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Measurement of Reaction Time in the Home for People with Dementia: A Feasibility Study

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Abstract

Background—Cognitive decline is the cardinal symptom of dementia. Accurate measurement of changes in cognition, while essential for testing interventions to slow cognitive decline, can be challenging in people with dementia (PWD). For example, the laboratory environment may cause anxiety and negatively affect performance.

Materials and Methods—In healthy people, researchers measure one aspect of cognition, attention, via assessing reaction times in a laboratory environment. This repeated measures study investigated the feasibility of reaction time measurement in participants' homes using the computerized psychomotor vigilance task (PVT) for PWD. Research questions were (1) Can laboratory controls be replicated in the home? (2) Where do PWD perform PVT trials optimally? and, (3) What are the preferences of PWD and their caregivers? Two groups that differed by sequence of testing location completed 12 reaction time assessments over 2 days. Caregiver and person with dementia dyad preferences were examined in a follow-up phone interview.

Results—Complete data were collected from 14 dyads. Although there were slight differences in lighting between settings, time of day, temperature and sound did not differ. There were no

significant differences in PVT performance between the two locations, but the group who tested in the home on Day 1 performed better than the group who tested in the lab on Day 1. All participants preferred home examination.

Discussion—It is feasible to measure reaction times in the home. Home testing contributes to optimal performance and participants preferred the home.

Keywords

Alzheimer's disease; dementia; reaction time; psychomotor vigilance task

Vigilant attention, that is, the ability to vigilantly attend to, quickly select, and respond to incoming stimuli, is central to human function and essential for safe and effective human performance. Vigilant attention is the key to everyday cognitive function. In healthy people sleep disturbance causes impaired vigilant attention and can lead to accidents and loss of life (Van Dongen, Maislin, Mullington, & Dinges, 2003). In people with dementia, impaired vigilant attention is often the first indication of cognitive decline (Foldi et al., 2005) and the most direct cause of functional status decline (Tabaton et al., 2010). It also contributes to worsening memory (Nordlund et al., 2010).

One standard measure of vigilant attention is simple reaction time during a vigilance task (Wild, Howieson, Webbe, Seelye, & Kaye, 2008). As investigators work to develop and test interventions to ameliorate and/or prevent cognitive decline, a valid and reliable measurement of reaction time in people with dementia could be an important tool for assessing outcomes. The purpose of this study was to establish the feasibility of using repeated measures of reaction time in the home setting in people with dementia (PWD). We will use the information from this feasibility study to establish research protocols for the study of sleep disturbance and vigilant attention in PWD.

Background

When sleep is disturbed in healthy people, there are changes in metabolic and electrophysiological processes in the prefrontal cortex specific to vigilant attention (Dumermer & Dinges, 2005). Following sleep deprivation, functional magnetic resonance imaging shows changes in cerebral blood flow in the prefrontal cortex (Simon et al., 2002; Wang et al., 2005) and increased compensatory activation in the cerebral prefrontal cortex during a task that requires vigilant attention (Drummond, Gillin, & Brown, 2001).

Sleep researchers have investigated the effect of sleep disturbance on vigilant attention with repeated measures of simple reaction time (every 2 hr continuously) using the Psychomotor Vigilance Task (PVT) and behavioral monitoring in a laboratory (Chee et al., 2008; Van Dongen, Mott, Huang, Mollicone, McKenzie, & Dinges, 2007; Weaver et al., 2007). Sleep researchers have reported that slow and inconsistent reaction times measured with the PVT are a dependable indicator of impaired vigilant attention in children ages 6–11 with sleep apnea (Venker et al., 2007), sleep-deprived men ages 25–66 (Adam, Retey, Khatami, & Landolt, 2006), police academy recruits with a prior night of short sleep (Neylan et al., 2010), sleep-deprived miners (Ferguson, Paech, Dorrian, Roach, & Jay, 2010), and men and

women of various ages (20–74) with sleep disturbance (Blatter et al., 2006). Further, investigators have validated the PVT for use in time-constrained work environments such as healthcare, aircraft flight decks, and air traffic control rooms (Lamond, Dawson, & Roach, 2005; Loh, Lamond, Dorrian, Roach, & Dawson, 2004).

