



Research Article

Parkinson's disease disrupts the ability to initiate and apply episodic foresight

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Abstract

Objective: While Parkinson's disease is associated with impairments in many aspects of prospective cognition, no study to date has tested whether these difficulties extend to problems using episodic foresight to guide future-directed behavior. To provide the first examination of whether people with Parkinson's disease are impaired in their capacity to initiate and apply episodic foresight. **Method:** People with Parkinson's disease ($n = 42$), and a demographically matched neurotypical comparison group ($n = 42$) completed a validated behavioral assessment that met strict criteria for assessing episodic foresight (Virtual Week-Foresight), as well as a broader neurocognitive and clinical test battery. **Results:** People with Parkinson's disease were significantly less likely than the comparison group to acquire items that would later allow a problem to be solved and were also less likely to subsequently use these items for problem resolution. These deficits were largely unrelated to performance on other cognitive measures or clinical characteristics of the disorder. **Conclusions:** The ability to engage in episodic foresight in an adaptive way is compromised in Parkinson's disease. This appears to be a stable feature of the disorder, and one that is distinct from other clinical symptoms and neurocognitive deficits. It is now critical to establish exactly why these difficulties exist and how they impact on real-life functional capacity.

Keywords: cognition; episodic foresight; future behavior; neuropsychology; Parkinson's disease; virtual week

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In 2020, the worldwide prevalence of Parkinson's disease (PD) was estimated to be 9.4 million, a rise of 3.4 million from 2016 (Maserejian et al., 2020). At the same time, increasing life expectancy has contributed to greater disease duration in more recently diagnosed cohorts (Macleod et al., 2014). This now makes PD one of the leading causes of disability globally (Dorsey et al., 2018), meaning that it is of unprecedented importance to understand the symptoms particularly contributing to disease burden in this cohort. However, while the impact of motor symptoms on functional capacity has been the focus of considerable research (Chapuis et al., 2005; Hariz & Forsgren, 2011; Wressle et al., 2007), the role of neurocognitive impairment has received comparatively less attention.

In broader clinical literature, failures of prospective cognition are widely acknowledged to be amongst the most debilitating neurocognitive symptoms because they fundamentally disrupt the ability to anticipate, plan and/or act with the future in mind (Henry, 2021). A recent meta-analytic review revealed that PD is associated with moderate to large sized deficits in two key aspects of prospective cognition, planning (forward thinking and the subsequent execution of a sequence of actions) and prospective memory (PM; memory for future intentions, such as remembering to take medication; Coundouris et al., 2020), with such deficits

linked to atrophy and dopaminergic depletion of neural structures including prefrontal regions (Costa et al., 2008; Smith et al., 2011). Moreover, this meta-analysis highlighted a surprising omission in this literature, as it found that no study to date had examined whether PD disrupts another important aspect of prospective cognition: the ability to use episodic foresight to guide future-directed behaviors. From a neurological perspective, PD-related impairment in foresight can be anticipated, as there is considerable overlap in the brain regions implicated in both episodic foresight and the neuropathology of PD, including structures in the prefrontal cortex, the medial temporal lobe, and the fronto-parietal control network, (Benoit & Schacter, 2015; Bertossi et al., 2016; Camicioli et al., 2004; Klobušíková et al., 2019; Niethammer et al., 2012; Schacter et al., 2017; Yang et al., 2020)

Of the various forms of prospection, episodic foresight has been proposed to be the most flexible and functionally powerful, requiring not only the ability to imagine future scenarios but to also use these imaginings to guide future-directed behavior (Schacter et al., 2008; Suddendorf & Corballis, 1997). Indeed, this ability to foresee the future has been proposed in the literature as an important determinant for other prospective abilities (Atance & O'Neill, 2001; Schacter & Addis, 2007; Schacter et al., 2008; Suddendorf & Moore, 2011; Terrett et al., 2016). Specifically, episodic foresight

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has been conceptualized as a means of optimizing planning efficiency during the initial selection and development of plans, and has also been regarded as an effective strategy for PM, as simulating a future intended action strengthens the encoding of this behavior during the intention formation stage. Episodic foresight is thus a practical, anticipatory skill, which enhances wellbeing, directs behavior and emotions, and allows for educated, future-directed appraisals (Atance & O'Neill, 2001; Schacter et al., 2008; Spreng & Levine, 2006). Managing finances, going shopping, and food preparation, are some of the many daily activities considered critical for independent living that are reliant on this ability (Suddendorf & Henry, 2013).

