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The feasibility of standardized cognitive assessments for vestibular patients

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The Feasibility of Standardized Cognitive Assessments for Vestibular Patients

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PUBLIC PRESENTATION

This work is accepted for presentation, in part or in full, at Speech-Hearing Association of Virginia on 03/08/19.

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Abstract

Vestibular dysfunction, or impairments in the inner ear and/or brain structures that process sensory information and help control balance, has a high correlation with cognitive deficits, or problems with mental processes. This relationship negatively affects daily activities and quality of life in persons that live with vestibular dysfunction. Though there is sufficient research proving the relationship, few studies have applied that information in ways to better help the population with vestibular dysfunction. The purpose of this study was to assess the feasibility of a cognitive assessment battery (a set of correlated assessments delivered in one session) tailored to measuring performance in the specific cognitive domains that are affected by vestibular dysfunction, and to determine its practicality for clinical and research use. A thorough review of the literature was conducted to determine which tests exist that assess the specific cognitive domains that may be affected by vestibular disorders: attention, memory, executive function, language, visuospatial skills. The Cognitive Linguistic Quick Test (CLQT) was found to be the most appropriate, as it measures performance in these domains. In order to determine the practicality of the assessment, the CLQT was administered to a college population and an older population who were tested and found to have no vestibular abnormalities. The use of a validated objective measurement tool will improve the quality of research and the ability of clinicians to identify and address cognitive deficits and measure treatment effectiveness in vestibular patients.

Introduction

It is estimated that 40% of the US population will experience dizziness or balance problems in their lifetimes (National Institute on Deafness and Other Communication Disorders, 2014). Similarly, in the United States, 27.7% of adults over 75 years old reported problems with dizziness or balance in the past year (Ward, Agrawal, Hoffman, Carey & Santina, 2013). These numbers reinforce the importance of the specialized field of study regarding complex vestibular function.

The vestibular system, a collection of sensory organs within the inner ear, tracks one's physical position in space, providing information about motion, equilibrium, and spatial orientation to the vestibular nuclei in the brain (Watson, Black & Crowson, 2016). Vestibular disorders include Benign Paroxysmal Position Vertigo (BPPV), labyrinthitis, neuritis, Meniere's Disease, and otosclerosis, as well as dysfunction resulting from migraines and traumatic brain injuries (VeDa, n.d.). Vestibular dysfunction can result in physical symptoms such as oscillopsia, a condition in which stationary objects in the visual field jump or blur with head movements; vertigo, which is dizziness that creates the illusion of spinning; tinnitus, ringing of the ears when there is no external sound; hyperacusis, heightened sensitivity to sound; and instability while standing (Ward et al., 2008).

Vestibular dysfunction can also result in cognitive discrepancies in attention, concentration, remembering, and reasoning (VeDa, n.d). Cognition is the mental process that involves "acquisition, storage, manipulation, and retrieval of information" ("What is Cognition?", 2015). Various cognitive functions, also known as domains, include social cognition, executive function, memory, attention, and psychomotor speed ("What is Cognition?", 2015). Cognition is the process of thinking, and the vestibular system requires mental resources and attention to function. One study showed that when subjects thought about past events they swayed backward, and when they thought about future events they swayed forward, which demonstrated the balance changes that occur during cognition (Mast, Preuss, Hartmann & Grabherr, 2014). Though the link between the two systems is difficult to study while both are performing at maximum capability, the relationship becomes clear when there is a malfunction in one or both systems.

Theories Underpinning the Cognitive-Vestibular Relationship

Two prominent theories explain the relationship between vestibular dysfunction and cognitive deficits. The first theory posits an indirect link: there are limited cognitive resources that can be allocated to mental tasks and balance tasks at the same time (Bigelow & Agrawal, 2015; Ellis, Klaus & Mast, 2017; Hanes & McCollum, 2006; Talkowski et al., 2005). For example, one study showed that a patient's reduced performance on a cognitive task being performed concurrently with a balance test can be attributed to the brain's focusing attentional resources on balance at the expense of the cognitive task (Bigelow & Agrawal, 2015). Hanes and McCollum (2006) hypothesized that cognitive tasks are extremely susceptible to confounding variables, such as lack of motivation or more apparent needs. The brain prioritizes tasks, and the task of most importance will prevail; that is, keeping the body upright.

