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Computerized Dynamic Visual Acuity with Volitional Head Movement in Patients with Vestibular Dysfunction

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Professional Research Project submitted to the Faculty of the University of South Florida in partial fulfillment of the requirements for the degree of

Doctor of Audiology

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Tampa, Florida

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Computerized Dynamic Visual Acuity with Volitional Head Movement in Patients with Vestibular Dysfunction

Erika L. Johnson

(ABSTRACT)

Patients with non-compensated vestibular dysfunction frequently complain of the ability to maintain dynamic visual acuity during activities which require the movement of the head. When this occurs the patient is experiencing oscillopsia, which is the symptom resulting from a non-functional vestibulo-ocular reflex (VOR). To measure the presence of oscillopsia, tests of dynamic visual acuity (DVA) may be used.

A recent test of DVA has been reported which is administered while patients are walking on a treadmill. Although this test has been shown to be useful in evaluating DVA in patients, there are several disadvantages to treadmill use. These include physical space, cost and accessibility. Additionally, walking at the required treadmill speed to produce sufficient head movement may pose difficulties and be medically contraindicated for patients with certain health risks. The purpose of this study was to evaluate a different method to measure DVA in patients which would not require the use of the treadmill, but instead utilize a volitional head movement to reveal oscillopsia. In this study, patients performed the DVA test in two conditions: (1) walking on a treadmill, and (2) seated on a chair volitionally moving the head.

In this study, DVA was tested in both conditions with 15 adults with normal vestibular function, and 16 adults with vestibular impairment. Results revealed that both methods, treadmill walking and volitional head movement, appeared equivalent for measuring DVA in normal subjects and vestibular impaired subjects. The lack of finding a significant main effect of method, and interactions that include method, supports the equivalence of volitional head movement to a treadmill approach for the measurement of DVA.

Introduction

A common complaint of patients with chronic non-compensated vestibular dysfunction is the provocation of dizziness and unstable gaze during active head movement. The primary origin of this symptom is a degradation of the vestibulo-ocular reflex (VOR) (Honrubia & Hoffman, 1997). The VOR is responsible for compensatory eye movement which provides gaze stabilization and allows one to have steady vision when the head is in motion (Demer, Oas, & Baloh, 1993). A dysfunction of the VOR will cause the vestibular system to transmit an inacurrate signal to the vestibular nuclei and cerebellum. The central vestibular pathway will then have insufficient or inaccurate information to compensate for head movement, and thus vision becomes blurred. When this occurs, the patient is experiencing a symptom termed "oscillopsia," i.e., blurred vision upon head movement (Brickner, 1936).

According to Leigh and Zee (1999), an abnormal VOR may lead to oscillopsia during head movements via three mechanisms: abnormal gain, abnormal phase shift (timing) between eye and head rotations, and a directional mismatch between the vectors of the head rotation and eye rotation. Gain is a measure of accuracy and is the ratio of amplitude of eye rotation to head rotation (Honrubia & Hoffman, 1997). Thus, an ideal gain measure of 1.0 implies that eye movement velocity occurs in the equal and opposite direction as head movement. The phase shift, or temporal difference of eye and head movements may be compared and is expressed in degrees (Leigh & Zee, 1999). The ideal phase that compensates for head movement is 0°.

Patients who experience a VOR-based oscillopsia frequently complain of the inability to maintain visual acuity during activities which require movement of the head. The simple act of reading signs while walking or driving may be difficult for patients with a vestibular impairment. A more critical implication of degradation in visual acuity with head motion would be for pilots or astronauts who rely heavily on focusing on discrete instrumentation readings during flight. In addition to oscillopsia being present with locomotion, for some individuals it may occur while chewing food, or in severe cases it may occur due to transmitted cardiac pulsation.

Traditionally, caloric testing is most frequently used to detect vestibular loss. Caloric stimulation, however, is equivalent to testing an ultra-low frequency head rotation of only 0.003Hz (Jacobson, Newman, & Peterson, 1998). Thus, caloric testing does not fully assess the function of the VOR, which is responsible for gaze stabilization above 1 Hz. Head movements and activities such as walking or running occur at frequencies of 2-4 Hz (Grossman, Leigh, Abel, Lanska, & Thurston, 1998). Therefore, to truly measure the presence of oscillopsia due to VOR dysfunction, the test must be conducted with head frequency movement above 1 Hz.

For patients who experience oscillopsia, it would be beneficial to have a test to diagnose and assess a functional impact of the symptom. Such a test would also be useful in comparing the presence of oscillopsia pre- and post- vestibular rehabilitation therapy to evaluate treatment efficacy. The literature suggests that this may be accomplished by using a dynamic visual acuity (DVA) test, which measures one's visual acuity during high frequency head movement (Bhansali, Stockwell, & Bojard,1993; Herdman, Schubert, & Tusa, 2001; Herdman, Tusa, Blatt, Suzuki, Venuto, & Roberts, 1998; Hillman, Bloomberg, McDonald, & Cohen, 1999; Lee, Durnford, Crowley, & Rupert, 1997; Longridge & Mallinson, 1984).

DVA is defined as the threshold of visual resolution obtained during relative motion of either visual targets or observer (Miller & Ludvigh, 1962). Several tests of DVA have been developed that accurately measure the function of the VOR, and more importantly the presence of oscillopsia. These tests are generally scored by comparing an active DVA score to a baseline static visual acuity score. Patients who have normal VOR function should have no or only minimal degradation in visual acuity with head movement as compared to a baseline, or no movement, performance score. A patient with a non-compensated VOR dysfunction, however, would show a greater degradation in visual acuity with head movement as compared to a baseline score.

