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ORIGINAL ARTICLE

Drooling in Parkinson's Disease: Evidence of a Role for Divided Attention

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Abstract

Drooling is a frequently reported symptom in Parkinson's Disease (PD) with significant psychosocial impact and negative health consequences including silent aspiration of saliva with the associated risk of respiratory infections. It is suggested that in PD drooling is associated with inefficient oropharyngeal swallowing which reduces the effective clearance of saliva rather than hyper-salivation. This is compounded by unintended mouth opening and flexed posture increasing anterior loss of saliva. It is reported to occur most frequently during cognitively distracting concurrent tasks suggesting an impact from divided attention in a dual-task situation. However, this supposition has not been systematically examined. This study assessed whether frequency of saliva swallows reduced, and drooling severity and frequency increased, when people with PD engaged in a cognitively distracting task. 18 patients with idiopathic PD reporting daytime drooling on the Unified Parkinson's Disease Rating Scale (UPDRS) were recruited. They completed the Radboud Oral Motor Inventory for PD saliva questionnaire and the Montreal Cognitive Assessment. UPDRS drooling score, disease stage, duration, gender, and age were recorded. Swallow frequency and drooling severity and frequency were measured at rest and during a distracting computer-based language task. There was no significant difference between drooling severity at rest and during distraction (Wilcoxon signed rank test $z = -1.724$, $p = 0.085$). There was a significant difference between at rest and distraction conditions for both drooling frequency (Wilcoxon signed rank test $z = -2.041$, $p = 0.041$) and swallow frequency (Wilcoxon signed rank test $z = -3.054$, $p = 0.002$). Participants swallowed less frequently and drooled more often during the distraction task. The frequency of saliva swallows and drooling are affected by divided attention in a dual-task paradigm. Further studies are needed to explore the exact role of attention in saliva management and the clinical applications in assessment and treatment.

Keywords Drooling · Dysphagia · Parkinson's · Dual task · Divided attention

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Introduction

Drooling is a frequently reported symptom in Parkinson's Disease (PD) with daytime drooling affecting 28% of people with PD [1]. It has significant psychosocial impact and negative health consequences, including silent aspiration of saliva with increased risk of respiratory infection [2–6]. Drooling is thought to occur due to reduced efficiency and variable frequency of saliva swallows reducing the effective clearance of saliva, rather than hyper-salivation. This is compounded by hypomimia leading to unintended mouth opening and flexed posture increasing anterior loss of saliva [7]. Greater prevalence is associated with severity of PD; male gender; ageing; hallucinations; duration of PD; Unified Parkinson's Disease Rating Scale

(UPDRS) greater than 28; dysarthria; dysphagia; orthostatic hypotension; and history of using antidepressants [2].

Drooling tends to be intermittent and occurs most severely when engaged in a concurrent distracting task [3]. While historically it has been considered that saliva management has been considered as an automatic process, the observation of drooling occurring most frequently during concurrent tasks suggests that there may be a role for divided attention in daytime drooling in PD; however, this supposition has not been systematically examined in research or in current clinical practice.

In clinical practice, current assessments are based on self-report and observational tools which track symptoms across tasks and time but do not include specific consideration of the impact of attention and cognition [2, 8–10]. Similarly, behavioural and pharmacological treatments are focussed on control of drooling symptoms and do not address possible causes of fluctuations. Medication can be used to reduce the quantity of saliva and behavioural rehabilitation to prompt the frequency of saliva swallows; however, clinically these treatments are not successful for all patients and there has been no systematic consideration of factors limiting success of interventions [2, 11–16].

