is pervious work evaluating sex differences in domains of attention and working memory (Bayram et al., 2020; Liu et al., 2015; Reekes et al., 2020), executive function (Cholerton et al., 2018; Curtis et al., 2019; Reekes et al., 2020), language (Auclair-Ouellet et al., 2021; Locascio et al., 2003; Reifegerste et al., 2020), and visuospatial function (Bayram et al., 2020; Curtis et al., 2019; Riedel et al., 2008). All individuals were tested in his or her best "On" medication state.

Instruments

Mini-Mental State Examination (MMSE)

The MMSE (Folstein et al., 1975) is a widely used instrument to gauge global level of cognitive function in areas of orientation, registration, attention and calculation, recall, and language.

Unified Parkinson's Disease Rating Scale (UPDRS)

The UPDRS (Fahn & Elton, 1987) is a clinical scale used to determine the severity of PD. Areas surveyed include (I) mentation, behavior, and mood; (II) activities of daily living, (III) motor performance, and (IV) complications from therapy. Scores from UPDRS III (motor evaluation) questions 20 (Tremor at Rest), 21 (Action or Postural Tremor of Hands) and 22 (Rigidity) for dominant hand/limb were also compared across groups.

California Verbal Learning Test (CVLT)

The CVLT (Delis et al., 1987) measures the ability to retain an orally presented list of words belonging to four distinct semantic categories. Examinees are read the same 16-item word list five times and asked to spontaneously recall as many words as possible after each presentation. The total number of words recalled on the five learning trials is an index of immediate recall. After a second, interference list is presented and recall of it tested, free and cued recall of the first list is assessed. Long delay free recall (LDFR) is measured by asking examinees to spontaneously recall words from the first list after a filled 20-min delay. This edition of the CVLT was the most recent edition published at the time of data collection.

Wechsler Memory Scale 3rd edition (WMS-III)

The WMS-III (Wechsler, 1997b) is used to assess various elements of episodic memory. The WMS-III consists of multiple subtests

https://doi.org/10.1017/S1355617723000097 Published online by Cambridge University Press

including measures of immediate and delayed auditory and verbal memory used in combination to produce composite index scores. This edition of the WMS was the most recent edition published at the time of data collection.

Auditory memory. The Auditory Memory Index measures the ability to retain orally presented information. The subtests contributing to the index are immediate and delayed portions of Logical Memory and Verbal Paired Associates. The stimuli for Logical Memory are brief prose passages. Examinees are read two stories and asked to repeat the content from memory. Responses are scored for content which is given credit regardless of the order in which it is described. The stimuli for Verbal Paired Associates are a series of word pairs. Following presentation, examinees are presented a word from each pair and asked to recall the paired word. These subtests also involve the same stimuli as those from their immediate index counterparts; however, examinees are asked to recall the information after a filled 30-min delay interval (Auditory Delayed Memory, composed of Logical Memory II & Verbal Paired Associates II).

Visual memory. The Visual Memory Index measures the ability to recall visually presented information immediately after presentation. The subtests contributing to the Visual Memory index are the immediate and delayed portions of Faces and Family Pictures. Faces involves the presentation of a set of pictures of faces one at a time immediately followed by presentation of pairs of face pictures with the examinee having to recognize which of the two faces was previously presented. In Family Pictures, examinees are shown illustrations of families engaging in various activities and asked to answer questions about the pictures immediately after presentation. These subtests also involve the same stimuli as those from their immediate index counterparts; however, examinees are asked to recall or recognize the information after a filled 30-min delay interval (Visual Delayed Memory, composed of Faces II & Family Pictures II).

Wechsler Adult Intelligence Scale 3rd edition (WAIS-III)

The WAIS-III (Wechsler, 1997a) is used to assess various elements of intelligence and cognitive ability. The WAIS-III consists of thirteen subtests of attention, visuospatial and construction skills and semantic memory used in combination to produce index scores as well as verbal, performance and full-scale intelligence quotients (IQ). This edition of the WAIS was the most recent edition published at the time of data collection.