Several methods have been reported in the literature to measure DVA. A rather simple method of measuring DVA was used by Bhansali et al. (1993) using a traditional Snellen eye chart. These authors tested DVA in 22 patients with bilateral vestibular weakness (caloric total sum of peak warm and cool responses less than 12 deg/sec for each ear). To measure DVA, patients were instructed to oscillate their head in the

horizontal plane at a frequency of about 1 Hz while reading aloud the letters on the eye chart. In the study, a DVA score was considered abnormal if the smallest readable line with head movement was more than three lines poorer than the smallest readable line without head movement. Of the 22 patients in the study, 18 (82%) had abnormal DVA scores. A limitation in the study was that the head movement used was approximately 1Hz. A rate of at least 2 Hz is the recommended frequency to measure DVA (Lee, Durnford, Crowley, & Rupert, 1997). During head movement below 2 Hz, the VOR's ability to maintain gaze stabilization is strongly influenced by the optokinetic and smooth pursuit systems (Zackon & Sharpe, 1987). The support of the additional ocularmotor control mechanisms, therefore, may have contributed to the fact that four of the patients in the study had normal DVA scores. Although a one-time or limited use of a Snellen eye chart may be effective in evaluating the presence of oscillopsia, it may not be a desirable method to use when repeated measures are needed. Its use with pre- and post vestibular rehabilitation performance may be affected as the limited number of letters may be memorized with repeated trials.

Herdman et al. (1998) measured DVA using a computerized system to test DVA in 42 normal patients, 29 patients with unilateral vestibular loss and 26 patients with bilateral vestibular loss. In the study, the protocol required patients to move their head horizontally with a rate sensor on their forehead while reading visual targets. An optotype (the letter "E") was displayed on a computer screen when the patient's head movement was between 120 and 180 degrees per second**.** The subject was to indicate the direction of the orientation of the "E" as it appeared on the screen. The test was stopped when the subject incorrectly identified the direction of the "E" for all optotypes at a particular acuity level.

Results of the study indicated that the test was effective in differentiating between normal patients and those patients with a vestibular dysfunction, as well as distinguishing between patients with unilateral and bilateral vestibular deficits. For the baseline conditions, there were no significant differences in the average of missed optotypes between groups. Normal individuals missed an average of 0.4 ± 1.7 optotypes with their head stationary (baseline), and with movement, they missed an average of 2.4 ± 2.7 optotypes. Patients with a unilateral deficit missed an average of 0.9 ± 1.5 optotypes in

the baseline condition accompanied by an increase in degradation of 15.6 $\pm$ 5.6 optotypes with head motion toward the affected ear. Patients with bilateral vestibular loss missed an average of 2.2 $\pm$ 3.5 optotypes with no head movement. With head movement, patients in this group missed an increase average of 19.98 $\pm$ 6.6 optotypes. The Herdman et al. protocol (1999) using the rate sensor method, did not allow for the presentation of the stimuli on the computer screen until the patient was performing the test with head movement at the prescribed or target velocity. The limitation of using a rate sensor would be its cost and need for additional clinical equipment.

An experimental approach was used to reveal oscillopsia which included the use of telescopic lenses to measure DVA (Demer, Honrubia, & Baloh, 1994). Demer et al. (1994) tested 13 individuals with normal vestibular function with telescopic spectacles which caused subjects to experience an artificial experimental oscillopsia. In the study, visual acuity was measured in the thirteen normal individuals and two patients with bilateral vestibular loss. A computer-controlled projection system was used during vertical, sinusoidal head motion of the optotypes (eye chart letters to be read), or the patient. DVA was measured by having the patients read single lines of white Sloan letters as they appeared on a screen. Threshold acuity was defined as the smallest optotype size in which the patient correctly identified the majority of the letters. Results found DVA to be degraded in a predictable fashion to the velocity of the head motion both with the use of the telescopic spectacles and with the patients with bilateral vestibular loss.

More recently, a new and easily administered test of DVA performed while walking on a treadmill has been reported (Hillman, Bloomberg, McDonald, & Cohen, 1999). The test was designed to address the issue of DVA under a condition that is commonly experienced in activities of daily living, i.e., walking. Other tests of DVA, which were previously discussed, did not reflect everyday activity.

The Hillman et al.(1999) protocol used the vertical pertubation caused by the heelstrike when walking as the test method to reveal oscillopsia. Although several other tests of DVA use a horizontal head motion to induce oscillopsia, this test uses a vertical plane head motion. Activities such as walking or jogging produce a vertical head motion with each step. This has been recognized to induce vertical pertubation, or rhythmic

oscillations (shockwaves) to the trunk and head (Grossman et al., 1988). In addition, driving over bumpy terrain or turbulent conditions while flying may also cause vertical head motion which could induce oscillopsia.

Hillman et al. measured DVA in ten normal patients and five patients with bilateral vestibular dysfunction. In the study, patients viewed numbers of five different sized fonts (20, 18, 16, 14, & 12 point) which randomly appeared on a laptop computer. Patients were instructed to read the numbers aloud as they appeared on the screen. Each patient performed the test while standing (baseline) and while walking on a treadmill at a speed of 3.5 miles per hour. Performance was calculated as percent of correct responses for each font size.

Results of the study revealed that the bilateral vestibular impaired group showed statistically significantly poorer scores with walking than did the normal group. In the normal group, differences in DVA score from baseline was only seen at the smallest font sizes (14 and 12 point) while walking on the treadmill. In contrast to the normal individuals, the bilateral vestibular impaired patients had statistically significant decreases for all font sizes while standing and while walking. The results, therefore, indicated that the test of DVA used in the study was effective for diagnosing the presence of oscillopsia and has been shown to be a valid, reliable, and sensitive method for evaluating DVA in patients with bilateral vestibular deficits. An interesting finding in this study, however, was that the vestibular impaired group performed significantly poorer than the normal group in the baseline condition, despite reporting near normal corrected static acuity.