People with mild to moderate PD are known to have reduced attentional skills and increased cognitive load and divided attention in dual-task situations can affect aspects of movement such as freezing of gait and walking and talking [17–22]. More specifically in the field of swallowing, there has been limited research that considers the impact of attention, cognition, and dual-task effect on drooling or swallowing. Brodsky et al. [23], examining the impact of divided attention on swallowing in people with PD, found that the anticipatory stage of swallowing is slowed down by increasing demands of concurrent tasks but the oropharyngeal process of swallowing is unaffected. However, Troche et al. [24] found that swallow safety was compromised for people with PD and mild cognitive impairment but improved for people with PD with significant cognitive impairment in a dual-task setting. The authors argued that poor attentional resource allocation led to cognitive motor interference in mild cognitive impairment but the parallel task increased stimulation, thereby improving levels of arousal and benefiting swallow performance in severe cognitive impairment. Although there is a discrepancy between the two studies, they suggest a link between cognition and swallowing which warrants further consideration. More specifically with drooling in a retrospective study of cognitive dysfunction and drooling, Rana et al. [25] found that there was an association between drooling and dementia suggesting a possible impact from impaired cognition on saliva management. However, there are no studies looking at cognition and drooling in dual-task settings.

Research into the role of attention and cognition in saliva management in PD is indicated. The aim of this study was to investigate if saliva swallow frequency and drooling severity and frequency in PD is affected by divided attention during a cognitively distracting task.

Research questions:

- Does the frequency of saliva swallows reduce when engaged in a concurrent cognitively distracting task compared to at rest?
- Does the severity of drooling increase when engaged in a concurrent cognitively distracting task compared to at rest?
- Does the frequency of drooling increase when engaged in a concurrent cognitively distracting task compared to at rest?
- Are there factors that correlate with changes in swallowing and drooling associated with age, disease stage and duration, cognitive function and self-report of drooling?

The hypothesis was that in people with PD saliva swallow frequency will reduce and drooling severity and frequency will increase when engaged in a concurrent cognitively distracting dual task.

Methods

The study was approved by the Newcastle and North Tyneside Research Ethics Committee and conducted within the Research Governance Framework.

Participants

People with idiopathic PD reporting daytime drooling on the UPDRS drooling and saliva question 2.2 at level 3 or 4 [26] (Table 1) were approached to participate in the study during routine clinical care from Northumbria Healthcare NHS Foundation Trust and South Tyneside NHS Foundation Trust. If they expressed an interest they met with the research team to discuss the study and written consent was taken at a second visit. To be included participants had to have a diagnosis of PD confirmed by their treating clinician using the United Kingdom brain bank criteria [27]; be under the care of the participating Trusts; be able to fully participate in the tasks in the study protocol; be able to give full voluntary informed consent. Participants with cognitive impairment could participate if they met the inclusion criteria. Participants taking saliva management medication had to stop their medication for 3 days before the study visit. Patients were excluded if they could not meet the inclusion criteria or had had botulinum toxin therapy or surgery on their salivary glands.

Table 1 UPDRS question 2.2 [26]

Saliva and drooling		
Over the past week, have you usually had too much saliva during when you are awake or when you are asleep?		
0:	Normal	Not at all (no problems)
1:	Slight	I have too much saliva, but do not drool
2:	Mild	I have some drooling during sleep, but none when I am awake
3:	Moderate	I have some drooling when I am awake, but I usually do not need tissues or a handkerchief
4:	Severe	I have so much drooling that I regularly need to use tissues or a handkerchief to protect my clothes

Sample size was calculated at 18, based on the frequency of swallowing with and without distraction as the main outcome measure with the required power set at 80% and a significance level at 5% for a non-parametric two-tailed Wilcoxon signed rank test. It was estimated the swallow rate would decrease to below one swallow per 5 min during distraction based on two previous studies that found swallow rates of 0.8/min with a standard deviation (SD) of 0.11 in 21 patients [10] and swallow rate of 3.1 in 5 min (SD 2.85) in 20 people with PD [16] and pilot work suggesting that swallow frequency during distraction might be as infrequent as one swallow per 15 min.

Study Design

The study was a cross-sectional observational study combining quantitative measures of swallow frequency and drooling at rest and during a cognitively distracting task with cognitive assessment and semi-quantitative self-report questionnaires. The study took place in the participants' homes to reduce fatigue and perceived burden. Data collection took 2.5 h split over two visits. Participants were offered a choice of appointment times to ensure they were "on" with their medications and it was convenient for them.