Given its complexity, many researchers argue that this skill draws on several distinct and interrelated abilities including episodic memory and executive control. According to the constructive simulation hypothesis, episodic memories provide the foundation to construct future hypothetical events (Addis & Schacter, 2008), but executive functions have also been implicated as critical to inhibit simply recasting past memories (Schacter et al., 2007; Suddendorf & Corballis, 2007; Suddendorf & Henry, 2013). That is, episodic foresight also depends on one's ability to hold and manipulate memories, in order to flexibly recombine past experience.

To date, the broader episodic foresight literature has been dominated by phenomenological paradigms that either rely on the participant rating their experience (such as the vividness of future simulations), or which use more objective measurements to index the quantity of episodic details in future event narratives (see e.g., Gamble et al., 2019, Hallford et al., 2018). For the latter, a large amount of episodic detail generated in a future event narrative is presupposed to reflect more detailed pre-experience, and thus a greater capacity for episodic foresight. Indeed, of the one study to assess episodic foresight in people with PD, a purely phenomenological measure was used. Specifically, de Vito et al. (2012) prompted participants to mentally pre-experience autobiographical events and showed that the PD group generated significantly fewer episodic details relative to the comparison group, indicative of problems engaging in episodic future thinking. However, while the ability to imagine future scenarios is a fundamental component of episodic foresight, a measure of the ability to *use* this imagining to appropriately guide future-directed behavior is critical to inform whether problems with episodic foresight actually lead to functional difficulties in everyday life.

The present study therefore aimed to provide the first examination of whether PD-related deficits are evident in the functional application of episodic foresight. In service of this goal, the validated paradigm VW-Foresight was used (Lyons et al., 2014), as this is the only behavioral measure available for adults that meets strict criteria for demonstrating episodic foresight (Suddendorf & Corballis, 2010). The task involves participants' independently identifying and resolving problems through acquiring and subsequently using items at an appropriate time-point without external, overt cueing (Lyons et al., 2014; Lyons et al., 2016), therefore making this methodology distinct from the original Virtual Week and other prospection assessments. Specifically, in both the broader planning and PM literatures, the methodology has involved prescribing an action or outcome which is then independently planned or initiated using a rehearsed intention. However, there is no requirement to self-generate an intention as the problem, cue, and intention are explicitly directed by the stimuli or task. For instance, in Kliegel et al. (2000) study, the primary focus was the extent to which participants developed sophisticated

or well-elaborated plans after being provided with a circumscribed, defined set of tasks, and not the capacity to independently identify a problem and self-generate an intention to subsequently solve this. Thus the critical distinction between VW-Foresight and measures of prospective memory and planning is that it does not assess the ability to create or initiate future plans based on provided instructions, but assesses one's ability to independently identify a future problem and self-generate an intention to resolve this (Suddendorf & Corballis, 2010).

Given that episodic foresight imposes demands on many of the neural structures and networks known to be affected by PD, and that both phenomenological and functional episodic foresight impairments have been identified in many other clinical groups (e.g., Lyons et al., 2016; Lyons et al., 2019; Mercuri et al., 2018; Terrett et al., 2017), this study was designed to test the preregistered prediction that episodic foresight would be significantly disrupted in people with this disorder. A secondary aim was to establish the cognitive and clinical correlates of any observed episodic foresight difficulties. A broad cognitive battery was used that included a measure of premorbid IQ, as well as measures that have been theorized to either play a role in supporting episodic foresight (i.e., executive function; Schacter et al., 2007; Suddendorf & Corballis, 2007; Suddendorf & Henry, 2013), or which tap into cognitive constructs that previous literature shows people with PD often experience difficulties with (attention, recognition, and recall; see Kudlicka et al., 2011; Watson & Leverenz, 2010).

Method

This study formed part of a larger preregistered testing protocol (https://osf.io/rvgh5/?view_only=414e3f3db9d04dfb19928275ad3650e) that detailed four distinct studies. Only methods relevant to this study are described below.