Despite the positive findings revealed in evaluating DVA with the Hillman et. al (1999) protocol, there are several disadvantages to treadmill use. These include physical space, cost of equipment, and accessibility. Additionally, walking on a treadmill at 3.5 miles per hour may pose difficulties or be medically contraindicated for patients with cardiovascular, orthopedic, and/or neuromuscular disease due to their health status.

An alternative method of measuring DVA has been utilized at the American Institute of Balance since 2000. In this approach, patients, while seated, are required to move their head volitionally in the vertical plane at 2.0 Hz in coordination with a metronome tone. Although we believe this method holds much promise for clinical

application, we wished to validate the findings obtained by a comparison of DVA scores with those obtained with the Hillman et al. (1999) treadmill approach. If the methods are equivocal, there should be no difference in DVA scores as a function of vestibular status (normal vs. impairment) in non-movement or baseline conditions. There should, however, be a decrement in DVA scores in movement conditions for individuals with vestibular dysfunction**.** There should be only a minimal effect of font size for both normal and vestibular patients. Decrements in vision in the baseline condition should occur only at the smallest font size for both groups. Decrements in visual acuity with movement should occur at all font sizes for the vestibular impaired patient. Normal individuals should show no degradation with head movement.

If the data in the current study were found to support the overall use of volitional head movement in terms of the aforementioned findings, then we wished to know if both methods would reveal similar results regarding DVA scores obtained in baseline and movement conditions in patients with and without vestibular dysfunction. It would be expected that for baseline performance, both normal individuals and vestibular impaired patients should have similar DVA scores, but with movement (regardless of method) performance degradation would be seen with only the vestibular impaired group. More specifically, we also wanted to examine both methods to compare effects of font size with movement in individuals with different types of vestibular disorders. It would be important to reveal similar font size degradation between methods in that poorer performance would be seen at the smaller font sizes as compared to the larger font sizes. Thirdly, we would investigate if there are any differences, as a function of testing method, in DVA scores obtained in patients with varying forms of vestibular dysfunction. If these hypotheses are supported, then the results would indicate the clinical utility of the use of a volitional head movement technique for assessment of DVA with the new computerized test.

Methods

Participants

Participants in this study were 15 adults with normal vestibular function and 16 adults with vestibular impairment. The group with vestibular impairment consisted of ten adults with unilateral vestibular dysfunctions (UVD), three adults with bilateral vestibular dysfunction (BVD), and three adults with non-compensated high frequency vestibulopathy (HFV). Two adults with UVD and one adult with HFV had concurrent benign paroxysmal positioning vertigo (BPPV). There were 19 females and 12 males in this study, with ages ranging from 27-69 years, mean age 53.5. All patients were recruited and tested at the American Institute of Balance, located in Seminole, Florida.

All patients had undergone complete videonystagmograpy (VNG) testing including bithermal air calorics, (warm 50° C, cool 24°C), to assess vestibular function. Unilateral vestibular deficits were defined as at least a 25% difference (unilateral weakness) in slow-phase eye velocity between with caloric testing. A bilateral weakness was defined as a total bithermal caloric response slow-phase eye velocity less than 17°/sec. Prior to testing, each subject completed a questionnaire to document relevant case history information. Additionally, patients provided documentation of normal cardiac, pulmonary, respiratory, and musculoskeletal function in order to ensure their safety for treadmill walking during testing. Patients were tested with corrective lenses, if needed to assure best-corrected vision.

Instrumentation

A Compaq Presario Model 1270 laptop computer, was used to present the DVA test. The computer monitor was placed 2 meters from the patient. A Microsoft PowerPoint program (PowerPoint 2000) was used to present the optotypes. The optotypes presented were a string of white numbers on a black background with font sizes ranging from 12-to 20-point fonts in increments of two points. Each trial consisted of 10 slides, (two slides per font size), presented in random order. An auditory cue was presented for the volitional head movement method with a Matrix MR500 Quartz Metronome. Treadmill walking was performed on a Landice Model 8700 treadmill. Volitional head movement testing and treadmill walking were performed in separate

rooms. Each room had similar lighting, so contrast of the computer screen was similar for each condition.

Test Protocol

In random order, the participants performed the DVA test in two conditions: (1) seated in a chair and (2) walking on a treadmill. The patients were asked to read aloud the numbers on each slide as they were presented. Participants performed the test for one trial while stationary (i.e. no head movement) in each condition in order to obtain a baseline acuity score to provide information on visual acuity without head movement.

The head movement trials required the participants to both walk on the treadmill and volitionally move their head in the vertical plane at 2.0 Hz while reading the numbers. Velocity of the patients head movement during the volitional head movement trial was controlled through the use of an auditory metronome cue. If patients were noted to interrupt their head movement during testing, the examiner would coach or cue the patient's head with his/her hands. Furman and Durrant (1999) have shown that somatasensory cuing was efficacious without contaminating results in inducing periodic head rotation for subjects having difficulty with volitional head movements at higher frequencies. Treadmill speed was set at 3.5 miles per hour. This speed was consistent with the Hillman et al. study of DVA using a treadmill. Patient safety was of prime concern, so treadmill speed was modified, if needed, due to patient health status and/or limitations.

Average testing time per patient was approximately 5 minutes per testing method. The test was scored on a "DVA gram" and performance was defined as the percentage of correct responses at each font size. The DVA score with head movement was then compared to the score without head movement.

Results

To address the overall utility of the volitional head movement method performance, as measured by the percentage of correct responses at each font size for baseline (i.e, no movement) and movement conditions, both the treadmill and volitional head movement methods were examined. An analysis of variance (ANOVA) was

conducted to examine the effect of vestibular status (normal vs. impaired), method of testing, movement condition, and font size on DVA test performance. The results are shown in Table 1.