The primary outcome measures were as follows: drooling severity and frequency and frequency of saliva swallows at rest and during a cognitively distracting task. Secondary outcome measures were the correlates of age, disease stage and duration, cognitive function and self-report of drooling.

In visit 1, baseline measures of, age, disease stage, duration since diagnosis and UPDRS 2.2 score [26] were collected. Hoehn and Yahr [28] disease stage was determined from the clinical record and treating clinician. Participants completed a baseline cognitive assessment on the Montreal Cognitive Assessment (MoCA) [29] which includes measures of attention and is sensitive to mild cognitive impairment in PD [17]. Self-report of drooling was assessed with the Radboud Oral Motor Inventory for PD-Saliva subset (ROMP-S) [9].

In visit 2, each participant completed two tasks while having their swallow frequency and drooling severity and frequency measured. The order of tasks was the same across all participants. At the end of task 1 participants had a break before task 2.

Task 1: a 30-min baseline observation at rest in a chair while watching a 24-h news programme to ensure participants maintained alertness. In trials of the research protocol, it was found that participants were prone to fall asleep without the programme in the background. They were asked not to talk during the observation.

Task 2: Observation while completing a distracting computer-based word association task. Data were only collected on drooling severity and frequency not performance on the distracting task based on the terms of the Research Ethics committee approval. The task was developed for a previous study to investigate the effect of lexical ambiguity and idiomatic language on reaction times in people with PD and was selected as a distracting task for the current study as such lexical tasks have been shown to be challenging for people with Parkinson's [30] and have been used as effective distraction in swallowing studies [23].

Participants sat in front of an ACER portable laptop with a 15-inch colour monitor and at a distance of 30–60 cm from the screen. The task was run on E-prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Text size for lexical elements was 28 point.

Participants heard a sentence, then saw a written word on the screen. Participants had to decide if the written word was related with the sentence they just heard (e.g. they heard: *He picked up the spade*. The word on screen might be: garden; card; space). There were 46 lexically ambiguous sentences, 40 idiomatic sentences and 30 foil sentences. They pressed the left red button on the mouse if the word was related and the right green button if it was unrelated. The written word was presented after 5 secs and remained on screen until the person responded. Participants completed the sentences randomly grouped in 4 blocks which took around 20 min in total to complete. The task was explained to participants as a language puzzle looking at word associations. It was explained that there were no right or wrong answers for the purpose of this study and we were not collecting their performance information. They were allowed to talk during the tasks.

Study Measurements

Swallow frequency was measured using a commercial off-the-shelf earpiece microphone *Piezoelectric Accelerometer Microphone* to record swallow sounds onto a Sony ICD-SX1000 voice recorder which had been used in previous drooling studies [15] cross referenced with a video recording using a Canon Legria HF R606 camcorder.

Drooling severity and frequency were quantified using the Drooling Severity and Frequency rating scale [8, 31] as an observational measure during rest and distraction tasks. The scale has been used in a number of studies with PD and other conditions as a self-report tool or an observational assessment [32–34]. Drooling severity and frequency were rated on the scale in 5-min intervals and the average was calculated. Counts were made live; therefore, the assessors could not be blinded to condition and participants were aware of the observations (Table 2).

Data Processing and Analysis

The recordings of swallow sounds were analysed using the PRAAT [35] acoustic analysis programme. Swallow frequency was calculated by counting the number of swallow sounds heard that corresponded with characteristic acoustic traces on screen. This method has been used for analysis of swallow sounds in previous research [36]. The acoustic trace counts from the audio recordings were cross referenced with observed swallows on the video recordings. Consistent with previous studies [10, 16], the mean number of swallows in 5 min was calculated by dividing the total number of swallows by the total minutes of the observation to give the mean in 1 min then multiplying by 5 to give mean number of swallows in 5 min.

