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A novel evaluation of daytime vigilance in patients with Parkinson's disease using a virtual reality street-crossing task

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Abstract

Introduction: Patients with Parkinson's disease (PD) commonly experience sleep dysfunction, including daytime sleepiness. Excessive daytime sleepiness affects vigilance and attention, which can impact safety in tasks such as driving or crossing a street. No reliable measures of vigilance in this population currently exist. **Methods**: 25 subjects with Parkinson's disease completed subjective evaluation of daytime sleepiness (Epworth Sleepiness Scale) and a virtual reality street-crossing task. Subjects also completed the Useful Field of View (UFOV) test as a measure of visual processing. The primary vigilance outcome measure was the number of looks left and right per minute with higher values indicating better vigilance. We hypothesized a negative correlation between looks per minute (visual attention) and subjective sleepiness. **Results**: Preliminary analysis of this small sample shows a non-significant trend toward a negative correlation ($r = -0.06$) between visual attention and sleepiness. Adjusted for UFOV scores, subjective sleepiness still cannot predict visual attention. However, the Epworth is strongly positively correlated with near misses ($r = 0.46$, $p = 0.02$). Additionally, the UFOV is a strong predictor of visual attention and there is a significant negative correlation between visual attention and UFOV ($r = -0.56$, $p = 0.005$). **Conclusions**: Preliminary data indicate no significant correlation between subjective daytime sleepiness and vigilance. Interestingly, daytime sleepiness did correlate with close calls to pedestrian crashes, and visual processing (UFOV) negatively correlated with visual attention (looks/minute), indicating that subjects with PD may not correct for visual processing deficits. Failure to reject the null hypothesis may indicate that subjects with Parkinson's disease underestimate their daytime sleepiness.

Keywords: *Parkinson's disease, excessive daytime sleepiness, Useful Field of View, Virtual Reality street-crossing simulator, vigilance*

Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder with motor symptoms including tremor, stiffness, slowness, and lack of balance as well as non-motor symptoms such as sleep dysfunction and excessive daytime sleepiness.[1-2] Though motor symptoms are disabling, non-motor symptoms also negatively affect quality of life in individuals with this disorder.[3-4] Fifty to seventy-five percent of all PD patients report excessive daytime sleepiness.[5] Daytime sleepiness affects alertness and attention, which can hinder the successful and safe completion of everyday tasks such as driving or crossing a street.[4] An objective measure of daytime vigilance is needed in order to better understand the extent to which daytime sleepiness affects attention and safety in real life situations.

Several methods can be used to evaluate daytime sleepiness and vigilance. Questionnaires (such as the Epworth Sleepiness Scale[6]) ask patients about their level of alertness over the past month. The psychomotor vigilance task[7] is used to measure the impact of sleep loss on vigilance. These methods are useful, but they do not evaluate how sleepiness and vigilance affect safety during daily activities.

This observational study will investigate the relationship between performance on a virtual reality (VR) street-crossing simulator[8-9] and validated measures of daytime sleepiness and vigilance in subjects with Parkinson's disease. Our hypothesis is that the virtual reality street-crossing simulator task will be feasible in this patient population and that performance on the task will correlate with validated measures of daytime sleepiness and vigilance.

This research is novel in that this virtual reality simulation has never been used with PD patients, although it has been validated in other populations.[8-9] If it is found that the VR simulation is indeed a feasible objective measure that can be used to evaluate vigilance and daytime sleepiness in realistic situations, it can potentially be used as an outcome measure in other studies that involve sleep or medications in PD.

Methods

For this pilot study, 25 patients with Parkinson's disease were recruited from the population of individuals followed in the Movement Disorders Clinics at the University of Alabama at Birmingham. Inclusion criteria for the study included clinical diagnosis of Parkinson's disease, asymmetric onset of PD, and the ability to walk without assistance. Exclusion criteria included atypical features indicative of a Parkinson's Plus

disorder, neuroleptic treatment, history of multiple strokes or head injuries, and blindness.

All VR studies were performed at 10 a.m. (±30 minutes) to control for variation in circadian factors during the day. Upon arrival to the Youth Safety Lab, each participant completed the Epworth Sleepiness Scale (ESS), a subjective questionnaire used to evaluate daytime sleepiness in different situations over the previous month.

Next, each patient participated in the virtual reality street-crossing task, a measure of vigilance and attention. The VR environment consists of an elevated platform that represents a street-side curb with three screens on which the subject views the virtual environment of a two-lane street with bidirectional traffic (Figure 1). The subject observes the traffic and, when he or she feels it is safe to cross the street, steps off the platform. This triggers a cartoon representation of the subject to cross the street. The average number of looks left and right per minute is monitored, as this denotes visual attention to traffic, with higher numbers of looks suggesting greater attention to traffic. An important secondary outcome is the number of times that the participant is "hit" or nearly hit ("close calls") by a car, as these are an important safety measure. Performance on the UFOV is included as a covariate.