Effect of method

The first finding of interest is that the overall main effect of method was not statistically significant. Further inspection of Table 1 reveals that none of the interactions which included method reached statistical significance. Perhaps the interaction of most interest is the three-way interaction between diagnostic group, method, and movement. The data obtained for the baseline and movement conditions using the two test methods are illustrated in Figures 1 and 2, for the normal subjects and the vestibular disordered subjects, respectively.

It can be seen in Figure 1 that there was essentially no difference in mean DVA performance for normal patients as a function of testing method, which supports their equivalence. In addition, there was a lack of an effect of movement on mean DVA performance, as mean DVA scores for the movement conditions were 95% in both method conditions. This finding was expected because oscillipsia should not exist in normal individuals.

As can be seen in Figure 2, method had little to no influence on mean DVA score for patients with vestibular disorders. As expected, however, movement had a strong influence on mean DVA performance. Using either treadmill walking or volitional head movement, DVA scores significantly decreased in this population. It is also of interest to note that there was a small, although not statistically significant, difference in mean performance between volitional (mean= 70%) and treadmill (mean = 79%) DVA scores with movement. Since the goal of measuring DVA performance is to find a decrement from baseline with movement, the finding of a larger decrement using the volitional head procedure as compared to the treadmill method is quite intriguing.

Table 1

Analysis of Variance for One Between Groups Factor (i.e., Normal vs. Vestibular Dysfunction) and 3 Within Groups Factors (i.e., Method, Movement and Font Size)

Source	dF	MSE	F	p-level
Group (G)	1	160.24	13.43	.0009
Error	29	11.29		
Method (M)	1	5.92	2.196	.1491
Error	29	2.69		
Move (Mo)	1	266.31	27.33	.000
Error	29	8.74		
Font (F)	4	92.92	25.44	.000
Error	116	3.65		
G x M	1	8.59	3.18	.084
Error	29	2.69		
G x M	1	169.02	17.346	.000
Error	29	9.74		
M x Mo	1	11.62	3.90	.057
Error	29	2.97		
G x F	4	7.23	1.97	.102
Error	116	3.65		
M x F	4	0.356	.206	.934
Error	116	1.73		
Mo x F	29.0	29.02	13.88	.00
Error	116	2.1		
GxMxMo	1	6.65	2.23	.145
Error	29	2.97		
GxMxF	4	.44	.258	.904
Error	116	1.73		

Table 1 (Continued)

GxMoxF	4	9.81	4.69	.001
Error	116	2.08		
MxMoxF	4	.472	.280	.890
Error	116	1.68		
GxMxMoxF	4	.407	.241	.914
Error	116	1.68		

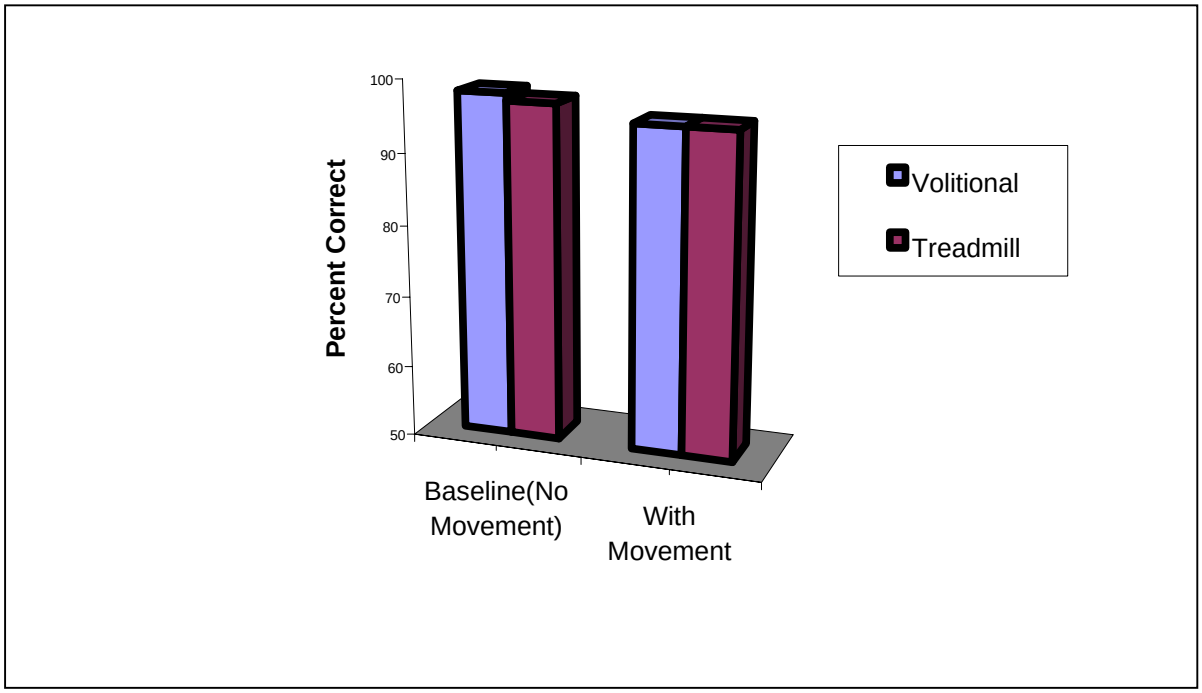

Figure 1. Average performance of 15 normal subjects without movement (baseline) and performance with treadmill and volitional head movement.