There are several commonly used measures of reaction time, but because our goal is to study sleep disturbance in PWD, we chose to use the PVT in a repeated measures design as the superior measure of vigilant attention in the context of sleep research. The PVT has many advantages. First, although the assessment is automated, participants do not use a keyboard and the apparatus does not look like a computer. A keyboard may be threatening for participants without computer skills (Brownadyke et al., 2002). Second, problems with examiner/participant interaction during test administration can be minimized with this automated assessment. Third, in healthy populations the PVT sensitively reflects changes in circadian rhythms and sleep disruption without being substantially confounded by a learning curve (i.e., practice effect; Drummond et al., 2005).

In addition to repeated-measures designs, the PVT is most frequently used in a laboratory setting with behavioral monitoring to control for factors that can affect reaction time performance and produce erroneous results. These factors include, but are not limited to, time of day, activity, diet, light, posture, sound, and temperature (Drummond et al., 2005). Control of these factors is particularly important to optimize performance and minimize erroneous results in PWD because of their easy distractibility. For example, bright lights, an uncomfortable chair, a hot room, or a ticking clock could exacerbate distractibility and result in slowed or inconsistent reaction times even in healthy persons. To reduce the likelihood of this type of distraction, measurement of reaction times should be done in what is called a sterile environment. Because repeated measures and the standardized conditions of the laboratory setting may increase anxiety and adversely affect performance for PWD, in the present study we examined the feasibility of obtaining repeated PVT measures in the home while maintaining elements of the sterile laboratory environment. Our research questions were

1. Can laboratory controls (light, sound, temperature) be replicated in the home?
2. Do PWD perform PVT trials optimally (i.e., fastest reaction times, fewest total errors and lapses) in the home or laboratory? and
3. What are the perceptions and preferences of PWD and their caregivers regarding home and laboratory PVT trials?

Method

Setting

We conducted the study in the University of Arkansas for Medical Sciences Clinical Research Center (CRC) and participants' homes. All participants lived in a mid-South metropolitan statistical area as defined by the United States Census Bureau. All homes were single family dwellings.

Sample

The Institutional Review Board approved the study. We began recruitment of PWD through our organization's memory research center and included persons with a consensus diagnosis of Alzheimer's disease. To achieve the necessary sample we also recruited from the Donald W. Reynolds Institute on Aging Clinic, Alzheimer's Arkansas support groups, and senior citizens housing sites. Instead of a consensus diagnosis of Alzheimer's disease, we required that individuals not enrolled in the memory research center have a physician diagnosis of dementia documented in the medical record. We provide additional details about the recruitment plan for this study elsewhere (Cole, Doan, Ballinger, & Brown, 2009).

After initial contact and an expression of interest, the principal investigator (CSC) met with enrollees in their home to explain the study, obtain informed consent and collect baseline data to determine if they met inclusion criteria. We used the MacArthur Competence Assessment Tool for Clinical Research to assess participants' capacity to provide consent (Appelbaum, 2000). Inclusion criteria were physician diagnosis of dementia, the taking of a consistent dose of a cholinesterase inhibitor or N-methyl D-aspartate receptor (NMDA) antagonist for at least 7 days prior to the study or no use of these drugs and availability of caregiver to stay with the participant. Participants also needed to be ambulatory and able to complete activities of daily living. We excluded patients if the caregivers reported acute medical or psychological illness or if the PWD was receiving anxiolytics or hypnotics. We did not exclude patients who were taking antipsychotics, but we did exclude those who had a score of 11 or more on the Geriatric Depression Scale (GDS; Yesavage et al., 1982). The GDS is a 30-item self-report questionnaire with a yes/no format that was specially developed for use with older adults. Possible scores range from 0 to 30, with higher numbers indicating more depression. A cutoff score of 11 yields a sensitivity of 84% and a specificity of 95% (Brink et al., 1982). We excluded participants with depression because it can affect cognitive performance. We also administered the Mini Mental State Examination (MMSE) to provide additional description of study participants. The MMSE, a 30-point questionnaire, tests orientation, registration, attention, calculation, recall, and language (Crum, Anthony, Bassett, & Folstein, 1993). Scores can range from 0 to 30, with higher numbers indicating intact cognitive performance. The MMSE provides a global assessment of cognition. It also has an attention subscale that can be calculated using either a mathematical task (serially subtracting 7s from 100) or a spelling task (spelling the word *world* backwards). Test-retest reliability is .83 and validity with similar measures ranges from .66 to .88 for the entire scale (Folstein, Folstein, & McHugh, 1975).