Processing speed. The Processing Speed Index measures the ability to respond to sequential stimuli in constrained time. The subtests contributing to the Processing Speed Index are Digit Symbol Coding and Symbol Search. Digit Symbol Coding requires individuals to decode a series of symbols using a continually presented key of symbols with corresponding numbers. Symbol Search requires individuals to view a simple figure and identify if that symbol is or is not contained within a short series of test figures. Each of these tests ask individuals to complete as many items as possible in 90 s.

Statistical analysis

One-way analysis of variance (ANOVA) using sex as the independent variable was performed for demographic and disease descriptive variables. Three multivariate analyses of covariance were performed using sex as our independent variable and age and years of education as covariates. Individual analyses were performed for each cognitive domain (verbal episodic memory, visuospatial episodic memory and processing speed) using SPSS (IBM v26). Each analysis was considered a single comparison reducing family-wise error by assuming independence of the dependent variables (Foster et al., 2018). Thus, we corrected for three comparisons and used an alpha of $p < 0.017$ (= 0.05/3) as the cut off for significance. There is also precedent for using a less stringent alpha cut off when the nature of the multiple comparisons (sex differences in cognitive function) is the same across comparisons and points to a similar conclusion (e.g., Ridker et al., 2008). Effect size (Cohen's *d*) was calculated using the formula described by Cohen (1988).

Table 1. Demographic variables

	N	Age (years)	Education (years)*	Full-scale IQ	MMSE
Male	111	65.82 (7.78)	15.07 (3.20)	98.09 (14.55)	26.77 (2.27)
Range		50–82	8–21	64–134	20–30
Female	56	65.46 (7.98)	13.80 (2.88)	95.66 (12.61)	26.98 (2.48)
Range		50–82	6–21	70–122	20–30

Note. Mean (SD) for demographic variables of age, years of education, IQ and global cognitive status. *Significant difference between sexes, $p < 0.05$.

Results

Group differences

Demographic data is contained in Table 1 and disease descriptive data in Table 2. One-way ANOVA revealed no significant differences across sexes for age ($F(1,165) = 0.076$, $p = 0.783$), full-scale IQ ($F(1,157) = 1.105$, $p = 0.295$) or MMSE score ($F(1,165) = 0.318$, $p = 0.574$). There was a significant difference in years of education favoring males ($F(1,165) = 6.246$, $p = 0.013$). We used age and years of education as covariates in all analyses of cognitive measures. There were no differences in disease descriptive variables such as illness duration ($F(1,60) = 0.023$, $p = 0.880$), Hoehn & Yahr Scale ($F(1,91) = 1.289$, $p = 0.259$), or UPDRS I ($F(1,107) = 0.183$, $p = 0.670$), II ($F(1,106) = 3.113$, $p = 0.081$) or III ($F(1,106) = 0.957$, $p = 0.330$); however, females described more complications of therapy indicated by higher UPDRS IV scores ($F(1,105) = 6.565$, $p = 0.012$). Moreover, no differences were identified for dominant hand/limb resting tremor [UPDRS III question 20 ($F(1,93) = 0.222$, $p = 0.630$)], action or postural hand tremor [UPDRS III question 21 ($F(1,81) = 2.354$, $p = 0.129$)] or rigidity [UPDRS III question 22 ($F(1,94) = 0.213$, $p = 0.645$)].