Participants

The PD group was individuals on stable medication being treated at the Princess Alexandra Hospital. Recruitment for neurotypical (i.e., no neurological disease or neurological development disorder) older adults occurred online (Facebook advert, University of Queensland website), through media outlets (Your Time Magazine, Ageing Mind Initiative Newsletter), and word of mouth. To be eligible participants had to: (1) Be a native English speaker, or have high levels of English proficiency; (2) Have no current or past brain trauma; (3) Have no current/previous diagnosis of a serious psychiatric illness (e.g., bipolar disorder, schizophrenia). In the case of *previous* anxiety/depression, only those clearly linked to a specific negative life event (e.g., losing a spouse, financial hardship) were considered eligible. For the PD group, if the *current* anxiety/depression onset occurred after PD-diagnosis these participants were included (although note, those with severe on-going issues involving suicidal ideation, or recent hospitalization were not). For the comparison group, participants could not be receiving treatment for psychiatric illness at the time of testing; (4) Have no current/reoccurring issues with substance abuse including the use of either drugs or alcohol for purposes other than intended or in excessive, uncontrolled amounts; (5) Have no other illness that may impact day-to-day functioning and engagement with activities and; (6) Score 24 or higher on the Mini-Mental State Examination (MMSE; Folstein et al., 1975).

Fifty PD participants completed the test battery, with seven later excluded due to psychiatric illness ($n = 4$), brain trauma

Table 1. Parkinson's disease related participant information

Participant information	<i>n</i>	<i>M</i> (<i>SD</i>)
Disease duration (years)	41	6.26 (3.71)
Disease onset (<i>n</i> = 41)	<i>n</i>	%
Young (below 49 years)	7	17.07
Late (50 and above)	34	82.93
H&Y stage (<i>n</i> = 40; <i>M</i> = 2.36, <i>SD</i> = 0.88)		
1–1.5	9	22.50
2–2.5	15	37.50
3	12	30.00
4	4	10.00
Current Parkinson's disease treatment ^a (<i>n</i> = 42)		
Levodopa + Benserazide	31	73.81
Levodopa + Carbidopa	4	9.52
Levodopa + Carbidopa + Entacapone	6	14.29
Rasagiline	12	28.57
Prampipexole	10	23.81
Rotigotine	3	7.14
Safinamide	1	2.38
Deep brain stimulation	5	11.90

H&Y = Modified Hoehn and Yahr scale.

^aMajority of participants were using multiple treatments.

Disease onset based upon the Parkinson's Foundation's classification (see parkinson.org).

(*n* = 1), a combination of brain trauma and psychiatric illness (*n* = 1), a low score on the MMSE (*n* = 1), or not understanding the tasks involved (*n* = 1). The final PD sample consisted of 42 participants (50% Male; age *M* = 64.81 years, *SD* = 10.20 years; education *M* = 13.15 years, *SD* = 4.16 years; MMSE *M* = 28.79, *SD* = 1.22). Table 1 details diagnosis and treatment information for the PD group.

Sixty-one neurotypical individuals completed the test battery as a comparison group, with 19 later excluded due to psychiatric illness (*n* = 1), and to ensure that the two groups were matched demographically¹. The final comparison group comprised 42 participants (50% Male; age *M* = 65.00 years, *SD* = 8.92 years; education *M* = 14.61 years, *SD* = 3.16 years; MMSE *M* = 28.79, *SD* = 1.09; see Supplementary Table 1 for a complete demographic breakdown). Three independent *t*-tests were completed for age, years of education, and scores on the MMSE and showed that the two groups were demographically matched (*ps* = .928, .074 and 1.000, respectively).

Materials

VW-foresight

VW-Foresight (Lyons et al., 2014) is a computerized game where participants move a token around a board with the role of a die (see Figure 1a). Each circuit constitutes one *virtual day*, with participants in this study completing one experimenter assisted practice day, and two individually completed test days. There was no time limit on completing the game, with participants taking on average 50 min.