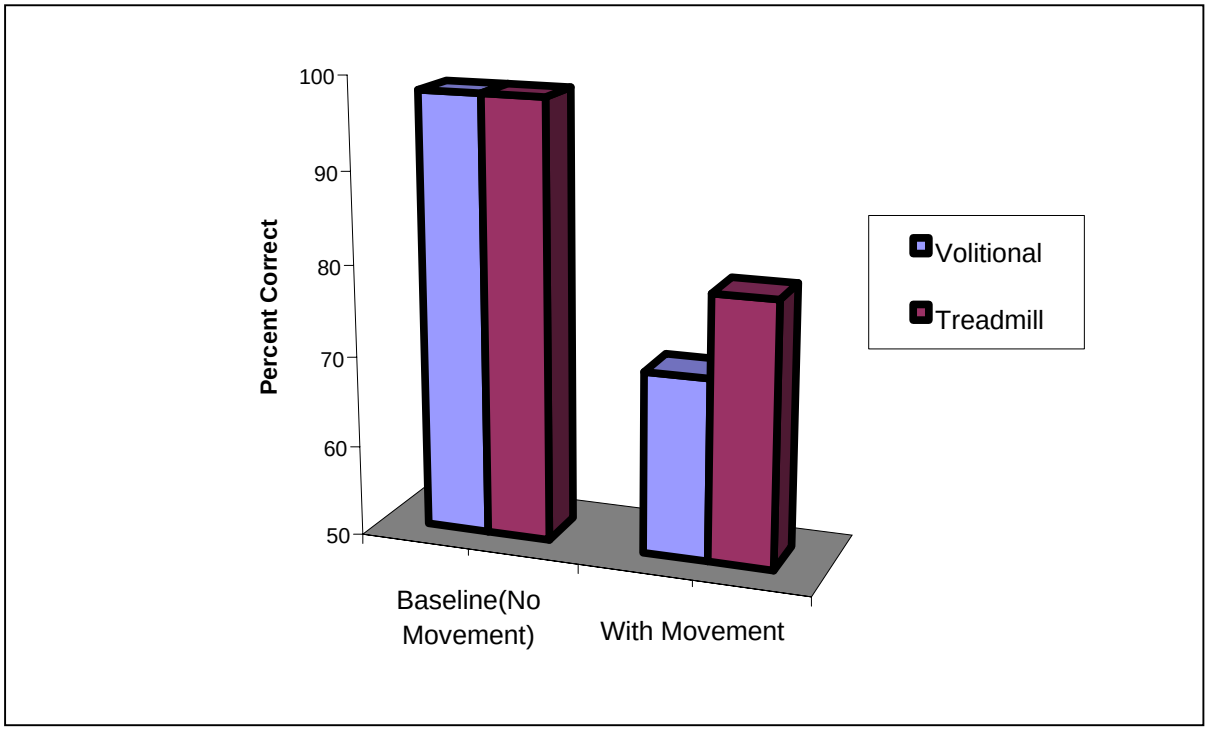

Figure 2. Average performance of 16 impaired subjects without movement and performance with treadmill and volitional head movement.

In summary, the lack of finding a significant main effect of method, and interactions that include method, supports the equivalence of volitional head movement to a treadmill approach for the measurement of DVA. Further, the data obtained demonstrate that vestibular status as well as movement condition have a similar affect on DVA regardless of method of testing. Prior to concluding that the methods are equivalent, however, it was necessary to examine the interaction between font size and method of measurement in both baseline and movement conditions.

Effect of Font Size

Figure 3 and 4 show the effect of font size as a function of method for the baseline and movement conditions, respectively. Mean performance is collapsed across all subjects. As can be seen if Figure 3, mean DVA scores remained close or equal to 100% for all font sizes, with the exception of the smallest font size in the baseline condition, regardless of testing method. As expected, with movement, DVA performance decreased with decreasing font size (Figure 4). Of most importance, the pattern of performance decrement was independent of method of testing. These findings lend to further support the equivalence of volitional head movement to the treadmill method for the assessment of DVA.

Effect of type of vestibular disorder

Given that the methods appeared equivlent for the measurement of DVA in subjects with normal as well as undifferentiated vestibular dysfunction, an examination of the effect of type of vestibular disorder appeared warranted. For this analysis, the data were collapsed across font size and subjected to an ANOVA to examine the effects of type of vestibular disorder, method of testing, movement condition, and their interactions. These results are shown in Table 2.