Figure 1. Screenshot of the virtual reality street-crossing task.

Prior to starting the VR task, the walking speed of the participant is measured to calculate a pedspeed for the virtual reality task. The pedspeed determines the speed at which the cartoon representation of the participant crosses the virtual street. A member of the study team demonstrates both a safe crossing and an unsuccessful crossing ("hit") on the VR task prior to the subject's first orientation trial to eliminate curiosity. Before participating in orientation or data trials, the participant is fitted with a headband holding a head-tracking device to measure looks left and right. The participant then completes a total of twelve orientation trials, each consisting of one street crossing.

Between the orientation and data collection trials of the VR task, the Useful Field of View Test (UFOV) is administered. The UFOV is a measure of visual processing speed during which the participant identifies objects that are displayed in the central and peripheral visual field on a touch-screen computer. This test, which consists of three subtests of increasing difficulty, allows assessment of deficiencies in visual processing speed that could influence performance on the virtual reality street-crossing task.

After the completion of the UFOV, the participant completes twelve data collection trials in the virtual reality environment. These trials are administered in the same manner as the twelve orientation trials. Both orientation and data collection trials are recorded via a video camera for hand-scoring as an additional measure of looks left and right.

Results

Based on this pilot study, individuals with Parkinson's disease were able to perform the virtual reality task in the virtual reality environment with minimal difficulty, showing that use of this task in the PD population is feasible. Table 1 gives the demographics of the first 25 PD participants. The summary statistics of outcome measures are featured in Table 2, and the distributions of outcome measures can be seen in Figure 2.

Table 1. Subject demographics

	Mean ± S.D.	Minimum	Maximum
Age (years)	64.4 ± 8.7	43	83
Gender (% male)	68	___	___
Duration of disease (years)	8.5 ± 5.5	1	20

Table 2. Summary statistics of outcome measures

	Mean	SD	95% CI
Looks·min^{-1}	33.07	11.38	28.38, 37.77
ESS	9.76	4.75	7.80, 11.72

	Median	Minimum	Maximum
Hits	1	0	8
Close calls	1	0	4
UFOV	387	70	904

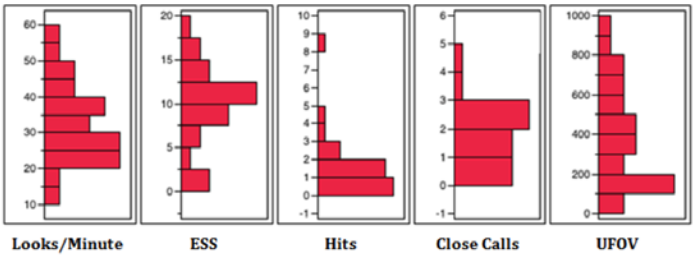

Figure 2. Distributions of outcome measures.

Correlations between outcome measures were calculated using Pearson Correlation coefficients (Table 3). Analysis of the primary outcome measure shows a non-significant trend toward a negative correlation between visual attention (looks left and right per minute) and subjective sleepiness, as measured by the Epworth Sleepiness Scale. Following adjustment for UFOV scores, it was found that subjective sleepiness still cannot predict visual attention to traffic.

Evaluation of secondary outcome measures (Table 3) shows that the Epworth Sleepiness Scale is strongly positively correlated with close calls to pedestrian crashes. Additionally, the Useful Field of View test is a strong predictor of both visual attention (looks per minute) and close calls.

Table 3. Pearson correlations for outcomes

	Epworth	Hits	Close calls	UFOV
Looks·minute^{-1}	-0.06	-0.392	-0.069	-0.557
	p = 0.78	*p = 0.53*	*p = 0.75*	***p = 0.005***
ESS		0.101	0.46	0.277
		p = 0.632	***p = 0.021***	*p = 0.190*
Hits			0.215	0.333
			p = 0.303	*p = 0.112*
Close calls				0.454
				p = 0.026

Discussion

This preliminary data indicates no significant correlation between subjective daytime sleepiness and vigilance, suggesting either that patients with PD may underestimate their degree of daytime sleepiness or that the VR task is unable to adequately measure visual attention in this population. However, daytime sleepiness, as measured by the Epworth Sleepiness Scale, is positively correlated with close calls to pedestrian crashes, indicating that excessive daytime sleepiness may be a cause for concern for this population in regard to safety. Visual processing (measured by the UFOV) is negatively correlated with visual attention (looks per minute) which suggests that subjects with PD may not correct for visual processing deficits. This may also be a safety concern, as close calls are positively correlated with visual deficits. Continued study to evaluate a larger sample size is ongoing.

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