The task is described in detail in Lyons et al. (2014). However, in brief, the aim of the game is to: (1) identify problems when they arise; (2) identify and store items that may help to solve these problems; and (3) recognize when the problem context re-arises and use the relevant stored item for problem resolution. For example, each

¹Due to COVID restrictions, The PD and healthy comparison group were recruited and tested concurrently. Early checks of demographic matching revealed many group differences in key demographics. Accordingly, prior to running any of the study's analyses, 18 participants were removed from the comparison group. These exclusions were based solely on their demographic characteristics. Ten new neurotypical participants (with the required demographic characteristics) were then tested as their replacements.

episodic foresight task will begin with a problem embedded in a situation card (Figure 1b). At a later point, the opportunity to acquire an item helpful in solving this problem will occur within a daily activity card (Figure 1c). The chosen item will be stored for later use within "Your Stored Items," which are accessible both on the board, and within each situation card to allow for use at any time. When participants encounter a situation card in which an initial problem is still apparent (Figure 1d), they may resolve the problem by selecting the item required from "Your Stored Items."

The key dependent measures are item acquisition and item use. Item acquisition is scored as the number of target items acquired using the daily activities cards. Item use is, however, more complex, and as in previous studies (see Lyons et al., 2014), was calculated in two ways. The first is the number of target items correctly used (unconditional item use). Here, an item is scored as correctly used when the item is selected for use while on the target situation card (i.e., the situation card that provides the context for the related problem to be resolved). However, given that the ability to use an item is contingent on first acquiring that item, another measure of item use (conditional item use) was also calculated, in which the number of items correctly used was first conditionalized on initial acquisition (i.e., the number of used items is divided by the number acquired, to produce a proportion of already acquired items).

Background measures

A broader neurocognitive test battery was also administered, which consisted of the Digit Span Test (Wechsler, 2008; forward span a measure of attention, and backward span a measure of working memory), phonemic and semantic Verbal Fluency (a measure of executive function; Henry & Crawford, 2004), the Hopkins Verbal Learning Test-Revised (HVLRT-R; Brandt & Benedict, 2001; a measure of verbal learning and recall; retention and recognition discrimination index scores calculated), and the National Adult Reading Test-Second Edition (NART; Nelson & Willison, 1991; an indicator of premorbid IQ).

Validated self and informant rated clinical measures were also administered: The Apathy Evaluation Scale (AES; Marin et al., 1991), the Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983), the Neuropsychiatric Inventory (NPI-Q; Kaufer et al., 2000), the Parkinson's Disease Questionnaire-39 (PDQ-39; Peto et al., 1995), and the Parkinson's Disease Sleep Scale (PDSS-2; Trenkwalder et al., 2011). For each of these measures higher scores are indicative of greater clinical symptoms (apathy, negative affect, psychiatric illness, PD severity, and sleep disturbances, respectively).

Procedure

The procedure complied with the Declaration of Helsinki for medical research involving human subjects and was approved by the Human Research Ethics committee of The University of Queensland (Approval No. 2018001920). The measures described in this paper formed part of a larger protocol completed in person, one-on-one, with no limit on the frequency or length of breaks. Participants had the option to complete testing at the University of Queensland, at Hospital, or at their home. Four PD participants elected to complete this testing over two days. All participants were provided with an information sheet outlining the purpose of the study, and the ethical testing and handling of responses. The information sheet was also discussed verbally with the researcher, before participants provided written consent.