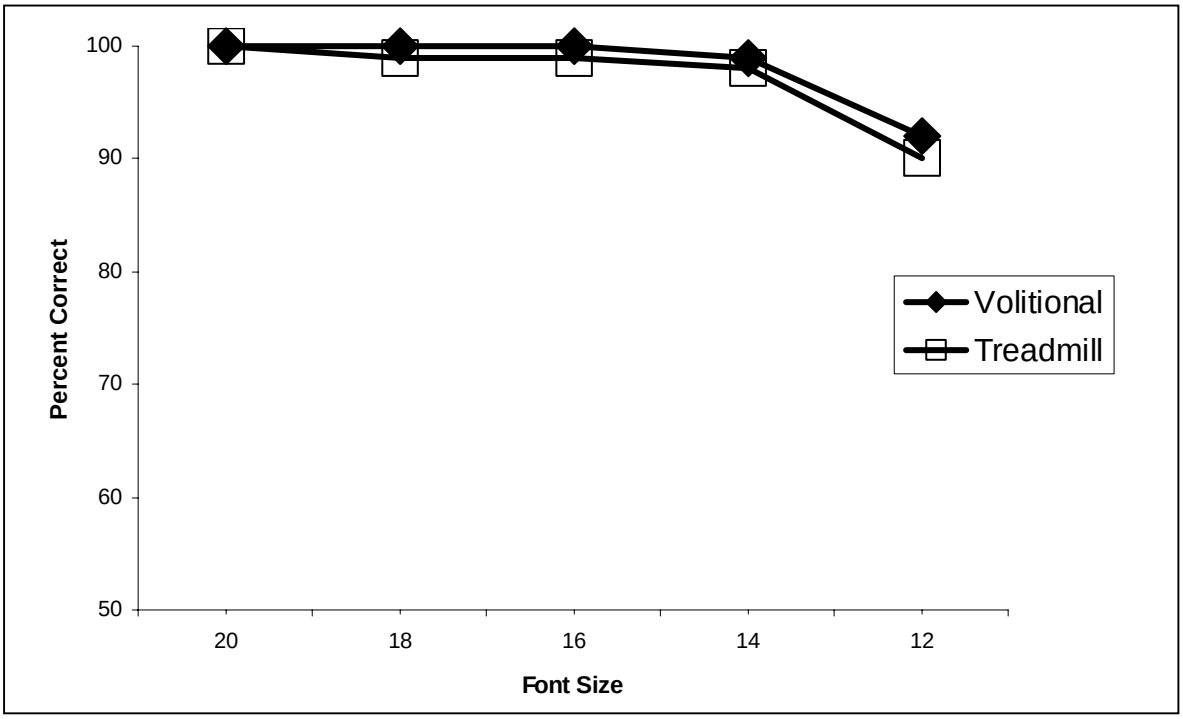

Figure 3. Average performance by font size in all subjects in the baseline conditions.

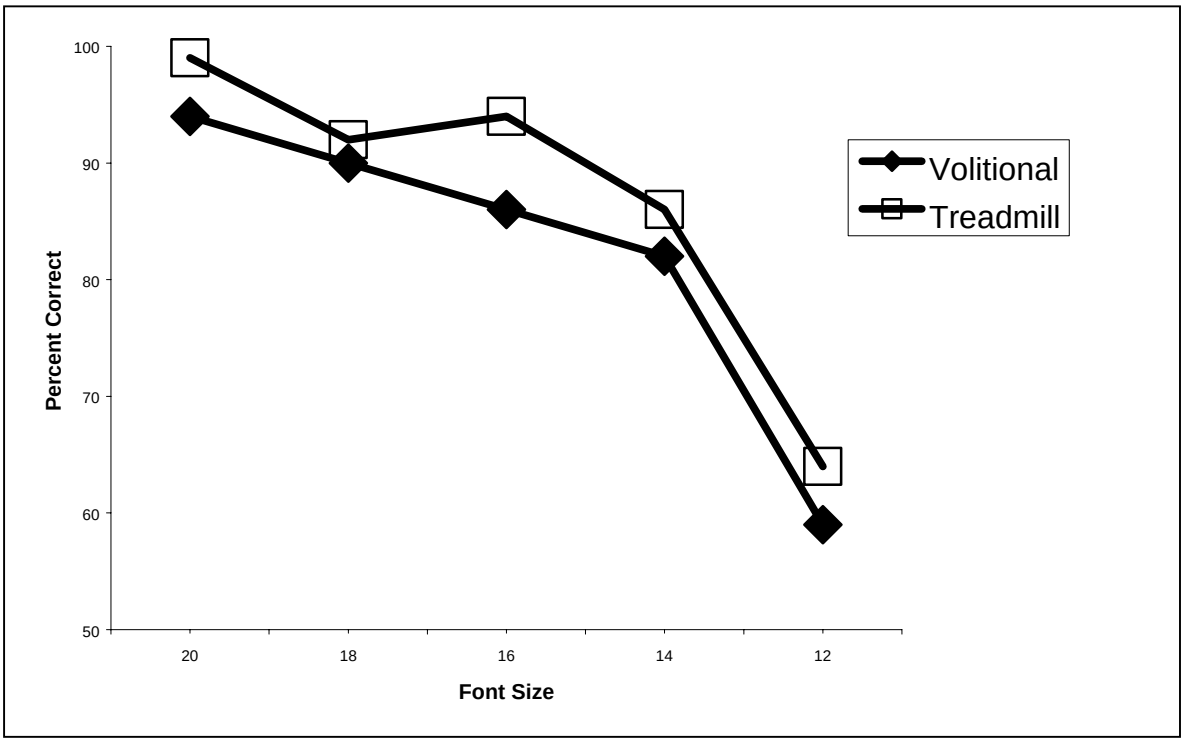

Figure 4. Average performance by font size in all subjects for movement conditions.

Table 2

Analysis of Variance for One Between Groups Factor (i.e., Normal, UVD, BVD, vs. HFV) and Two Within Group Factors (i.e., Method and Movement)

Source	dF	MSE	F	p-level
Disorder (D)	3	1902.91	17.73	.0000
Error	27	107.28		
Method (M)	1	95.76	4.41	.0452
Error	27	21.71		
Move (Mo)	1	9835.54	134.09	.0000
Error	27	21.71		
D x M	3	59.20	2.72	.0637
Error	27	21.71		
D x Mo	3	1936.34	26.39	.0000
Error	27	73.34		
M x Mo	1	120.00	4.36	.0462
Error	27	27.48		
D x M x Mo	1	23.80	.866	.4705
Error	27	27.48		

As with the first analysis, the main effect of method failed to reach significance. Of particular interest was that the interaction between method and movement reached significance. This finding is related to the results shown in Figures 1 and 2 above. It appears that the volitional head movement procedure may be slightly more effective in measuring decrements in DVA performance with movement in vestibular disordered patients.

The primary impetus for this analysis, however, was to examine the effect of type of vestibular disorder. As anticipated, the main effect of disorder was clinically significant with the mean percent correct collapsed across method and movement, equaling 96.86%, 88.30%, 75.33%, and 85.16% for the normal, UVD, BVD, and HFV groups respectively. Post-hoc testing using the Tukey HSD test revealed that the mean score for the normal subjects was significantly higher than all other groups. In addition, the mean score for the UVD group was significantly higher than the BVD group. The difference in mean scores for the HFV group was not significant from the UVD or BVD group. It was important to note that there were only three patients in the HFV group. The effect of having a small group size may be underpowered in order to reach clinical significance.