The final sample consisted of 14 dyads (PWD and their caregivers). We collected PVT data from the PWD, while caregivers provided data during a phone interview on testing preferences.

Study Procedure

After screening participants, we assigned them to one of two groups that differed only by testing sequence (home/CRC or CRC/home). We allowed participants to select their preferred testing sequence to the extent possible while keeping the group numbers balanced because we anticipated that scores could change on the 2nd day regardless of setting.

Although sleep researchers have generally carried out PVT testing every 2 hr for an entire 24-hr period, we believe this regimen would have been too burdensome for our population. Therefore, on both days of the study, participants completed the PVT six times only during day hours, at 9:00 a.m., 11:00 a.m., 1:00 p.m., 3:00 p.m., 5:00 p.m., and 7:00 p.m. (+/- 10 min). Mealtimes were standardized at 8:00 a.m., 12:30 p.m., and 5:30 p.m..

On the CRC day, we conducted all PVT measures in the same private room (with no windows, an opaque door, and consistent temperature). We played an audio recording of pink noise (a heterogeneous mixture of sound waves extending over a wide frequency range, sounding somewhat like radio static) at 35 decibels sound pressure level (dB SPL) during testing to mask extraneous sounds that might distract participants. The participants were seated upright in the same comfortable chair with good back support at a desk facing a tri-fold screen to minimize visual distractions and ensure a consistent environment. Between testing sessions the research staff monitored the participants every half hour and helped to keep participants pleasantly engaged in nonstimulating activities. The monitoring allowed for control of behaviors (e.g., napping) and dietary intake (e.g., caffeine) that could affect PVT performance.

On the home day, research staff traveled to the participant's home and replicated standardized laboratory testing conditions including the same comfortable chair, desk, and tri-fold screen. Research staff conducted scripted phone interviews 24 hr after the completion of PVT testing to determine which setting caregivers preferred and why.

Testing Conditions

Research staff videotaped all testing sessions, and the first author reviewed the tapes for timing, equipment settings, and furniture placement to ensure standardized testing procedures. Research staff recorded sound level, light intensity, and temperature before and after each trial. Only the research assistant remained in the room with the study participant during reaction-time testing.

Measures

The Psychomotor Vigilance Task (PVT)—We used the hand-held, self-contained PVT to measure reaction time in response to a series of visual (light-emitting diode LED) or auditory stimuli presented at variable intervals over 10 min. The PVT can be programmed for either right- or left-handedness. The intervals varied from 1 to 10 s. As a stimulus in the present study, we used a four-digit millisecond clock (red digits on a black background) presented in a 3 mm window near a response switch. Participants were instructed to depress the switch as quickly as possible after seeing the stimulus. We measured mean reaction time in milliseconds as well as false starts (response without stimulus presentation) and lapses (slow responses > 400 ms, indicating microsleep). Mean reaction time is the mean latency between the appearance of the visual stimulus and the participant response. In healthy persons PVT trials of 10 min are highly reliable within and between sessions (Loh et al., 2004) and test-retest reliability has been measured at $r = 0.8$ for all components of the PVT (McEvoy, Smith, & Gevins, 2000). Mean reaction times in healthy well-rested people average 300 ms (Drummond et al., 2005).

Sound—Research staff positioned a sound meter (Quest Technologies 2100) on a tripod on the participant's left to avoid erroneous measures due to reflected sound. We checked the meter calibration before each test day to assure that it was maintained according to manufacturer's recommendations. Settings for the sound meter were maintained at 30–100 dB, slow response (fast response is used only for short-duration noises such as passing traffic), and weight “A,” which emulates the low-level response of the human ear and is used for most noise measurement (Quest Technologies, 2000).

Light—The light meter (Gossen 3-Colour Light Meter) measured intensity of incident light in lux (units indicating the density of the light that falls on a surface) from 10 to 190,000 lux. We positioned the light meter directly in front of the participant prior to and after testing. Average indoor lighting ranges from 100 to 1000 lux, and average outdoor sunlight is about 50,000 lux (Gossen Foto, 1998).