The second theory proposes a direct link: the brain is structured such that vestibular and cognitive impulses are closely positioned anatomically (Hitier et al.,2014; Mast et al., 2014; McGeehan et al., 2017; Harun, Oh, Bigelow & Agrawal, 2017; Seemungal, 2014). Mast and colleagues (2014) theorize that the vestibular cortex overlaps with cognitive networks in a way that produces the close relationship. Furthermore, Seemungal (2014) wrote about self-motion perception and how it is mediated through cortical networks, not just a single area of the brain.

This implies that many cortical areas that contain cognitive pathways also show a vestibular response. The close anatomical regions of the brain that support both vestibular function and cognitive function demonstrate how interconnected the two systems are.

Cognitive Correlates to Vestibular Dysfunction

Previously, vestibular dysfunction was thought to only affect balance and spatial orientation; cognitive deficits are a more recent discovery. A growing body of research reveals that vestibular dysfunction is correlated with cognitive performance deficits (Alsalaheen et al., 2016; Bigelow& Agrawal, 2015; Cohen, Provasi, Leboucher & Israël, 2017; Ellis et al., 2017; Hanes & McCollum, 2006; Harun et al., 2017; Hitier, Besnard & Smith, 2014; Lotfi et al., 2017; Mast et al., 2014; McGeehan, Woollacott & Dalton, 2017; Moser, Vibert, Caversaccio & Mast, 2017; Popp et al., 2017; Seemungal, 2014; Semenov et al., 2016; Talkowski, Redfern, Jennings & Furman, 2005; Wiener, Hamilton & Sidney, 2013). Generally, cognitive deficits are impairments to the mental processing of information. Cognitive dysfunction impacts the ability to perform daily activities, which compromises quality of life. Vestibular dysfunction produces cognitive deficits across many domains, such as spatial awareness, memory and attention.

Research reports that a common cognitive deficit secondary to vestibular dysfunction is a lack of spatial memory/navigation (Alsalaheen et al., 2016; Bigelow & Agrawal 2015; Cohen et al., 2017; Hanes & McCollum, 2006; Hitier et al., 2014; Mast et al., 2014; Moser et al., 2017; Popp et al., 2017; Semenov et al., 2016). An example of a spatial entity is a mental time line because past dates are located on the left end of the mental line, while future dates are located on the right end of the mental line. Another cognitive domain linked to the vestibular system is self-motion perception, which is awareness of where one’s body is in space (Bigelow & Agrawal, 2015; Cohen et al., 2017; Hitier et al., 2014; Mast et al., 2014; Popp et al., 2017; Semenov et al., 2016; Seemungal et al., 2014). This link between spatial cognition and vestibular function is important because spatial awareness is essential in maintaining upright posture.

Additionally, memory is a facet of cognition often affected by vestibular dysfunction. Visual memory deficits are one of the most common in patients with vestibular disorders (Alsalaheen et al., 2016; Bigelow & Agrawal, 2015; Cohen et al., 2017; Hitier et al., 2014; Mast et al., 2014; Popp et al., 2017; Semenov et al., 2016). Deficits were found on number-cognition tests, which require visual memory (Hitier et al., 2014; Mast et al., 2014; Moser et al., 2017). Visual memory can be tested on number-cognition tests because visual memory issues affect one's ability to recall what was visually processed. Short-term memory was also found to be impaired in those with vestibular dysfunction (Hanes & McCollum, 2006; Hitier et al., 2014; Moser et al., 2017; Popp et al., 2017; Semenov et al., 2016). Short-term memory has a duration of 15 to 30 seconds, with a capacity of seven items plus or minus two (McLeod, 2009). Short-term memory is used to recall phone numbers, comprehend sentences, or remember someone's name. Memory is an important aspect of cognition that is negatively impacted by vestibular abnormalities.

Vestibular dysfunction also negatively impacts attention. Reaction time (Alsalaheen et al., 2016; McGeehan et al., 2017) and executive function (Bigelow & Agrawal, 2015; Moser et al., 2017; Popp et al., 2017), both measures of cognitive attention, have been found to be lacking in the general population with vestibular dysfunction. Vestibular dysfunction not only negatively impacts the general population, but also children with Attention Deficit Hyperactivity Disorder (ADHD). One study found that vestibular dysfunction in children with ADHD resulted in even poorer voluntary and involuntary attention when compared to their peers (Lotfi et al., 2017).