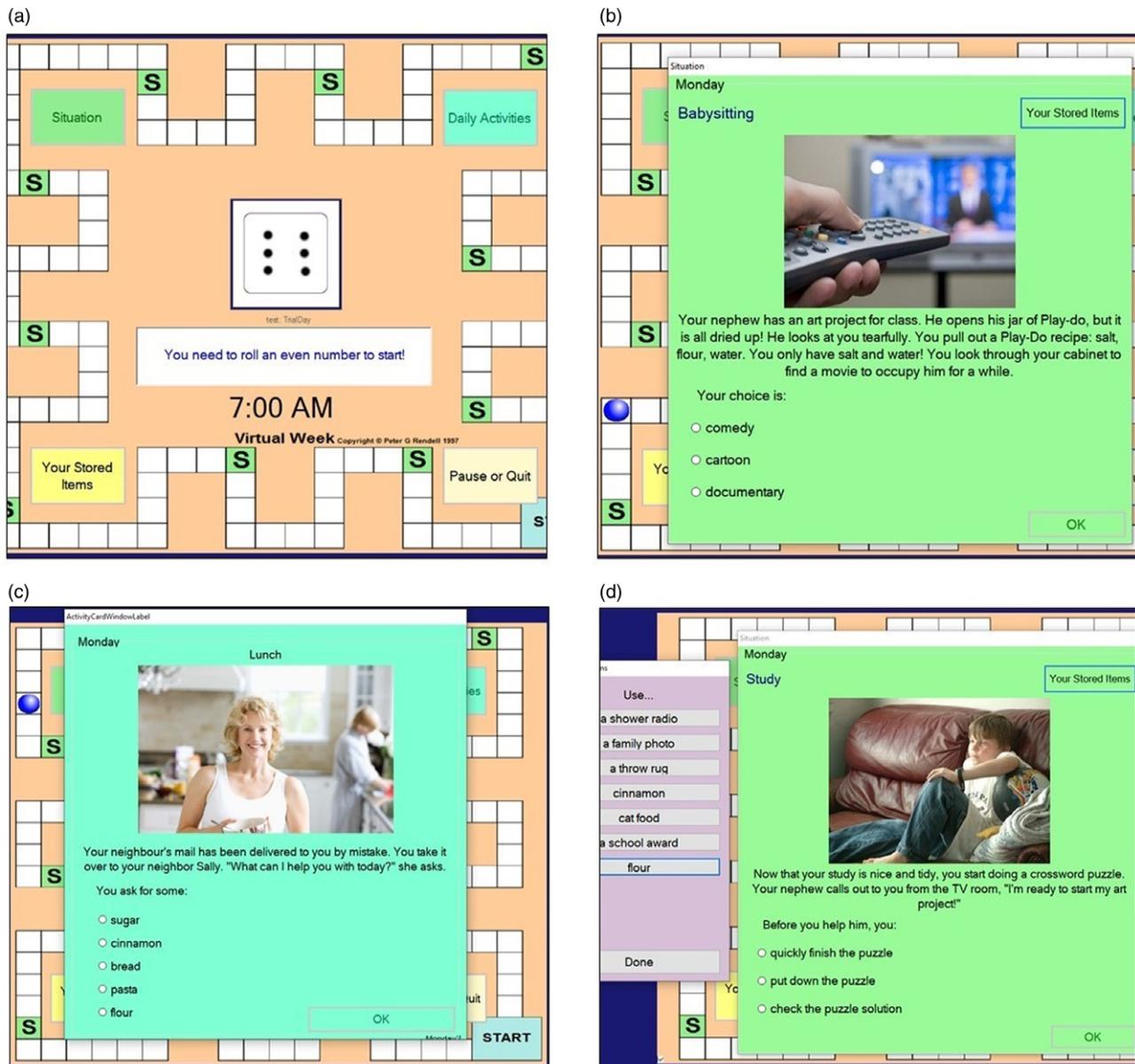


Figure 1. Virtual week-foresight task breakdown.

As most neurocognitive and clinical assessments were administered using a laptop, prior to commencing the researcher gauged participants' comfort in controlling the computer mouse. Based on this appraisal, the computer mouse was partially/completely controlled by the researcher in 24 instances (PD Group = 19, Comparison Group = 5; i.e., due to shaking, bradykinesia, unfamiliarity²). In these circumstances, the only difference to testing was that participants verbally, rather than physically, responded to questions/instructed the examiner how to move the mouse.

At the conclusion of testing all participants were reimbursed \$80 in Gift Cards for time and travel expenses. This study coincided with the COVID-19 pandemic (commenced January 2020, concluded April 2021), and consequently small changes were

²As results were unaltered with these participants' exclusion, all participants were retained in the analyses.

made to the testing session to be in line with current restrictions at time. This included a mask being worn by the researcher and/or participant, a second screen was introduced to help maintain a safe distance between the researcher and participant, hand sanitizer was provided, and all material cleaned after each session.