Since the interaction between diagnostic group and method failed to reach statistical significance, mean DVA performance for each of the four diagnostic groups in the movement and no movement conditions was collapsed across testing methods and is shown in Figure 5. As expected, the interaction between disorder and movement was also significant. Mean scores under the baseline conditions collapsed across method of testing were 97.80%, 97.80%, 98.33%, and 97.00% for normal, UVD, BVD, and HFV groups respectively. Thus, there were no significant differences in the no movement (baseline) conditions as a function of disorder. In the movement condition, the mean scores were 99.93%, 78.80%, 52.33%, and 73.33% for the normal, UVD, BVD, and HFV groups respectively.

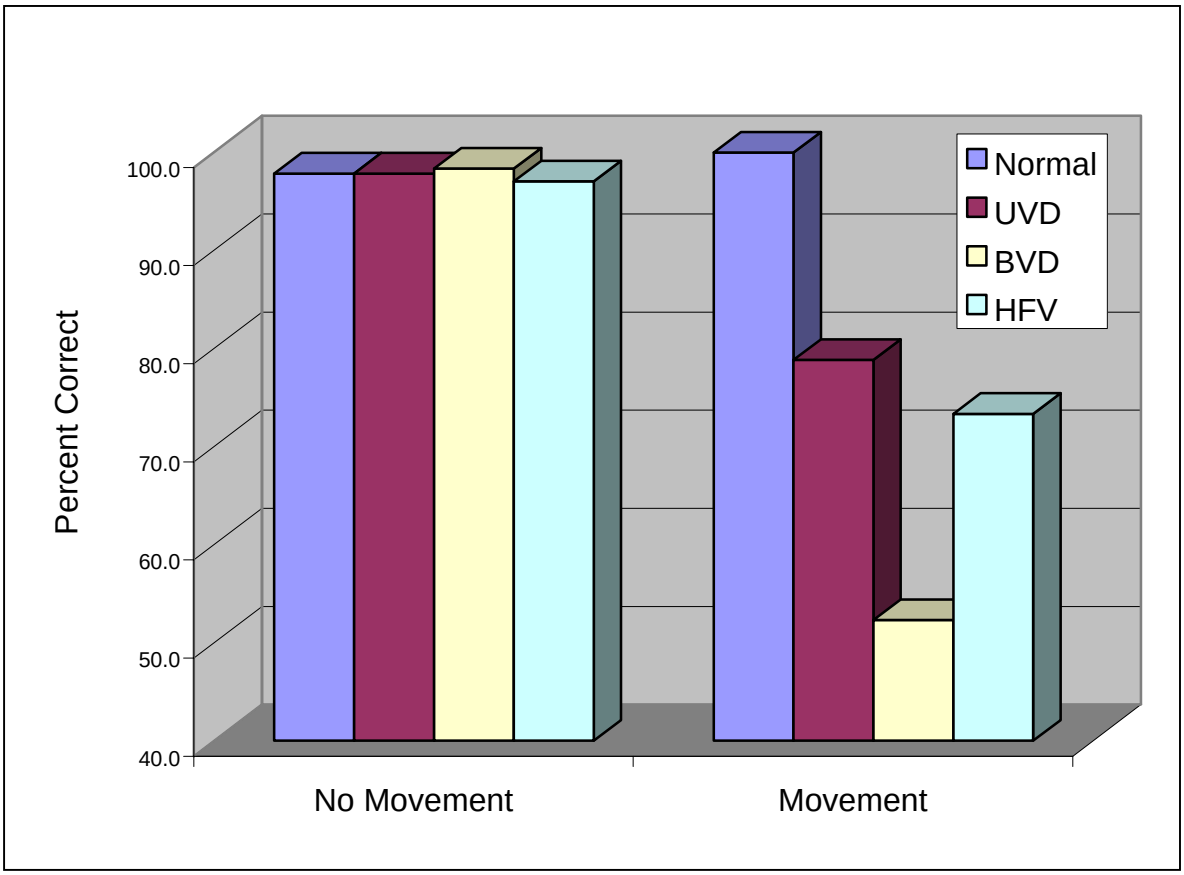

Figure 5. Average performance of 15 normal and 16 impaired subjects grouped by type of vestibular impairment.

Post-hoc testing was conducted examining only the movement condition through the use of an independent t-test with Bonferroni correction to control for Type I error. The difference between the means for the normal group and the UVD ($t(23) = 4.81$, $p<.0000$, BVD $t(16) = 11.35$, $p<.0000$, and HFV ($t(16) = 6.99$, $p<.0000$. There was also a significant difference in mean scores between the UVD and BVD group $t(11) = 3.11$, $p<.000$. There was not, however, a significant difference in mean performance seen between the UVD and HFV group ($t(11) = .676$, $p<.512$), or the BVD and HFV groups ($t(4) = -.231$, $p<.08$. As previously mentioned, the lack of statistical difference between the BVD and HFV may be because of the lack of power due to the small population size. Further research with a larger population of these diagnostic categories would be needed

to reveal if a larger population size would reach the mean scores between the BVD and HFV group to be clinically significant.

Discussion

The main impetus for this study was to determine if DVA measured with a voltional head movement procedure were similar to those obtained using a treadmill method. Thus, the most important finding was that the procedures appeared equivalent for measuring DVA in normal subjects and vestibular impaired subjects. In measuring DVA performance, font size should affect ability in movement but not in baseline conditions. The data presented in this study showed that the volitional head movement procedure gave equivalent results as a function of font size in both baseline and movement conditions to those obtained with the treadmill procedure.