A second viewer recounted 50% of the videos for 10 min between the 5- and 15-min time markers of each recording. This count was compared with the original count to calculate interrater reliability. Where there were questions about the presence or absence of a swallow, the two reviewers watched the video to arrive at consensus agreement. Due to the nature of the tasks, it was not possible to blind the second assessor to the task condition.

Data were non-parametric. Therefore, a two-tailed Wilcoxon signed rank test was used to compare swallow frequency and drooling rates across conditions. The significance level was set at 5%. In addition, Spearman's correlation analyses were used to assess the relationships between baseline measures of cognitive function, disease severity and duration, age and self-report measures (UPDRS 2.2 and ROMP) and the primary outcome measures.

Results

Demographic, Disease and Self-Report Characteristics

Eighteen people met the inclusion criteria and consented to participate. All participants who consented to participate completed the study. Demographic, disease and drooling self-report characteristics are shown in Table 3.

Fourteen (78%) participants were male. Five (27.8%) participants had a Hoehn and Yahr score of 2, eleven (61.1%) of 3 and two (11.1%) had of 4. Ten (55.6%) had UPDRS score for question 2.2 of 3 and eight (44.4%) had a score of 4. On the MoCA, eight participants fell below the 26+ score for normal cognition. Breakdown of ROMP-S severity scores is shown in Table 4.

Table 2 Drooling severity and frequency scale [8, 31]

Drooling severity scale	
1	Never drools, dry
2	Mild—drooling, only lips wet
3	Moderate—drool reaches the lips and chin
4	Severe—drool drips off chin & onto clothing
5	Profuse—drooling off the body and onto objects (furniture, books)
Drooling frequency scale	
1	No drooling
2	Occasionally drools (1–2 in 5 min)
3	Frequently drools (3–4 in 5 min)
4	Constant drooling (present throughout 5 min interval)

Table 3 Demographic, disease and drooling self-report characteristics of participants

Variable	Median	Interquartile range	Full range
Age	75	68.8–83.5	65–90
Duration (years)	5	3.8–11	1–20
MoCA (26+ normal range)	27	23.8–29.3	15–30
UPDRS qu. 2.2	3	3–4	3–4
ROMP-S (23 ± 6.4 needs treatment)	21.50	15.8–27	15–44

Drooling and Swallow Frequency

Reliability

On the nine video recordings scored by a second rater blind to the first rater's scores, there was 100% agreement for swallow totals both for the 'at rest' and 'distraction' conditions. There was also full agreement between live counts from rater 1 and swallow sounds identified from the PRAAT acoustic trace.

Table 5 shows the median and interquartile range for drooling severity and frequency at rest and with distraction and the swallow frequency, based on mean number of swallows in 5 min at rest and with distraction.

There were strong correlations between drooling frequency at rest and in distraction ($r = 0.928$, $p \leq 0.001$) and between drooling severity across conditions ($r = 0.667$, $p = 0.001$). The association of swallowing frequency at rest and in distraction approached significance ($r = 0.389$, $p = 0.055$). There was a significant negative relationship between swallowing frequency and drooling severity at rest ($r = -0.419$, $p = 0.042$), but not for any other associations between swallowing and drooling.

To examine whether variables differed significantly across conditions, we compared scores using Wilcoxon signed rank tests. Results appear in Table 5. Median drooling severity during distraction was more severe but the difference was not statistically significant ($z = -1.724$, $p = 0.085$). There was a significant difference between drooling frequency at rest and with distraction ($z = -2.041$, $p = 0.041$) and between swallow frequency at rest and with distraction ($z = -3.054$, $p = 0.002$).