Statistical analyses

The *Hmisc* (Harrell, 2021), *ggpubr* (Kassambara, 2020), *rstatix* (Kassambara, 2021), and *tidyverse* (Wickham et al., 2019) packages were used within RStudio (version 4.0.0; RStudio Team, 2020) to analyze the data. For VW-Foresight, mixed-model analyses of variance (ANOVA) were conducted, with *foresight task* (percentage of item acquired, percentage of items used) as the within-subjects factor, and *group* as the between-subjects factor. Pearson's

correlations were calculated to explore cognitive and clinical correlates of VW-Foresight in the PD group. All statistical analyses were two-tailed and $ps < .05$ considered significant.

Missing data only occurred in the informant rated NPI-Q (severity cases = 5, distress cases = 4; See Supplementary Table 2 for a complete informant breakdown). In these instances, the mean response from that participant group was inputted. In the 27 cases where two responses were provided, the following sequential steps were taken to choose one informant: (1) fewer missing data; (2) partner over other relationships; (3) most regular physical contact; and (4) relationship length.

Results

For VW-Foresight data, the first ANOVA (in which item use was *unconditionalized*), revealed a main effect of group, $F(1, 82) = 17.20, p < .001, \eta_p^2 = 0.17$, indicating that the PD group were impaired overall, $Ms = 50.68\%$ and 69.90% , $SDs = 33.81\%$ and 29.34% respectively. A main effect of task was also found, $F(1, 82) = 211.97, p < .001, \eta_p^2 = 0.72$, which reflected overall performance being greater for item acquisition relative to item use, $Ms = 80.10\%$ and 40.48% , $SDs = 19.21\%$ and 32.05% respectively. However, there was no interaction between the group and task, $F(1, 82) = 2.85, p = .095, \eta_p^2 = 0.03$.

The second ANOVA with *conditionalized* item use returned an identical pattern of results, with a main effect for group ($F(1, 82) = 15.08, p < .001, \eta_p^2 = 0.16$; $Ms = 54.43\%$ and 72.64% , $SDs = 34.25\%$ and 28.26%) and task ($F(1, 82) = 91.55, p < .001, \eta_p^2 = 0.53$; $Ms = 46.98\%$ and 80.10% , $SDs = 34.86\%$ and 19.21%), but no interaction between the two ($F(1, 82) = 1.07, p = .303, \eta_p^2 = 0.01$). These data are displayed visually in Figure 2.

Finally, it can be seen in Table 2 that no clinical measures were correlated with item acquisition or use in either of the two groups (see Supplementary Table 3 for descriptive statistics). The only cognitive correlate to emerge was between item acquisition and verbal fluency, which emerged as a moderate sized association in both groups. The only cognitive correlate to emerge for both groups was between item acquisition and verbal fluency, which emerged as a moderate sized association.

Discussion

The present study makes a novel and important contribution to the broader PD literature by showing for the first time that, in line with preregistered hypotheses, people with PD are significantly and

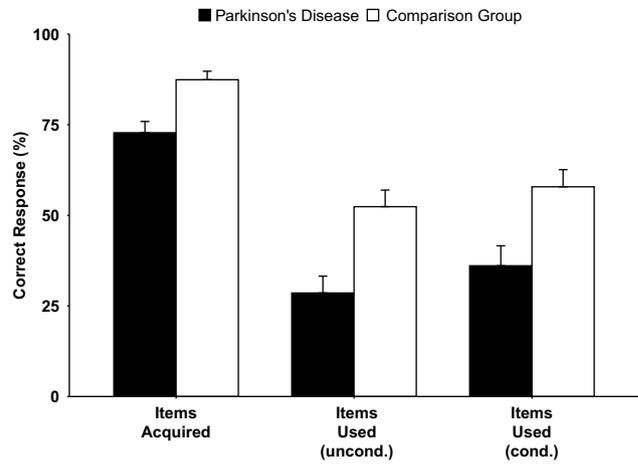


Figure 2. Performance on virtual week-foresight for Parkinson's disease and comparison group participants. Bars represent one standard error of the mean.

substantially impaired in their capacity to use episodic foresight to guide future behavior. Relative to the comparison group, the PD group were less likely to both initially acquire items needed to solve later problems, as well as to later use these items when the situation was appropriate, with each of these deficits large in magnitude. The latter of these effects also emerged regardless of whether item use was treated as independent of initial item acquisition, or first conditionalized upon it. These data therefore suggest that the PD-related difficulties in episodic foresight are not driven by a particular task demand, but instead reflect broader disruptions in the higher-level abilities that allow for problem identification, potential solution forecasting, and solution implementation. The findings also align with other clinical studies that have used VW-Foresight and identified a reduced capacity in both initial item acquisition as well as later problem resolution (Lyons et al., 2016, 2019; Terrett et al., 2017), and therefore provides further support for the view that broad-based problems with episodic foresight may be a common feature of clinical illness.