Other studies have had similar findings concerning attention (Bigelow & Agrawal, 2015; Moser et al., 2017; Popp et al., 2017).

Cognitive Testing Used with Vestibular Disorders

Many empirical tests exist to measure specific cognitive skills (Table 1). The variability of tests used in the literature makes it difficult to compare and compile results. Each research team used a different combination of balance tests and cognitive tests to determine the relationship between the two, making it hard to know which methods will produce the most accurate results. Table 1 below shows some of the major cognitive assessments that have been administered to vestibular patients, which cognitive domains they test, a description of the assessment, and the researchers who utilized the assessment; the diversity of the literature is clearly illustrated.

Table 1

Common Cognitive Assessments Used with Vestibular Disorders

Cognitive Assessment	Cognitive Domain(s) being Assessed	Description of Assessment	Researcher(s) who utilized assessment
The Test for Attentional Performance (TAP): Alertness and Visual Scanning	- Alertness - Visual Scanning	The assessment determines attentional performance and ability to visually scan the environment while driving. The subjects react to easily distinguishable stimuli with a motor response.[a]	Popp, P., Wulff, M., Finke, K., Rühl, M., Brandt, T., & Dieterich, M. (2017)
The Stroop Color and Word Interference Test	- Processing Speed - Executive Functioning	The subjects rapidly read and name a set of words and color bars. Then, the subjects name the color of the font of the word that flashed on screen.[b]	Popp, P., Wulff, M., Finke, K., Rühl, M., Brandt, T., & Dieterich, M. (2017)

Corsi Block-Tapping Test	- Short-term memory - Working memory - Executive Function	9 blocks are arranged on a board, the subject must repeat the pattern(s) tapped by the experimenter backwards or forwards.[c]	Popp, P., Wulff, M., Finke, K., Rühl, M., Brandt, T., & Dieterich, M. (2017)
Digit Span	- Memory Span - Working memory	The subject repeats a sequence of random numbers. They are scored based on the length of the sequence.[d]	Erickson, K.R., DeWeese, M., & Simons, A. (n.d)
Mini Mental State Exam	- Orientation - Attention - Immediate and Short-term recall - Language - Comprehension and completion of commands	The subject completes 30-point questionnaire on a sheet of paper.[e]	Erickson, K.R., DeWeese, M., & Simons, A. (n.d)
Cambridge Neuropsychological Test Automated Battery	- Decision Making - Attention and Reaction Time - Spatial Working Memory - Visual memory	The subjects perform differing activities on a touch screen computer.[f]	Lotfi, Y., Rezazadeh, N., Moossavi, A., Haghgoo, H. A., Rostami, R., Bakhshi, E., et al. (2017).

Note. [a]PsyTest (2018). [b]Scarpanian & Tagini (2017). [c]PsyToolKit (2017). [d]Dynaread (n.d). [e]Folstein, M.F., Folstein, S.E., McHugh (1975). [f]Postma & Van der Ham (2017).

The research that has been performed to find the relationship between vestibular dysfunction and cognitive deficits has laid the groundwork for a deeper knowledge of each system. One area where the literature is lacking is the application and synthesis of this knowledge. While each study has concluded that vestibular dysfunction often results in cognitive decline, few studies have gone further to discuss how to use this information in practice. No study has synthesized the results to create a practical application, and no standard approach to study the cognitive deficits in vestibular patients exists. Now that substantial evidence for the connection of the two systems has been established, an objective measurement tool merits validation so that clinicians and researchers can better recognize and measure the symptoms of vestibular dysfunction.

Methods

A feasibility design was used for this project. A feasibility study assesses the viability and practicality of a proposed idea in order to determine if the idea will work and whether or not proceeding further would be valuable. The study uncovered the strengths and weaknesses of the Cognitive Linguistic Quick Test (CLQT). It is an addendum to a prior IRB-approved study that allows a full battery of vestibular tests to be given to subjects.

Participants

The study consisted of 18 participants with normal vestibular and cognitive function. Nine of the participants were between the ages of 21 and 24, with an average age of 21 years old. The other 9 participants were between the ages of 44 and 70, with an average age of 63 years old. The participants were subjects in the Vestibular Sciences Lab at James Madison University, where they underwent a series of vestibular tests to determine their inner ear function. Each participant had normal test results, thus making them eligible to be cognitively assessed for this study. The participants were required to have no vestibular abnormalities to create normative data specific to this population for the CLQT.