In the verbal episodic memory tasks, results from the CVLT (Table 3) showed significant differences by sex in immediate free recall ($F(3,151) = 19.310$, $p < 0.001$, Cohen's $d = 0.62$) and long delayed free recall ($F(3,151) = 10.072$, $p = 0.002$, Cohen's $d = 0.43$) with females outperforming males. However, we saw no significant differences between males and females after alpha correction on the WMS-III (Table 3) immediate verbal episodic memory tasks of Logical Memory I ($F(3,151) = 2.495$, $p = 0.116$) and Verbal Paired Associates I ($F(3,151) = 5.730$, $p = 0.018$), nor delayed verbal episodic memory tasks of Logical Memory II ($F(3,151) = 4.036$, $p = 0.046$) or Verbal Paired Associates II ($F(3,151) = 1.695$, $p = 0.195$).

Results were variable on tasks of visuospatial ability (Table 4). Female performance was not significantly different from males on the immediate ($F(3,158) = 2.425$, $p = 0.121$) or delayed ($F(3,158) = 0.043$, $p = 0.835$) recall portion of the WMS-III Faces subtest (I and II), but females did outperform males on

https://doi.org/10.1017/S1355617723000097 Published online by Cambridge University Press

Table 2. Disease descriptive variables

	UPDRS I	UPDRS II	UPDRS III	UPDRS IV*	Hoehn & Yahr (median)	UPDRS III Q20	UPDRS III Q21	UPDRS III Q22
Male	3.04 (1.87)	9.77 (6.14)	10.84 (6.75)	8.53 (4.11)	2	0.34 (0.70)	0.35 (0.72)	0.72 (0.80)
Range	0–8	0–29	0–27	0–18	0–3	0–3	0–3	0–3
Female	3.21 (1.89)	12.24 (7.85)	12.30 (8.03)	10.73 (4.09)	2.5	0.26 (0.81)	0.13 (0.55)	0.65 (0.71)
Range	0–8	0–33	0–37	0–17	0–3	0–3	0–3	0–2

Note. Mean (SD) for disease descriptive variables of illness duration, UPDRS I-IV, Hoehn and Yahr scale and questions from UPDRS III on tremor and rigidity, *$p < 0.05$.

Table 3. Verbal episodic memory

	Total words 1–5*	LDFR*	Logical Memory I	Logical Memory II	Verbal Paired Associates I	Verbal Paired Associates II
Male	37.81 (10.92)	7.44 (3.84)	31.09 (13.13)	16.40 (7.96)	12.64 (8.44)	4.59 (3.50)
Female	45.00 (11.65)	9.06 (3.33)	32.83 (10.77)	18.29 (8.18)	15.00 (7.42)	4.98 (2.41)
Cohen's d	0.62	0.43				

Note. Significant difference between sexes (*$p < 0.017$) on the California Verbal Learning Test (CVLT) in total words produced through trials 1–5 and long delayed free recall (LDFR). No statistical differences were seen between sex on immediate and delayed portions of Logical Memory and Verbal Paired Associates from the Wechsler Memory Scale (WMS-III). Values indicate mean number of correct responses with standard deviations in parentheses.

Table 4. Visual episodic memory

	Faces I	Faces II	Family Pictures I*	Family Pictures II*
Male	31.93 (5.08)	32.74 (11.64)	26.47 (11.11)	26.20 (12.05)
Female	33.15 (5.10)	33.07 (4.97)	31.58 (11.65)	31.15 (11.89)
Cohen's *d*			0.44	0.41

Note. Significant difference between sexes (*$p < 0.017$) on immediate and delayed portions of the Wechsler Memory Scale (WMS-III) visual memory Family Pictures subscale. Values indicate mean number of correct responses with standard deviations in parentheses.

Table 5. Processing speed

	Coding#	Symbol Search
Male	41.49 (18.23)	19.48 (8.19)
Female	46.92 (17.72)	21.65 (9.38)
Cohen's *d*	0.30	

Note. Significant difference between sexes (#$p < 0.025$) on the Wechsler Adult Intelligence Scale (WAIS-III) processing speed subscales. Values indicate mean number of correct responses with standard deviations in parentheses.

Family Pictures I ($F(3,158) = 9.005$, $p = 0.003$, Cohen's $d = 0.44$) and Family Pictures II ($F(3,158) = 7.574$, $p = 0.007$, Cohen's $d = 0.41$).