Temperature—We measured ambient temperature in degrees Fahrenheit using the Wireless Indoor/Outdoor Thermometer (Radioshack Corporation, 2001). We positioned the thermometer directly in front of the participant and recorded temperature prior to and after each testing session.

Participant preference—The research staff used a scripted phone interview to ask caregivers about the lifestyle and environmental elements (activity, diet, light, posture, sound, temperature, time) that contributed to optimal performance, what caused poor performance, and where (CRC or home) performance was optimal.

Data Management and Analysis

Research staff downloaded PVT data after each day of testing, then verified it and saved it to the server (backed up daily) using Access software. We protected server access through limited right of entry and passwords and stored all hard-copy data in a locked office in a locked cabinet. We summarized raw data using the REACT data analysis software for the PVT-192 (Ambulatory Monitoring, Inc.). The software reduces the data and produces summary reports that include, but are not limited to, mean, median, and mode reaction times.

Results

Preliminary analysis with SPSS 17.0 focused on assessing description of the sample and whether or not any of the environmental variables at the two locations significantly differed. A total of 23 dyads signed the informed consent document, and we collected complete baseline (i.e., screening) data from 19. Of these 19, 4 potential PWD participants scored higher than 11 on the GDS and were excluded. An additional participant withdrew consent after baseline data collection, leaving 14 dyads with complete data. Of these, 11 were Caucasian (78.6%) and 3 were African American (21.4%). Of the persons with dementia, 5 were female (35.7%) and 9 were male (64.3%). Their average age was 78.3 years (SD 5.93), with a range of 64–87. Three had graduate degrees, 4 had completed college, 3 had completed partial college, 2 had completed high school, and 2 had completed less than the 10th grade. The average MMSE score was 22.60 (SD 4.12; indicating mild-to-moderate

dementia); the average GDS score was 6.07 (SD 3.15). Although the group of participants who tested in the CRC on Day one and in the home on Day two ($n = 8$) was slightly older (78.9), more cognitively impaired (21), and less depressed (5.37) than those who tested in the home on day one, t -tests did not show significant differences ($t = -0.37, p = .72; t = 1.72, p = .11; t = 0.90, p = .38$, respectively).

We used paired t - tests to identify significant differences in mean measurements in environmental variables between locations. Lighting was significantly different ($t = -19.14, p = .00$). Mean incident light ranged from 216.73 to 310.67 lux in the home and 2573.33 to 3020.00 lux in the CRC. There were no differences in temperature ($t = -1.48, p = .15$) or sound ($t = -0.44, p = .67$). Temperatures ranged from 67.6 to 73.7°F in the home and 70.8 to 72.9°F in the CRC. Sound ranged from 48.3 to 50.17 dB SPL in the home and 50.33 to 52.09 in the CRC.

To determine where people with dementia optimally performed PVT trials, we conducted a one-way multivariate analysis of variance (MANOVA) to identify the effect of PVT testing session (Times 1 through 12), group (home/CRC or CRC/home), and location (home or CRC) on the dependent variables (mean reaction time, total errors, and lapses). We used a Bonferroni correction with a significance level of 0.01 (0.05 divided by three dependent variables). We found the greatest differences between the home/CRC and CRC/home groups. The group who tested in the home on Day 1 had overall faster mean reaction times (428 ms vs. 1603 ms), fewer errors (2.5 vs. 7.9) and fewer lapses (10.54 vs. 37.9) than the group who tested in the CRC on Day 1, however the Wilks's lambda of .93 was not significant ($F [4,149] 2.66, p = .04$), and the partial eta squared was small at .07. Table 1 contains the means and the standard deviations on the three dependent variables by the three factors.

We summarized results of the scripted phone interviews with frequencies. Caregivers most often reported time of day as important to optimal performance. The only suggestion for improvement was to shorten the testing days. When we asked them where PVT performance was better, 3 caregivers said the home, and 2 said the CRC. Consistent with our data, 9 reported no difference.

Discussion

Performance on the PVT did not vary significantly between the home and CRC settings. While there were slight differences in sound and temperature between the two settings, these differences did not adversely affect PVT performance. There was a significant difference in lighting between the settings, which also did not appear to have an effect on performance. However, this difference could be remedied with appropriate task lighting. The best level of luminance for a video display such as that used by the PVT is 300–400 lux (Gossen Foto, 1998). In the present study, then, the home lighting was superior to the brighter lighting in the CRC for performance of the PVT. To prevent excessive distraction and ensure acoustical comfort the World Health organization suggests that ambient sound levels should not be higher than 55 dBL (Berglund, Lindwell, & Schwela, 1999). Although sounds were slightly louder in the CRC than in the home, neither location exceeded recommended limits.