Given that the ability to initiate and engage in episodic foresight is a critical prerequisite for healthy, safe, and autonomous living (Suddendorf & Henry, 2013), these data also help extend our understanding of how cognitive impairment may contribute meaningfully to disease burden in PD specifically. PD-related impairment in other cognitive domains has previously been shown to limit capacity in several important functional domains including

Table 2. Pearson's bivariate correlations of background cognitive and clinical measures with virtual week-foresight (unconditional item use)

Group and measure	Forward digit span	Backward digit span	HVLT-R retention	HVLT recognition discrimination index	NART premorbid IQ	Verbal fluency	AES	HADS	NPI-Q severity	NPI-Q distress	PDQ-39 summary index	PDSS-2
PD Item acquisition	-.01	.03	.01	.09	.21	.37*	-.19	-.21	-.31	-.29	-.25	-.08
PD Item use	.03	.23	.13	.17	.14	.15	-.04	.07	-.33	-.31	-.08	.04
Comparison Item acquisition	-.06	.19	.56**	.29	.04	.36*	-.15	-.12	-.06	-.04	-	-
Comparison Item use	-.02	.35*	.35*	.19	.12	.17	-.10	-.19	.16	.16	-	-

AES = apathy evaluation scale; HADS = the hospital anxiety and depression scale; HVLT-R = Hopkins verbal learning test-revised; NART = The national adult reading test; NPI-Q = the neuropsychiatric inventory informant rated; PD = Parkinson's disease; PDQ-39 = Parkinson's disease questionnaire-39; PDSS-2 = Parkinson's disease sleep scale revised.

* $p < .05$.

** $p < .001$.

$n = 42$ for each group. Except NPI-Q where $n = 20$ for Parkinson's disease and $n = 29$ for comparison group.

management of finance, medication adherence, and practical decision-making (Kudlicka et al., 2018). Indeed, a review by Koerts et al. (2016) delineated how nonmotor symptoms contribute meaningfully to the earlier retirement rates associated with PD. Given that the ability to foresee and initiate preparatory action is essential for independent function, research is now needed to directly test how PD-related episodic foresight disruptions impact individuals' basic and instrumental daily living skills.

While the secondary aim of this study was to explore potential clinical and cognitive correlates of episodic foresight deficits in PD, the results showed that episodic foresight difficulties occurred quite independently of broader clinical symptoms and were only weakly related to broader cognitive function. The only relationship identified for both groups was with one of the executive control measures (verbal fluency), which was positively correlated with item acquisition. As noted earlier, executive control processes have been argued to play a critical role in successfully engaging episodic foresight (Schacter et al., 2007; Suddendorf & Corballis, 2007; Suddendorf & Henry, 2013). Interestingly, however, a relationship with our second measure of executive function (Digit Span Backwards) only emerged for item use in the healthy comparison group, suggesting that episodic foresight may be more dependent on some executive resources than others. For instance, it may be that episodic foresight relies less on one's capacity to store and manipulate information (as measured by Digit Span backwards; Wechsler, 2008), and more on one's ability to engage in effortful self-initiation (as is required in the verbal fluency task; Crawford & Henry, 2005; Ruff et al., 1997). Further research is now needed to explore this issue. The only other significant association between cognitive function and episodic foresight to emerge was between verbal learning (retention) and item acquisition. However, again this association emerged only in the healthy comparison group. Given that all other studies that have assessed the relationship between verbal learning and episodic foresight in both clinical and nonclinical samples have failed to identify significant associations (e.g., Lyons et al., 2016; Lyons et al., 2019), this does not appear to be a particularly reliable or robust relationship.