Finally, for processing speed (Table 5), we found a statistical trend for superior female performance compared to males on WAIS-III Digit Symbol Coding ($F(3,140) = 5.499$, $p = 0.020$, Cohen's $d = 0.28$) but not on Symbol Search ($F(3,140) = 2.103$, $p = 0.149$).

Discussion

We evaluated sex differences in both verbal and visual episodic memory as well as processing speed in persons with PD. We found that males with PD performed significantly worse on several tests of episodic memory involving verbal and visuospatial memory despite no differences in disease descriptive data and controlling for age and greater years of education in males. We found a trend toward decreased processing speed on a symbol digit coding task in males. Our findings are consistent with other reports showing superior performance in verbal episodic memory (Liu et al., 2015; Yang et al., 2018) and processing speed (Bayram et al., 2020; Cholerton et al., 2018; Reekes et al., 2020) in females with PD. While we found no differences in measures of visuospatial recognition memory (Faces I and II), we extend previous work by reporting that males with PD performed significantly worse on tests of immediate and delayed visuospatial recall (Family Pictures I and II).

Episodic memory

On measures of verbal episodic memory, we found that females with PD demonstrated significantly stronger performance in word recall compared to males with PD. Research on healthy controls shows superior performance by females on episodic memory tasks including autobiographical memory using the Autobiographical Interview (Fuentes & Desrocher, 2013) and verbal memory such as word recall (Dixon et al., 2004; Agneta Herlitz & Rehnman, 2008) and word, sentence and prose recall (Asperholm et al., 2019; Asperholm et al., 2020).

Our findings on visuospatial memory were mixed. We found a significant male deficit in the delayed Family Pictures subtest but not in the delayed Faces subtest. This discrepancy may be because Family Pictures is a free recall measure whereas Faces involves recognition memory, and recognition memory has been shown to be relatively preserved in PD (Whittington et al., 2000). Differences in performance between the sexes on these two tasks could also be due to the potentially larger spatial memory component in Family Pictures compared to Faces. Interestingly, this discrepancy would predict better performance in males than females on Family Pictures, a pattern of performance opposite to the one observed here, consistent with a sizeable and disproportionate drop in domain specific cognitive function. However, in studies by Dulay et al. (2002) and Chapin et al. (2009), Family Picture performance was best predicted by performance on other measures of declarative memory such as logical memory, suggesting that Family Pictures could be encoded verbally, and thus have both a visual and a verbal memory component. Indeed, the stimuli used in Family Pictures illustrate stories. Therefore, our observed sex differences may reflect the generally superior verbal skills of females rather than reflecting a deficit in visual memory skills.

https://doi.org/10.1017/S1355617723000097 Published online by Cambridge University Press

Processing speed

Increased adult age is associated with a slowing of processing speed resulting in impaired temporal capacity (limited time) and degradation of quantity and/or quality of available information (simultaneity), which degrades executive and other cognitive functions (Cummings, 1993; Salthouse, 1996). In healthy aging, deficits in processing speed have been postulated to subserve cognitive decline across a wide range of domains (Salthouse, 1996). However, findings of sex differences in processing speed in PD remain mixed with some studies reporting superior female performance (Bayram et al., 2020; Cholerton et al., 2018; Reekes et al., 2020) while others report no differences between male and females with PD (Chen et al., 2021; Liu et al., 2015). Our lab has previously shown that deficits in processing speed mediate the relationship between age and executive dysfunction in persons with PD (Nguyen et al., 2017). Moreover, in individuals with PD, processing speed deficits have been associated with progression from PD mild cognitive impairment to PD Dementia (Cholerton et al., 2018). However, our current findings were inconsistent, suggesting that findings may be task specific, especially for written versus oral versions of coding and symbol search. Though we found no differences in dominant hand/limb motor involvement, including a significant motor component may impact test outcome. Our previous reports of sex differences in processing speed were based on oral evaluation (Reekes et al., 2020).