As expected, we observed worse reaction times at the end of Day 1 (Sessions 5 & 6), consistent with fatigue in both groups. At the end of Day 2 the CRC/home group's reaction times actually improved, but they demonstrated an increased number of errors and lapses compared to the home/CRC group. We believe this apparent improvement actually reflects increased fatigue and frustration with the testing situation. These findings are consistent with those of sleep research studies in healthy populations in that time of day and fatigue due to increased numbers of hours of wakefulness are important considerations when measuring vigilant attention (Van Dongen & Dinges, 2003).

One potential limitation of our approach in the present study is an open question as to whether people with dementia have the stamina to complete 2 consecutive days of testing, as highlighted by the deterioration in performance from Session 1 to Session 12 and the caregivers' concerns regarding the length of testing. People with dementia may also have motor deficits that, while not precluding testing, prevent optimal performance; or they may have diminished sensory acuity, motor strength, flexibility, and adaptability that accompany advancing age. These factors could have influenced our results or those of similarly designed studies. Changes in reaction time could also reflect decreased motivation. Also, we used the GDS to measure depression, but the validity of the GDS may be compromised in demented populations (Wancata, Alexandrowicz, Marquart, Weiss, & Friedrich, 2006). Finally, because the groups in the present study were self-selected, we consider that there might be difference between subjects in the two groups. The mean MMSE score for the home/CRC group was 24 versus 21 for the CRC/home group. Although this difference is not statistically significant, it may be clinically significant when considering measurement of reaction times, and one would expect the CRC/home group to perform less well. Investigators conducting future studies in similar populations may consider these potential limitations in the study design.

Conclusion

Given the resources required to standardize the home testing environment, it is not likely that home reaction time testing is feasible for the clinical population. The purpose of this feasibility study, however, was to establish research protocols, and we conclude that home reaction time testing is, indeed, feasible. In fact, given subjects' preference for home over laboratory testing, home-based tests could facilitate subject recruitment and retention. The benefits of this approach could thus outweigh possible limitations. Additionally, this study provides the first published normative data for PVT use in people with dementia. These findings will be important to take forward as we design future studies.

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Table 1

Means and standard errors (SE) of dependent variables by session, group, and location. ($n = 14$).

	Reaction Time (ms)	Errors	Lapses
Session			
1	539.74 (425.99)	2.04 (3.73)	16.81 (8.50)
2	586.02 (425.99)	3.63 (3.73)	17.98 (8.47)
3	921.22 (293.70)	7.51 (2.57)	23.45 (5.84)
4	929.36 (293.70)	7.42 (2.58)	22.01 (5.84)
5	1428.79 (293.70)	4.25 (2.57)	21.58 (5.84)
6	1936.59 (429.97)	5.23 (3.76)	32.75 (8.55)
7	1016.36 (303.34)	3.50 (2.65)	24.79 (6.03)
8	865.78 (303.34)	3.50 (2.65)	26.79 (6.03)
9	998.83 (293.70)	8.48 (2.57)	28.13 (5.84)
10	903.97 (293.70)	7.62 (2.57)	23.88 (5.84)
11	847.02 (293.70)	5.39 (2.57)	27.21 (5.84)
12	909.00 (306.48)	5.13 (2.68)	21.61 (6.09)
Group			
Home/CRC	428.00 (152.44)	2.54 (1.33)	10.54 (3.03)
CRC/home	1602.74 (145.09)	7.97 (1.27)	38.00 (2.89)
Location			
Home	1088.82 (141.61)	2.34 (8.61)	18.53 (32.77)
CRC	905.22 (155.24)	1.42 (8.30)	14.20 (29.81)

Note. Sessions 1–6 took place on Day 1, while Sessions 7–12 took place on Day 2. The Home/CRC group tested at home on Day 1 and at the CRC on Day 2, while the CRC/home group tested at the CRC on Day 1 and home on Day 2. CRC = clinical research center.