Table 4 Distribution of ROMP-S severity scores

ROMP saliva scores	Number of participants
Mild: score 11 ± 2.6	0
Moderate: score 16 ± 5	10
Severe: score 23 ± 6.4	8

Correlations Between Baseline Measures and Primary Outcome Measures

The MoCA score showed a significant negative correlation with drooling severity (Spearman's correlation coefficient $r = -0.482$, $p = 0.043$, two tailed) and showed a near significant positive correlation with swallow frequency (Spearman's correlation coefficient $r = 0.461$, $p = 0.054$, two tailed) at rest. There were no other significant correlations between the baseline and outcome measures at rest.

There were no significant correlations between the baseline measures and the primary outcome measures during the distraction condition, nor between demographic and PD measures and change scores between baseline and distraction. The MoCA score, in particular, showed no significant correlation with change in swallow frequency (Spearman's correlation coefficient $r = -0.422$, $p = 0.081$, two tailed). ROMP-S measure correlated strongly with the UPDRS Drooling scale ($r = 0.738$, $p \leq 0.001$) but not with swallow and drooling measures, nor the MOCA.

Discussion

This is the first study to look at the role of attention in drooling in PD. It revealed that there was a significant effect of a distracting cognitive task on drooling and swallow frequency. Drooling severity was not significantly affected across tasks suggesting that severity is less vulnerable to the impact of distraction. When people with PD were engaged in a cognitively demanding distracting task they swallowed less frequently and drooled more. These findings suggest that saliva management in PD requires a degree of attentional scheduling to coordinate the monitoring, collection and clearance of saliva in the oral cavity.

The model of attention processing by Norman and Shallice [37] describes three levels of demands on the attention system: automatic tasks where concurrent tasks can occur and have no impact on the automatic task; partially automatic tasks requiring scheduled attention distribution; conscious tasks requiring full supervision of the task which allows decision making and trouble-shooting. Within this model, saliva management in PD would be

Table 5 Drooling severity and frequency and swallow frequency (number of swallows/5 min) median and interquartile scores

Measure	At rest Median (IQR)	With distraction Median (IQR)	*p* values Wilcoxon signed rank test
Drooling severity	1.3 (1.0–1.60)	1.6 (1.0–1.85)	$z = -1.724$, $p = 0.085$
Drooling frequency	1.6 (1.0–1.85)	1.8 (1.0–2.00)	$z = -2.041$, $p = 0.041$
Swallow frequency	2.4 (1.33–4.23)	1.1 (0.50–1.53)	$z = -3.054$, $p = 0.002$

classified as a partially automatic task requiring scheduled attention distribution. Therefore, when the complexity of the concurrent task is increased to requiring full supervision, the monitoring of the partially automatic task would be compromised. Whether saliva management for everyone requires scheduling of attention or whether this is a feature of PD remains unanswered. A recent study by Wu et al. [38] into the impact of attention on an automatic motor task found that people with PD need to recruit the attentional system for automatic motor tasks to compensate for the dopamine depletion in the striatum. It is possible to apply this finding to saliva management and it would suggest that prior to the onset of PD the brain is able to manage saliva without engaging the attentional system. When dopamine depletion starts to impact on the striatal system with consequent effects on attention, it could be hypothesised that saliva management starts to require partial scheduling of the attentional system to compensate, in the same way that in PD added attention is required to maintain voice intensity and stride length [20, 39]. If the attentional system is redeployed in a cognitively distracting task, attention scheduled to vigilance for saliva accumulation in the mouth reduces with a consequent reduction in swallow frequency and increase in drooling. This theory would explain why chewing gum [16] increases swallow frequency in people with PD as it maintains attentional scheduling and responsiveness to saliva accumulation and promotes the triggering of saliva swallows. Nieuwhof et al. [40] have offered imaging evidence for the differential pattern of striatal activation in people with PD under dual- versus single-task conditions that throws light on this assumption.