Although we conclude that the two methods are equivalent, it was also the case that the volitional head movement procedure produced a greater degradation in performance with movement than did treadmill walking in the vestibular impaired group. In fact, when font size was not considered, there was a significant interaction between method and movement, with movement causing a greater degradation in DVA when the volitional head movement procedure was used. This finding suggests that the volitional movement procedure may even be better than the treadmill method if our goal is to identify individuals whose DVA is affected by movement. Several observations made during the completion of this project may account for the greater decrements found with the volitional head movement procedure.

One reason that treadmill walking may have not produced as great of degradation in the disordered group was that nearly half (45%) of the subjects were unable to walk at the desired speed to produce sufficient head movement and heel strike pertubation. Interestingly, Hillman et al. noted that only 2 of their 5 vestibular impaired subjects were able to reach desired treadmill speed due to physical limitations. All of the subjects in the present study, however, were able to perform the volitional head movement at the speed of the auditory tone. Several subjects required the clinician's guidance through

somatosensory cuing to maintain proper head motion velocity. The ability for the clinician to be able to provide somatosensory cuing as needed was important as there appeared to be a natural tendency for several impaired patients to slow head motion in order to read the numbers.

When examining performance degradation within the disordered group, the subjects with BVD revealed the most degradation of visual acuity with head movement in comparison to the subjects with UVD or non-compensated HFV. This finding was not surprising as it is consistent with other studies of DVA that particularly examined the relationship between DVA performance of BVD and UVD subjects (Herdman et al., 1998; Herdman, Schubert, & Tusa, 2001).

There are several other benefits associated with the use of volitional head movement as compared to a treadmill procedure which warrant mention. First, and perhaps obviously, the voltional test does not necessitate cumbersome equipment such as the treadmill. The test requires only a computer takes less than five minutes to perform. An improvement in test administration which has now been implemented is the recording of the auditory tone cue onto the audio track of the PowerPoint presentation. This enables the test to be presented without the use of the metronome. This is currently the only computerized test of DVA which requires no expensive equipment such as a treadmill, magnetic search coils or rate sensors.

Clinical applications of this test would include assisting in the diagnosis of non-compensated high frequency vestibulopathy which manifests as a VOR based oscillopsia. Present vestibular tests such as ENG, calorics, and rotary chair do not access upper frequency limit (2-6 Hz) of VOR function. An additional application of this test is to provide pre- and post- vestibular rehabilitation therapy scores to demonstrate treatment efficacy. Further research may be pursued to correlate the CDVAT results with other tests of active head rotation, i.e. Vestiulo- Autorotation Test. These studies should prove useful in providing clinically useful and efficacious means of diagnosing and treating vestibular disorders.

References

Bhansali S.A., Stockwell C.W., & Bojarb D.I. (1993). Oscillopsia in patients with loss of vestibular function. Otolaryngology- Head and Neck Surgery, 109, 120-125.

Brickner, R.M. (1936). Oscillopsia: a new symptom commonly occurring in multiple sclerosis. Arch Neurol Psychiatr, 36, 586-589.

Demer, J.L., Honrubia, V., & Baloh, R.W. (1994). Dynamic visual acuity: A test for oscillopsia and vestibulo-ocular reflex function. The American Journal of Otology, 15, 340-347.

Demer, J.L., Olas, J.G., & Baloh, R.W. (1993). Visual-vestibular interaction in humans during and passive vertical head movement. Journal of Vestibular Research, 3, 101-114.

Furman, J.M. & Durrant, J.D. (1999). Somatasensory cuing of head-only rotational testing. Journal of Vestibular Reseach, 9,189-95.

Grossman, G.E., Leigh, R.J., Abel, L.A., Lanska, D.J., & Thurston, S.E. (1998) Frequency and velocity of head perturbations during locomotion. Exp Brain Research, 70, 470-476.

Herdman, S.J., Schubert, M.C., & Tusa, R.J. (2001). Role of central programming in Dynamic visual acuity with vestibular loss. Archives of Otolaryngology- Head and Neck Surgery, 127, 1205-1210.

Herdman, S.J., Tusa, R.J., Blatt, P., Suzuki, A., Venuto, P.J. & Roberts , D. (1998). Computerized dynamic visual acuity test in the assessment of vestibular deficits. The American Journal of Otology, 19, 790-796.

Hillman, E.J., Bloomberg, J.J., McDonald, P.V., & Cohen, H.S. (1999). Dynamic visual acuity while walking in normals and labrynthine- deficient patients. Journal of VestibularResearch, 9, 49-57.

Honrubia,V. & Hoffman, L.F. (1997). Practical anatomy and physiology of the vestibular system. In Jacobson, G.P. & Newman, C.W. (Eds.). Handbook of Balance Function Testing. San Diego, Singular Publishing Group, Inc., 9-52.

Jacobson, G.P., Newman, C.W., & Peterson, E.L. (1997). Interpretation and usefulness of caloric testing. In Jacobson, G.P. & Newman, C.W. (Eds.). Handbook of Balance Function Testing. San Diego, Singular Publishing Group, Inc., 193-233.

Lee, M.H., Dunford, S.J., Crowley, J.S., & Rupert, A.H.(1997). Visual vestibular interaction in the dynamic visual acuity test during voluntary head rotation. Aviat Space Environ Medicine, 68, 111.

Leigh J.R., & Zee, D.S. (1999). The Neurology of Eye Movements (3rd Edition). Contemporary Neurology Series.

Longridge, N.S., & Mallison, A.I. (1987). The dynamic intelligible E test. A technique for assessing the vestibuloocular reflex. Acta Otolaryngology (Stockh) 103, 273-279.

Miller, J.W.& Ludvigh, E.J. (1962). The effects of relative motion on visual acuity. Surv Opthalmol., 7, 83-116.

Zackon, D.H. & Sharpe, J.A. (1987). Smooth pursuit in senescence: effects of target Acceleration and velocity. Acta Otolaryngology, 104, 290-297.