Procedures

A review of the literature was conducted to determine which tests exist that assess the specific cognitive domains affected by vestibular disorders. The Cognitive Linguistic Quick Test (CLQT) was chosen. It was hypothesized that the test would be quick to administer and easily tolerated by participants. Participants underwent a series of vestibular tests to determine their inner ear function. Tests included Rotary Chair, Caloric Testing, Cervical Vestibular Evoked Myogentic Potential (cVEMP), Ocular Vestibular Myogenic Potential (oVEMP), Video Head Impulse Testing (VHIT), and foam board. Each participant was confirmed to have normal vestibular functioning before being assessed for cognitive functioning. The Cognitive Linguistic Quick Test (CLQT) was administered to each participant according to the instruction and prompts according to the instructions of the assessment. Participants also completed a subjective assessment created by the researcher aimed to rate their personal judgement of their stress during the CLQT (see appendix A).

The Cognitive Linguistic Quick Test (CLQT)

The Cognitive Linguistic Quick Test (CLQT) was administered to each participant according to the instruction and prompts according to the instructions of the assessment. The assessment was chosen because it assesses attention, memory, executive function, language, and visuospatial skills (see Table 3). The CLQT also takes less than thirty minutes to administer, is easily attainable, and easily scored; thus making it feasible for clinical use. The CLQT is suited for identifying areas in need of treatment or management. The assessment consists of ten tasks, half of which have minimal language demands and can be used as a stand-alone overview of cognitive domains. The ten tasks are Personal Facts, Symbol Cancellation, Confrontation Naming, Clock Drawing, Story Retelling, Symbol Trails, Generative Naming, Design Memory, Mazes, and Design Generation. Table 3 shows which cognitive domains each task assesses.

Subjective Survey

In addition to the CLQT, participants were asked to complete a brief survey regarding their impressions of the CLQT. The survey is shown in Table 4.

Table 3

Cognitive Domains Evaluated by each CLQT Task

	Cognitive Domains				
CLQT Task	Attention	Memory	Executive Functions	Language	Visuospatial Skills
Personal Facts		X		X	
Symbol Cancellation	X				X
Confronting Naming				X	
Clock Drawing	X	X	X	X	X
Story Retelling	X	X		X	
Symbol Trails	X		X		X
Generative Naming		X	X	X	
Design Memory	X	X			X
Mazes	X		X		X
Design Generation	X		X		X

Note: Helm-Estabrooks, N., Sc.D., CCC-SLP, BC-NCDA. (2001). *Cognitive Linguistic Quick Test: Examiner's Manual*. The Psychological Corporation.

Table 4
Subjective Survey completed by all participants

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
The assessment was too difficult	5	4	3	2	1
I was extremely frustrated for the duration of the assessment.	5	4	3	2	1
The assessment was too easy.	5	4	3	2	1
I felt bored while taking the assessment.	5	4	3	2	1
I felt stressed while taking the assessment.	5	4	3	2	1
The assessment was too hard for my abilities.	5	4	3	2	1

Results

The participants performed as expected of normal cognitive and vestibular functioning adults and scored within normal limits of the CLQT. The current study means and standard deviations for each of the cognitive domains were similar to the normative data means and standard deviations (See Table 5).