Consistent with previous research [25], the current study showed that increased drooling severity at rest is significantly correlated with declining cognitive function, though contrary to some previous research [2] none of the demographic and disease baseline measures significantly correlated with the primary outcome measures. There was no significant correlation between the cognitive scores and the outcome measures during distraction, however, there was a trend towards a negative correlation with change in swallow frequency scores which may suggest that worsening cognitive function increases the impact distraction has on swallow frequency. This is contrary to Troche et al. [24] who found dual tasking improved swallow function in the most cognitively impaired. This suggests that the relationship between deteriorating cognition and measures of saliva management is complex and warrants further investigation. Examination for possible subgroups of patients may also be warranted, in the light of the fact that in Troche et al.'s study [24] not all individuals demonstrated the effect, nor necessarily in the same direction.

A possibility for additional exploration also concerns the role of awareness of symptoms on performance. People with PD are well known to misestimate the extent of their symptoms [41–43]. In work on swallowing impairment pertinent to this point, Parker et al. [44] found in people with dysphagia after stroke that those with greater awareness of symptoms were safer swallowers. Noble et al. [42] found an apparently paradoxical improvement in swallowing safety as overall condition deteriorated. An explanation offered for this is that in the earlier disease stages when people with PD can be less aware of their impairments, they are more likely to engage in risky swallow behaviours. Once they are aware of potential difficulties after recognising a swallow impairment is present, they adapt their swallowing behaviour and adopt compensatory strategies, which effect an apparent improvement on swallow safety assessments. The same effects may be present when examining saliva control, suggesting that degree of awareness of drooling across time and situations may prove fruitful in uncovering variables that interact with drooling frequency and severity.

Currently assessment of drooling is primarily by self-report. The UPDRS question 2.2 and the ROMP-S [9, 26], both validated, reliable measures, were included in the study. However, no significant correlation was found between them and the live counts of drooling and swallowing. While this may be due to the small sample size and/or duration of the observational period, it suggests that perceptions of drooling differ from quantitative assessment of drooling. As noted above, there can be a discrepancy between self-report of dysphagia in PD and the quantitative assessment of dysphagia [42] and it may be that this is also apparent for drooling. Further research into the relationship between self-report and quantitative measures of drooling is needed.

The findings allow clinicians to provide people with PD a better explanation of drooling and when and why it is likely to occur intermittently and during distracting tasks. It allows them to recommend interventions that can be used in a targeted manner (e.g. targeted use of swallow reminder tools) during distracting tasks and encourage self-monitoring. However, these findings need to be taken further to develop assessments and treatments that can be used flexibly and effectively to managing these fluctuations in drooling.

The current study provides new insights into drooling and the role of attention but it has limitations in the design which should be addressed in future studies. While the sample was representative of the population [45] and achieved significance for the outcome measures the small size may account for the reduced power of correlations in the secondary analysis. Increasing the sample size and balancing the participants for age, gender, and disease stage would allow further analysis of these in influencing the effect of attention on saliva management.

Inclusion of more detailed baseline assessments including a fuller cognitive assessment, full Unified Parkinson's Disease Rating Scales score [25] and Parkinson's Disease Questionnaire-39 [46] would enable more detailed analysis of interrelationships between disease presentation, cognition, and saliva management.

This study found no significant change in drooling severity across conditions. Two factors that may be worthwhile addressing in a future study here concern the timespan of observation and the measurement of drooling severity. The measure of severity we employed may not have been sensitive enough for the degrees of variation observed in the study. More objective measures of drooling severity, e.g. weighing of cotton wool wads or gauze, may enable deeper insights into the variable, though these run the risk of altering the nature of the task and in themselves operating as some kind of cue to swallowing. A more objective measure would also allow a second assessor to verify the measurements which was not possible in the current study due to the variable visualisation of drooling from the video recordings. Secondly, duration of observations may have been too short to reveal potential differences. Prolonged observation may help address this issue, as well as the issue of participants being aware they were being observed. Longer or repeated observation sessions would permit more time for habituation to observation, although this issue applied equally to the two conditions in the present study, so should not have been a strong confounding factor.

Adding a control group of age and gender matched peers would have allowed comparison of outcome measures to address whether saliva management requires partial attentional resource allocation in the wider population.