While no other associations emerged, an important caveat is that the exclusion criteria placed on psychiatric illness (e.g., no severely depressed PD participants) and cognitive function (≥ 24 on MMSE) may have restricted the ability to identify significant correlations. Nevertheless, the key point here is that even in a relatively high functioning PD cohort (in terms of broader psychiatric and cognitive status), generalized episodic foresight impairments emerged that were large in magnitude. These data therefore suggest that problems with episodic foresight may be a relatively consistent feature of PD, and not simply secondary to particular clinical or cognitive symptoms of the disorder, although further work is now needed to see whether specific clinical presentations or comorbidities may be associated with even more prominent impairment.

The behavioral data reported in this study aligns with what is currently known about the neurological underpinnings of episodic foresight. Specifically, many of the neural structures and pathways believed to be critical to engage in foresight (Benoit & Schacter, 2015; Schacter et al., 2007, 2017), are also disrupted in PD (e.g., Brück et al., 2004; Camicioli et al., 2004; Klobušíková et al., 2019; Niethammer et al., 2012; Pelizzari et al., 2020). However, to date, the neural underpinnings of episodic foresight have focused only on the phenomenological aspects of foresight (future thinking). While this represents the foundation of episodic foresight, research is now needed to understand the neural regions that are responsible for allowing future-oriented cognitions and

behaviors to be put into action (Miloyan et al., 2019). Accordingly, studies are needed that examine how the specific neural changes associated with PD map onto one's capacity to adaptively use these episodic simulations to guide behavior.

Additionally, in light of evidence suggesting that the ability to adaptively engage in episodic foresight is somewhat compromised in people with PD, an important next step is to now better understand the relationship between episodic foresight and other cognitive skills, including other aspects of future-oriented cognition. Episodic foresight has been conceptualized as both a strategy for enhancing PM (by simulating the future) and as a way of optimizing planning efficiency (how we initially choose and develop a plan; Atance & O'Neill, 2001; Schacter & Addis, 2007; Schacter et al., 2008; Suddendorf & Moore, 2011; Terrett et al., 2016). PD-related deficits in episodic foresight might therefore contribute to the reduced capacity for PM and planning often seen in this cohort – and this represents an interesting avenue for future research to pursue.

Finally, questions might be raised regarding the "self-generated" component of VW-Foresight because a relatively obvious solution is suggested by the problem. While this aspect of the design certainly reduces the degree of difficulty associated with the self-directed problem identification and intention formation aspects of episodic foresight, in daily life it is easy to envisage many occasions where the problem and its solution might seem relatively obvious, but still require the engagement of this skill to secure benefits and avoid problems. Moreover, what was considered critical in the initial development and test validation of VW-Foresight was establishing that there was a relatively obvious problem, solution and resolution – so that where failures to acquire or use an item occurred, it could be readily attributed to a specific difficulty engaging in episodic foresight, and not with broader problem-solving abilities (for a further discussion of these issues, see Lyons et al., 2014). Importantly, and as noted previously, VW-Foresight was designed to meet Suddendorf and Corballis' (2010) stringent experimental design criteria for assessing episodic foresight. Nevertheless, it should be acknowledged that because of the relatively obvious nature of the problems and solutions presented, VW-Foresight should be regarded as measuring the capacity to flexibly exercise a quite basic level of episodic foresight only.

In conclusion, because of the considerable overlap in the neural structures critical for episodic simulation and those disrupted in PD, there was a strong neurobiological basis for predicting PD-related impairment in this capacity. It is therefore surprising that, prior to this study, the ability to initiate and apply episodic foresight had not previously been explored in PD, or indeed any other movement disorder. In line with preregistered predictions, the results from this study provide the first direct empirical evidence that the functional aspect of episodic foresight is significantly and substantially compromised in PD. Further, findings suggest that these difficulties may be a stable symptom of PD, and one that is quite distinct from other neurocognitive and clinical disease features. More work is now required to better understand when and why these deficits occur, and how they may impact functional capacity in everyday life. Such research will directly inform the development of interventions aimed at supporting and improving ones' ability to engage in self-generated future behavioral intentions, and thus allow people with PD to maintain a higher level of independence.

Supplementary material. The supplementary material for this article can be found at <https://doi.org/10.1017/S1355617722000182>

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