Common mechanism for cognitive deficits across domains?

Basal ganglia degeneration, the hallmark pathophysiological change of PD, is known to disrupt five basal ganglia-thalamo-cortical loops (Alexander et al., 1986). Specifically, the associative loop has connections to frontal lobe, which has long been associated with cognitive changes in PD (Auning et al., 2014; Kudlicka et al., 2011; Paek et al., 2020) and dopamine deficiencies negatively affect attention, stimulus distinction, affective regulation, and motor abilities (Mehler-Wex et al., 2006; Nieoullon, 2002). Mattay and colleagues (2002) also found that individuals with PD in a hypodopaminergic state had reduced efficiency of prefrontal cortical information processing. Later studies postulated that disruption to white matter connectivity and integrity was linked to cognitive dysfunction in PD and may serve as an early indicator of cognitive decline and PD disease progression (Linortner et al., 2020; Melzer et al., 2013; Rektor et al., 2018).

Interestingly, in addition to the hippocampus, memory has a strong frontal lobe component, subserving working memory as well as the encoding and retrieval of episodic memories (Fletcher & Henson, 2001). Frontal lobe dysfunction is common in PD (Taylor et al., 1986) and has been implicated in free recall and recognition of verbal memory in PD (Higginson et al., 2003; Higginson et al., 2005). Prefrontal cortex is also involved in the processing (Chafee & Goldman-Rakic, 2000) and maintenance (Belger et al., 1998; McCarthy et al., 1996) of visuospatial material in working memory. PD-associated prefrontal cortex damage has been linked to visuospatial recognition memory deficits (Owen et al., 1993) as well as visuospatial working memory. Visuospatial working memory has been identified as a core feature of PD (Owen et al., 1993; Owen, 1997). Furthermore, processing speed is associated with frontal-subcortical circuits, as well as disruption to frontal lobe white matter integrity (Turken et al., 2008). Thus, findings of sex differences in hippocampal dependent episodic memory functions are largely consistent with superior healthy female performance on verbal-based tasks. However, our finding of deficits in male visuospatial episodic memory and processing speed commonly associated with hippocampal and frontal lobe function, and frontal lobe white matter, respectively, suggest that there may be sex-specific mechanisms that impact frontal lobe deterioration in PD.

Limitations

This study consisted of presurgical assessments for individuals with PD eligible for DBS surgery. Levodopa equivalent dose was not collected in this study, but several studies have found no sex differences in dose (Reekes et al., 2020; Solla et al., 2012) and or type of medication (Umeh et al., 2014). Furthermore, no control group was collected for this study; however, the differences between PD and control groups in cognitive function has been extensively reported. The cross-sectional design of this study is not as reliable or powerful as a longitudinal design. Effect sizes, however, were in the small to medium range presented by Cohen, and while modest, are consistent in direction with existing literature and provide a first look at sex differences in memory subtypes in individuals with PD. Many cognitive tests require skills from overlapping domains such as Family Pictures, which requires auditory verbal-based cognitive abilities in addition to visual memory. Thus, it can be difficult to generalize deficits to a single cognitive domain. Moreover, this study used the first edition of the CVLT and the third edition of the WMS which were the most current at the time this data was collected. Due to these limitations, the results should be interpreted with care. However, given that effect sizes were generally larger for the CVLT than the WMS measures, future studies could focus on the CVLT when investigating sex differences in cognition in PD in order to maximize their ability to detect differences between the groups.

Acknowledgements. CH and ED would like to extend a special thanks to the late Dr. Sigvardt for her continued support throughout their careers.

Funding Statement. This works was supported by Kaiser Permanente Northern California in Sacramento, California and by the NIH NINDS under award R01NS064040 to ED.

Conflicts of Interest. None.

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