A key limitation on conclusions in this study relates to the interpretation of outcomes in the distraction condition. One can state that involvement in the lexical decision task was associated with a statistically significant poorer performance for drooling and swallowing frequency at a group level. However, a future study would require additional conditions to examine more directly the possible causative relationship between concurrent tasks and drooling. Investigations of dual-task influences on gait, balance and speech have shown mixed findings. McCaig et al. [47] established a positive effect of dual-task (walking and talking) condition on speech intensity (reminiscent of the positive effects found in Troche et al. [24] for swallow measures). However, this occurred only in a fast and not a slow walking condition; the gait conditions showed no effect on speech rate. Heinzel et al. [48] found an effect of a motor but not a cognitive (number subtraction) task on gait. The competing motor task (box checking) appeared to exercise an effect on gait but not vice versa. This suggests that differing competing task types may have different impacts. Against this, Strouwen et al. [49] found similar effects across differing dual tasks. Reflecting findings in the present study, of a strong correlation between at drooling and swallowing at rest versus distracting task conditions, Strouwen et al. [49] found their single task gait condition performance to be one of the strongest independent predictors of dual-task performance. In general, they also found that people with PD appeared to prioritise the concurrent task over the other task.

The reaction time (RT) and accuracy scores on the lexical decision tasks were unavailable for this study. Thus, it was impossible to investigate any potential interaction between drooling severity and lexical decision variables. Some participants may have adopted a strategy of maintaining attention to drooling at the expense of RT and/or accuracy. Those who performed most poorly on drooling variables may have been those who prioritised lexical decision performance over drooling.

An even more enhanced insight would have been possible if alongside a baseline condition for drooling there had also been repeated baseline measures for lexical decision. In this way, one would have gained indications of the direction(s) of influence between tasks-maintenance of lexical decision performance over drooling, vice versa, they both deteriorate, or they both remain unchanged. Such variable individual patterns have been observed in other dual-task investigations of people with Parkinson's [50], where for example walking and balance in the presence of competing tasks has shown the nature of interaction to be both variable across individuals and dependent in some studies on the types of competing tasks involved [20, 39, 48, 49]. Thus, alongside baseline measures of both drooling and the competing task a later study could fruitfully compare the effects of varying classes of concurrent task, e.g. motor versus cognitive, executive cognitive problem solving versus switching task or versus sustained attention.

The limited sample size meant that the study had a limited spread of cognitive abilities in the participants and all participants had a self-reported issue with drooling. In order to address discrepancies between studies of drooling severity and effects of competing tasks, a greater spread of severity of cognitive decline would strengthen insights. Further, given the observation that people with Parkinson's may demonstrate an apparent improvement in particular symptoms as they become more severe [24] and the patient becomes more aware of them [43], a finer grained measure of self-awareness of drooling symptoms would add to our knowledge of key factors in variability of performance on competing tasks.

Finally, it is thought that drooling may be worse in the "off" state in PD [2]. The current study was delivered during the "on" phase. Comparisons of outcomes across states could also deliver useful findings in a future study.

In summary, this study found a significant negative effect on drooling frequency during participation in a/distracting task, and gave preliminary indications for possible underlying mechanisms in variation in drooling, as well as providing information that could translate into clinical advice around saliva management. To definitively answer the question of the relationship of saliva management and cognitive function and engagement, however, there are key issues that still need to be resolved. Specifically, we draw attention to the need to track scores in the cognitive task between baseline and experimental conditions as well as examine the nature of interaction between saliva management and cognitive test scores to investigate variability of individual patient performance in terms of strategies adopted to prioritise one or other task or for there to be an impact on both tasks. We also advocate the implementation of a range of cognitive tasks, since germane studies indicate that there may be differing outcomes dependent on the nature of the competing task. Thus, the current study supports the need for further research with a larger in-depth study to elucidate the role of attention in saliva management and consider the clinical applications for assessment and treatment.

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Compliance with Ethical Standards

Conflict of interest There are no known conflicts of interest.

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