Table 5
Cognitive Domain Means and Standard Deviations of the CLQT

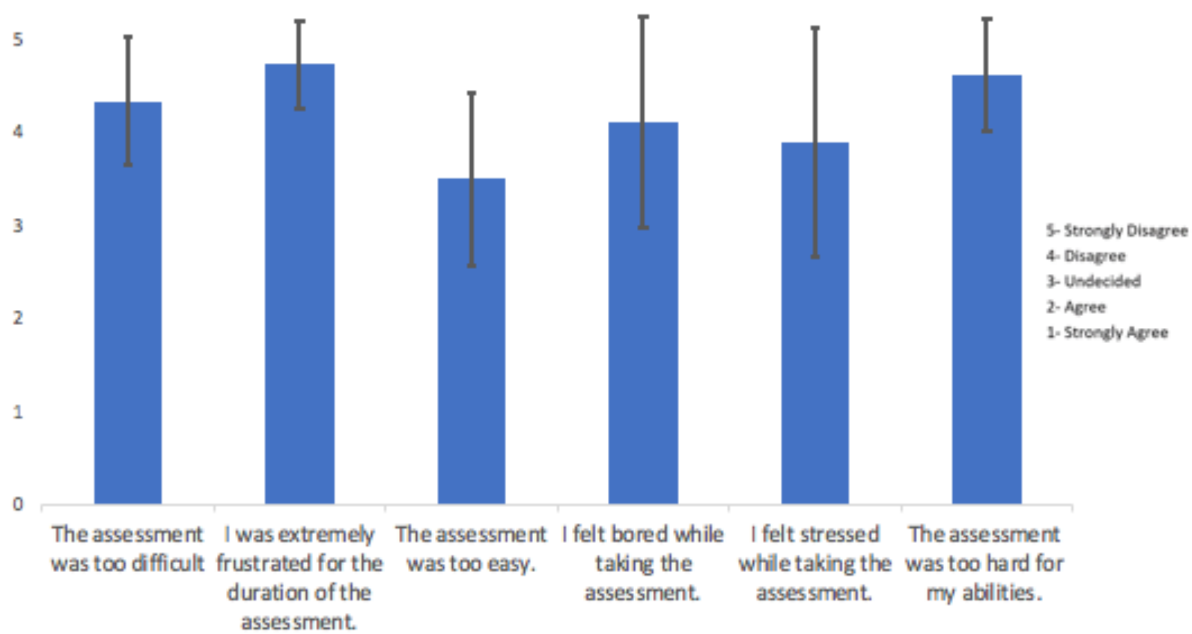
Cognitive Domains	Normative Data Mean	Normative Data SD	Current Study Mean	Current Study SD
Attention	199.62	10.65	201.28	13.49
Memory	168.17	11.90	169.61	9.85

Executive Functions	31.37	4.43	34.83	2.81
Language	32.64	2.57	33.44	2.55
Visuospatial Skills	95.42	6.47	97.89	4.96

As shown by the results of the subjective survey, the participants did not feel the CLQT assessment was too difficult or frustrating. The average response to all but two statements was between disagree and strongly disagree (see Figure 1). The participants disagreed to feeling stressed while taking the assessment, and were between undecided and disagreeing that they felt bored during the assessment.

Figure 1

Subjective Survey average response with standard deviation bars



Discussion

The Cognitive Linguistic Quick Test is a feasible option to use in clinical settings on patients with vestibular dysfunction to assess for cognitive deficits. The short amount of time needed for administration makes the assessment a valuable option for clinicians to use in practice. The length of time for administration of the created cognitive assessment battery is important because it will determine the usability for a clinician. Assessments that take too long are not practical in a clinical setting because the clinician only has a small window of time per visit. The CLQT is also easily obtainable, as it can be purchased online. The assessment can be administered by speech-language pathologists, occupational therapists, psychologists/neuropsychologists, and other qualified professionals, thus making it a practical choice.

As seen in the subjective surveys, the CLQT was readily tolerated by the participants. Out of the eighteen participants, only four agreed that they felt stressed during the assessment. Three of these four were in the older adult population, and one was in the young adult population. This is crucial to the introduction of the assessment as a clinical tool because the vestibular population can be susceptible to mental fatigue and overload. If a patient with vestibular dysfunction is agitated and frustrated by the assessment, the results could be inaccurate. In a clinical setting, assessments that do not cause distress are extremely valuable for the sake of the patient. As a clinician, the patient's mental stability is of utmost importance so a manageable assessment is ideal.

Conclusion

These results indicate that the CLQT is a feasible assessment to use in both clinical and research settings. The assessment is easily obtained and administered, accurate, time-sensitive, and easily tolerated by patients. The utilization of a universal objective measurement tool will improve the quality of research and the ability of clinicians to identify cognitive deficits that may influence treatment effectiveness in patients with vestibular dysfunction. Future studies will focus on using the CLQT in populations with vestibular dysfunction, where we hypothesize deficits specifically in the visuospatial skill subtest, to document its value in identifying cognitive deficits in this population.

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Appendix A

Participant Number

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1. The assessment was too difficult.	5	4	3	2	1
2. I was extremely frustrated for the duration of the assessment.	5	4	3	2	1
3. The assessment was too easy.	5	4	3	2	1
4. I felt bored while taking the assessment.	5	4	3	2	1
5. I felt stressed while taking the assessment.	5	4	3	2	1
6. The assessment was too hard for my abilities.	5	4	3	2	1

Comments: