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Comparison of Horizontal and Vertical Dynamic Visual Acuity in Patients with Vestibular Dysfunction and Nonvestibular Dizziness

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Abstract

Blurred vision with head movement is a common symptom reported by patients with vestibular dysfunction affecting the vestibulo-ocular reflex (VOR). Impaired VOR can be measured by comparing visual acuity in which there is no head movement to visual acuity obtained with head movement. A previous study demonstrated that dynamic visual acuity (DVA) testing using vertical head movement revealed deficits in impaired VOR. There is evidence that horizontal head movement is more sensitive to impaired VOR. The objective of this investigation was to compare horizontal and vertical DVA in participants with normal vestibular function (NVF), impaired vestibular function (IVF), and participants with nonvestibular dizziness (NVD). Participants performed the visual acuity task in a baseline condition with no movement and also in two dynamic conditions, horizontal head movement and vertical head movement. Horizontal DVA was twice as sensitive to impaired VOR than vertical DVA. Results suggest that horizontal volitional head movement should be incorporated into tasks measuring functional deficits of impaired VOR.

Key Words: Bilateral vestibular dysfunction, dynamic visual acuity, oscillopsia, unilateral vestibular dysfunction, vestibulo-ocular reflex

Abbreviations: BPPV = benign paroxysmal positional vertigo; DVA = dynamic visual acuity; IVF = impaired vestibular function; NVF = normal vestibular function; VOR = vestibulo-ocular reflex

Sumario

Una visión borrosa con los movimientos de la cabeza es un síntoma común reportado por los pacientes con una disfunción vestibular que afecta el reflejo vestíbulo-ocular (VOR). La alteración en el VOR puede ser medida comparando la aguda visual no acompañada de movimientos de la cabeza, con la aguda visual obtenida con movimientos cefálicos. Un estudio previo demostró que la prueba de aguda visual dinámica (DVA) usando movimiento vertical de la cabeza revelaba deficiencias relacionados con un VOR alterado. Existe evidencia que el movimiento cefálico horizontal es más sensible a un VOR alterado. El objetivo de esta investigación fue comparar el DVA horizontal y vertical en participantes con funcional vestibular normal (NVF), con función vestibular alterada (IVF) y en sujetos con mareo no vestibular (NVD). Los participantes realizaron sus tareas de agudeza visual en una condición basal,

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sin movimiento, y también en dos condiciones dinámicas, con movimientos de cabeza horizontales y verticales. El DVA horizontal fue dos veces más sensible a un VOR alterado que el DVA vertical. Los resultados sugieren que los movimientos volitivos horizontales de la cabeza deben incorporarse en las tareas que midan deficiencias funcionales con un VOR alterado.

Palabras Clave: Disfunción vestibular bilateral, agudeza visual dinámica, oscilopsia, disfunción vestibular unilateral, reflejo óculo-vestibular

Abreviaturas: BPPV = vértigo posicional paroxístico benigno; DVA = agudeza visual dinámica; IVF = función vestibular alterada; NVF = función vestibular normal; VOR = reflejo óculo-vestibular

The vestibulo-ocular reflex (VOR) is responsible for gaze stabilization during head motion. This is accomplished by activation of compensatory eye movements to counteract the effects of head movement on slippage of visual targets from the retina, thereby maintaining visual acuity (Longridge and Mallinson, 1987; Demer et al, 1993; Dannenbaum et al, 2005). Information concerning head position, which is essential for this process, is provided by the vestibular system. Patients with vestibular dysfunction, for which the central nervous system has not compensated, commonly report unstable gaze during active head movement (Longridge and Mallinson, 1987; Bhansali et al, 1993). This symptom was termed "oscillopsia" by Brickner (1936). Patients with bilateral and even unilateral vestibular impairment may demonstrate a functional VOR deficit on tasks measuring dynamic visual acuity (Bhansali et al, 1993; Herdman et al, 1998; Schubert et al, 2002; Roberts et al, 2006). For these patients, simple tasks such as reading signs while walking or driving may be difficult.

There are several tests of dynamic visual acuity (DVA) that have been reported in the literature as a means of assessing the impact of impaired VOR function (Bhansali et al, 1993; Herdman et al, 1998; Hillman et al, 1999; Schubert et al, 2002; Roberts et al, 2006). These tests are generally scored by comparing a baseline visual acuity score obtained with no head movement to a DVA score, with head movement in the vertical and/or horizontal planes. Patients with normal VOR function exhibit little degradation in visual acuity for these comparisons. On the other hand, patients with uncompensated VOR dysfunction exhibit degradation in visual acuity with head movement compared to the baseline score.

Although general scoring is similar among tests, there is some variability in study methodology. For example, visual stimuli range from letters on a Snellen eye chart (Bhansali et al, 1993) to computer-presented number stimuli (Hillman et al, 1999; Roberts et al, 2006) and even the optotype "E" (Herdman et al, 1998; Schubert et al, 2002). Some investigators have used a treadmill to provide a natural head movement for the dynamic condition (Hillman et al, 1999), while others have simply used volitional head movement (Bhansali et al, 1993; Herdman et al, 1998; Schubert et al, 2002; Roberts et al, 2006). Herdman et al (1998) and Schubert et al (2002) used a rate sensor to monitor head movement and restrict testing to movements at velocities within the VOR range.

Another area of variability among studies is the method of scoring. Bhansali et al (1993) determined the number of lines a participant had to move up to maintain dynamic visual acuity using their Snellen chart task. This yielded a visual acuity score (i.e., 20/30). Others have scored performance for identification of the orientation of a stimulus character in terms of logarithm of the minimum angle of resolution, "logMAR," which is the psychophysical term used for assessment of visual acuity (Herdman et al, 1998; Schubert et al, 2002). These two types of measures result in visual acuity data. Still, others have calculated percent that participants can correctly perceive number stimuli (Hillman et al, 1999; Roberts et al, 2006).

In the study by Herdman et al (1998), DVA was compared for participants with normal vestibular function and participants with impaired vestibular function. Participants indicated the direction of orientation of an optotype, "E," presented on a monitor under baseline and dynamic conditions. For the dynamic condition, participants volitionally moved their heads in the horizontal plane at a

rate of 120–180°/sec, which is above the range of the smooth pursuit eye movement system (Longridge and Mallinson, 1984). Head movement was monitored using a rate sensor attached to the forehead of each participant. The stimulus was not presented to the participant if head movement was outside the set range. The authors were able to differentiate participants with normal vestibular function from those with vestibular dysfunction based on performance for the dynamic condition. They report a sensitivity of 89.7% and a specificity of 93.5% when participants with vestibular dysfunction were compared to normal controls.

It has been suggested that vertical head movement is important to incorporate during assessment of VOR because it is representative of common activities such as walking (O'Leary, 2002). The initial investigation by Herdman et al (1998) only used horizontal volitional head movement. In a subsequent study, Schubert et al (2002) found that their group with bilateral vestibular loss did not perform as well as the control group with normal vestibular function on their vertical DVA task. There was no difference in performance when the group with normal vestibular function was compared to groups with unilateral vestibular dysfunction or nonvestibular dizziness. Sensitivity ranged from 23.1% for participants with unilateral vestibular dysfunction to 54.5% for participants with bilateral vestibular dysfunction. Specificity was reported as 90%. Results from Herdman et al (1998) and Schubert et al (2002) certainly suggest that horizontal head movement is more sensitive to impaired vestibular function than vertical head movement for their DVA task.

Utilization of a rate sensor was a key component of the methodology of Herdman and colleagues. This instrumentation ensures that other eye movement systems are only contributing a slight influence, if any, on performance. This is an important experimental control. The incorporation of such instrumentation, however, increases the cost of the test equipment. Alternatively, velocity remains approximately constant if the amplitude of head rotation and frequency of head movement are controlled (Roberts et al, 2006). For example, with head movement maintained at a constant rate of 2.0 Hz and oscillated through 40° of arc from right to left and returning to the rightward position, a peak velocity of 160°/sec is achieved. This is consistent with the velocity range used by Herdman et al (1998) and Schubert et al (2002).

Roberts et al (2006) recently described a DVA test incorporating number stimuli and volitional head movement in the vertical plane. For the baseline condition, participants reported their perception of the number stimuli presented on a laptop computer monitor. Baseline performance was compared to performance on a dynamic condition with the participant moving their head in the vertical plane to a 2.0 Hz auditory cue. Participants with impaired vestibular function performed significantly poorer than those with normal vestibular function on the vertical head movement condition. This is in agreement with other studies of DVA in participants with impaired vestibular function (Grossman and Leigh, 1990; Bhansali et al, 1993; Herdman et al, 1998; Dannenbaum et al, 2005). Sensitivity and specificity data were not reported for that study.

A comparison of the reports by Herdman et al (1998) and Schubert et al (2002) indicate increased sensitivity for their DVA task using horizontal head movements. Since our previous investigation only used vertical volitional head movement, it is certainly possible that performing our DVA task with horizontal volitional head movement may provide a more sensitive measure of the functional impact of impaired VOR. The purpose of the current investigation was to compare performance on a DVA task using two types of volitional head movement, horizontal and vertical. Results were obtained for a group of patients with normal vestibular function, a group with impaired vestibular function, and a group with nonvestibular dizziness. Based on the findings of Herdman et al (1998) and Schubert et al (2002), we hypothesized that horizontal volitional head movement would provide a more sensitive measure than vertical volitional head movement. We also hypothesized that the group with impaired vestibular function would perform poorer than the group with normal vestibular function and the group with nonvestibular dizziness given the potential for impact on the VOR.

METHOD

Participants

All participants were provided with and signed an informed consent document. Participants were recruited from the local community and from patients seen at our facility for comprehensive vestibular and equilibrium

evaluation. All patients underwent otolaryngologic and neurologic evaluation when appropriate. None of these patients had received therapy for dizziness or imbalance prior to our evaluation. Ten patients with no history of dizziness or imbalance were recruited and selected into our group with normal vestibular function (NVF). Eighty-eight adults were enrolled sequentially and, following diagnostic testing, were selected into either the group with impaired vestibular function (IVF) or the group with nonvestibular dizziness (NVD). Results from DVA testing were not considered for selection into any group.

Thirty-three participants were assigned to the IVF group. These patients had history and symptoms consistent with vestibular dysfunction. This was confirmed with diagnostic testing and included findings such as unilateral caloric weakness (≥23% difference in labyrinthine reactivity between ears), high-frequency headshake nystagmus, abnormal rotary chair results, abnormal vestibular evoked myogenic potentials, and so forth. Patients with benign paroxysmal positional vertigo (BPPV) as a sole finding were excluded from this group, but three patients with vestibular neuritis and BPPV were included in the IVF group.

Fifty-five participants were assigned to the NVD group. To be included in this group, there had to be an absence of remarkable vestibular diagnostic results. These criteria for grouping are consistent with those of Schubert et al (2002). Specific group information is provided in Table 1.

Stimuli and Instrumentation

The American Institute of Balance - Computerized Dynamic Visual Acuity Test® (AIB-CDVAT®) was presented to all participants using a Compaq Presario Model 1270 laptop computer. The monitor was positioned at a distance of 2 m from the seated patient. The AIB-CDVAT was developed using Microsoft PowerPoint (PowerPoint 2000) similar to Hillman et al (1999). The purpose of the AIB-CDVAT is to present visual stimuli to the participant and also a 2.0 Hz auditory cue during volitional head movement. The stimuli used with the AIB-CDVAT have been described previously (Roberts et al, 2006) but are mentioned in brief here. Stimuli consisted of a string of five white numbers presented on a black background. Each of the five numbers was from the set 0, 1, 2, 3, 4, 5, 6, 7, 8, or 9. The five-item stimulus set was varied on each trial. Each number was used only once for a given trial, and all numbers were used five times. Font was Tahoma, and the size varied from 12 to 20 in increments of 2. Font size was constant within a trial. These font sizes were selected because when viewed at 2 m, the stimuli correspond to a range of visual acuity from approximately 20/16 to 20/27 on a Snellen eye chart (Hillman et al, 1999; Roberts et al, 2006). This test is a stable measure, providing good test-retest reliability (Roberts et al, 2006).

Procedures

The visual acuity of all participants was tested using three conditions (baseline, dynamic vertical, and dynamic horizontal). All participants were tested in best corrected vision. Baseline visual acuity was measured while the participant was seated with no head movement. Dynamic visual acuity was tested in two separate runs, one with movement in the vertical plane and one with movement in the horizontal

Table 1. Group Characteristics

Group	Age Mean (Range)	Gender	Disorder (Number of Patients)
Normal Vestibular Function (NVF) n = 10	42 (27–68)	Female: 6 Male: 4	
Impaired Vestibular Function (IVF) n = 33	53 (20–79)	Female: 18 Male: 15	Labyrinthine Concussion (1) Labyrinthitis (1) Ménière's disease (4) Vestibular Neuritis (27)
Nonvestibular Dizziness (NVD) n = 55	51 (14–88)	Female: 33 Male: 22	Cardiovascular (1) Central Involvement (13) Cervicogenic (4) Mal de Debarquement (1) Migraine (6) Idiopathic (30)

plane. Although the baseline condition was always presented first, the order of presentation of the dynamic conditions was randomized.

During each dynamic task, head movement was maintained at a constant rate of 2.0 Hz by having the participant move their head in time to an auditory cue. At this frequency, the head of the patient was moved through approximately 40° of arc from up to down and returning to the upward position for the vertical condition and 40° from the right to the left and returning to the rightward position for the horizontal condition. A peak velocity of approximately 160°/sec is reached under these conditions, which is above the range of smooth pursuit eye movement (Longridge and Mallinson, 1987). Performance on each dynamic condition was compared to performance on the baseline condition.

The participant was asked to verbally report each of the five number stimuli observed on a trial. This was the same regardless of condition. Participants were limited in their time to respond as a new trial with different number stimuli appeared every three seconds. Font size varied randomly on each trial, and each font size was presented on two trials during a run. There were three conditions (baseline, dynamic vertical, and dynamic horizontal) with 10 trials per condition, so 30 total trials were presented to each participant. Average testing time per patient was approximately three minutes per condition (nine minutes total). The examiner recorded the items reported on each trial and determined an overall percent correct for each font size by weighting each correct number at 2% (50 total numbers in the 10 trials).

RESULTS

Data from both groups were averaged and plotted to examine trends. Results for each group are shown in Figures 1–3. Visual acuity scores for each group are provided in Table 2. An analysis-of-variance (ANOVA) was used to examine the effects of the between factor group (normal vestibular function, impaired vestibular function, or nonvestibular dizziness) and the within factors condition (baseline, dynamic vertical, or dynamic horizontal) and font size (20, 18, 16, 14, or 12). The effects of group [$F(2, 93) = 17.69$; $p < 0.001$], condition [$F(2, 186) = 16.88$; $p < 0.001$], and font size [$F(4, 372) = 23.49$; $p < 0.001$] were all significant. In addition, all of the interactions were significant ($p < 0.001$). This indicated that performance of each group was dependent on condition and font size.

To further investigate the interactions, the data of each group was analyzed separately using an ANOVA to determine the effects of condition and font size. To control for the possibility of Type I errors using multiple analyses, a Bonferroni-adjusted α level of 0.008 was used. For the NVF group, the main effects of condition [$F(2, 14) = 0.96$, $p = 0.41$] and font size [$F(4, 28) = 2.49$; $p = 0.07$] were not significant. The interaction did not reach significance ($p = 0.96$). This indicates that performance did not vary with condition or font for this group.

For the IVF group, the effects of condition [$F(2, 64) = 26.62$, $p < 0.001$] and font size [$F(4, 128) = 33.98$; $p < 0.001$] were significant, as well as the interaction ($p < 0.001$). Tukey Honest Significant Difference (HSD) post-hoc analysis revealed that visual acuity was significantly degraded for the dynamic horizontal condition compared to the baseline and also compared to the dynamic vertical condition for font sizes 18, 16, 14, and 12 ($p < 0.001$). There was no difference for font size 20. Performance was also significantly degraded for dynamic vertical at font sizes 14 and 12 compared to baseline performance ($p < 0.001$). Performance did not vary for other comparisons ($p > 0.008$).

For the NVD group, the effects of condition [$F(2, 108) = 11.83$, $p < 0.001$] and font size [$F(4, 216) = 21.78$, $p < 0.001$] were significant.

Table 2. Mean Performance (Range) for Both Groups for Each Condition

Group	Condition		
	Baseline	Vertical	Horizontal
Normal Vestibular Function (NVF)	97.8% (100–86)	97.8% (100–82)	98% (100–90)
Impaired Vestibular Function (IVF)	97.5% (100–84)	90.1% (100–40)	72.6% (100–12)
Nonvestibular Dizziness (NVD)	98.7% (100–80)	97.9% (100–80)	94.7% (100–56)

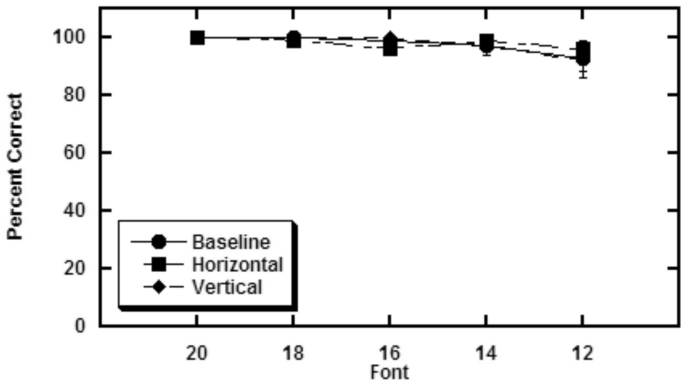

Figure 1. Average visual acuity performance of 10 participants with normal vestibular function for conditions without movement (Baseline), with volitional head movement in the horizontal plane (Horizontal), and with volitional head movement in the vertical plane (Vertical) is shown as a function of font size. Standard error bars are provided.

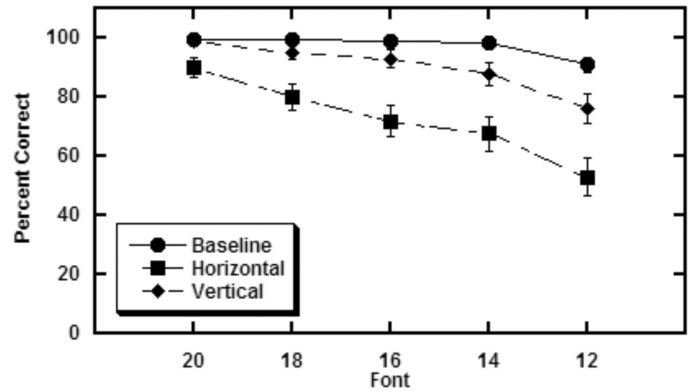

Figure 2. Average visual acuity performance of 33 participants with impaired vestibular function for conditions without movement (Baseline), with volitional head movement in the horizontal plane (Horizontal), and with volitional head movement in the vertical plane (Vertical) is shown as a function of font size. Standard error bars are provided.

The interaction was also significant [$F(8, 432) = 8.33, p < 0.001$]. Tukey HSD post-hoc analysis revealed that visual acuity for the dynamic horizontal condition was poorer compared to the baseline condition for font size 12 only ($p < 0.001$). There was no difference between visual acuity for baseline and dynamic vertical conditions ($p > 0.008$).

Collectively, these results indicate that baseline performance is similar for both groups. Performance diverges by group for the dynamic conditions. Visual acuity for the dynamic vertical condition was better than for the dynamic horizontal condition. There is less of an effect of condition for the NVD group except for the dynamic horizontal condition at font size 12 only. Visual acuity degraded across font sizes (except for font size 20) for the IVF group with the dynamic horizontal condition.

Sensitivity and specificity data were also obtained using results from these two groups. Table 3 is a contingency table with participant groups and DVA results. Performance for each dynamic condition was compared to performance

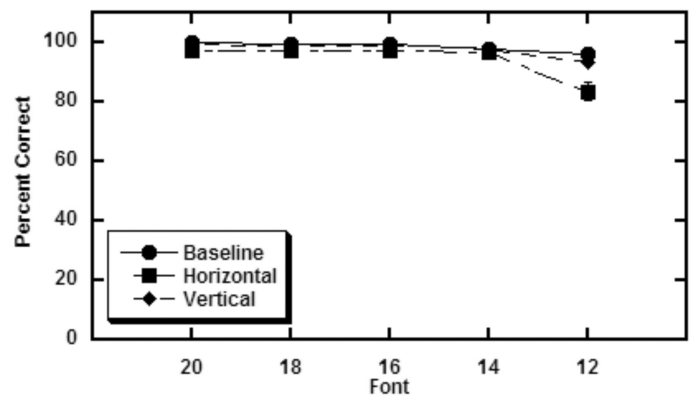

Figure 3. Average visual acuity performance of 55 participants with nonvestibular dizziness for conditions without movement (Baseline), with volitional head movement in the horizontal plane (Horizontal), and with volitional head movement in the vertical plane (Vertical) is shown as a function of font size. Standard error bars are provided.

Table 3. Contingency Table

	Vertical DVA			Horizontal DVA		
	Positive Vestibular	Negative Vestibular	Total	Positive Vestibular	Negative Vestibular	Total
Abnormal DVA	NVF = 0 IVF = 14 NVD = 0	NVF = 0 IVF = 0 NVD = 4	18	NVF = 0 IVF = 22 NVD = 0	NVF = 0 IVF = 0 NVD = 9	31
Normal DVA	NVF = 0 IVF = 19 NVD = 0	NVF =10 IVF = 0 NVD = 51	80	NVF = 0 IVF = 11 NVD = 0	NVF = 10 IVF = 0 NVD = 46	67
Total	33	65	98	33	65	98

Note: DVA = dynamic visual acuity; IVF = impaired vestibular function; NVD = nonvestibular dizziness; NVF = normal vestibular function.

for the baseline condition. Results were considered abnormal if the difference exceeded the mean difference by 2 SD. The limit for normal was a decrease in visual acuity of 5.2% for the dynamic vertical condition and 9% for the dynamic horizontal condition. These limits were determined using data from the group of ten participants with normal vestibular function. Sensitivity of the dynamic vertical condition was 42.4% compared to 66.7% for the dynamic horizontal condition. Specificity was 93.8% and 86.2% for the vertical and horizontal conditions, respectively. Positive predictive values were 77.8% for the vertical and 71.0% for the horizontal conditions. Negative predictive values were 76.3% for the vertical and 83.6% for the horizontal conditions. Accuracy was 76.5% for the vertical and 79.6% for the horizontal conditions.

DISCUSSION

Effect of Condition

The primary purpose of this investigation was to determine if performance on a test of DVA differs for horizontal compared to vertical volitional head movement. There was no effect of condition for our group of normal participants. However, both the IVF and NVD groups exhibited degradation in visual acuity, though not at all to the same extent for the dynamic horizontal condition. Only the IVF group exhibited decreased performance for the dynamic vertical condition. Performance was significantly poorer at four of the five font sizes for dynamic horizontal compared to dynamic vertical for this group. This is in agreement with previous reports in which patients with impaired vestibular function had greater difficulty on a DVA task incorporating horizontal head movement (Herdman et al, 1998) compared to the same task using vertical head movement (Schubert et al, 2002).

In the current investigation, sensitivity and specificity for the dynamic vertical condition were 42.4% and 93.8%, respectively. For the DVA task used by Schubert et al (2002), a sensitivity of 23.1% and a specificity of 90% was reported for vertical head movement in their group with unilateral vestibular impairment. This is in close agreement with our results. Sensitivity for the current task improved to 66.7% for our dynamic horizontal condition with a specificity of 86.2%. Herdman et al (1998) reports a sensitivity of 89.7% and specificity of 93.5% for horizontal head movement. Results for both tasks (the current investigation and Herdman and colleagues) support that DVA with horizontal volitional head movement is more sensitive to impaired vestibular function than DVA with vertical volitional head movement.

It is interesting that sensitivity and specificity reported by Herdman et al (1998) for horizontal dynamic visual acuity is better than that found in the current study. Intuitively, the use of a rate sensor may provide some explanation for this difference. However, a rate sensor was also used by Schubert et al (2002) for vertical dynamic visual acuity, and sensitivity and specificity are better for the task in the current study that did not employ such a sensor.

Schubert et al (2002) proposed a couple of explanations why horizontal DVA may be more sensitive to VOR dysfunction. Each labyrinth has three semicircular canals, one in the horizontal plane and two in the vertical plane. If an entire vestibular labyrinth on one side is not functioning, Schubert et al (2002) suggested it may still be possible for the two intact vertical canals on the opposite side to assist the VOR with gaze stabilization during vertical head movements. For the same individual, VOR during horizontal head movements may be impaired because the single intact horizontal canal is unable to provide sufficient information to stabilize gaze.

In addition, as in Schubert et al (2002), the current study defined unilateral vestibular dysfunction based on test results (i.e., caloric responses, rotary chair results, etc.) that stimulate the horizontal semicircular canals. The reality is that some patients may indicate impaired vestibular function when this structure is stimulated, but other parts of the labyrinth may be entirely functional. As Schubert et al (2002) discusses, posterior semicircular canal function may be intact in individuals with certain disorders such as vestibular neuritis. This viral inflammation primarily affects the superior branch of the vestibular nerve (Fetter and Dichgans, 1996). Utricle, anterior semicircular canal, and horizontal semicircular canal function may be affected, while saccule and posterior semicircular canal function may be spared. The saccule and posterior semicircular canal are innervated primarily by the inferior branch of the vestibular nerve. If the posterior semicircular canal is intact on the side with absent horizontal semicircular canal function, the patient may have no difficulty with vertical DVA but may

have degradation with horizontal DVA.

This may be supported in the current study by the fact that 11 of the 33 participants with impaired vestibular function had normal vestibular evoked myogenic potentials (VEMPs). The VEMP is a myogenic response measured from the sternocleidomastoid muscle in response to an intense auditory stimulus (Colebatch and Halmagyi, 1992). The response originates from the saccule, which is innervated primarily by the inferior branch of the vestibular nerve. Although presence of a normal VEMP does not provide a measure of posterior canal function, it does suggest that the inferior branch of the vestibular nerve is functional. It is certainly possible that a functional posterior semicircular canal on the involved side may have allowed many of these patients to perform the vertical DVA task with greater success than the horizontal DVA task.

The dynamic horizontal condition did prove to be a more sensitive measure of DVA for most patients with impaired vestibular function. From a clinical perspective, however, vertical DVA may remain important to assess. In the current investigation, one patient in the IVF group only exhibited degradation in visual acuity for the dynamic vertical condition. The functional impact of impaired VOR may have been missed in this patient had DVA only been measured with horizontal head movement, and this could affect diagnosis and subsequent treatment. O'Leary (2002) describes a patient with vertical oscillopsia that had been misdiagnosed by multiple clinics until a vertical VOR (Vestibular Autorotation Testing) task was performed. The patient showed abnormalities on this task, and an appropriate therapy regimen was instituted based, in part, on this result.

Fourteen of the IVF participants had abnormal horizontal and vertical DVA. Therapy designed to focus only on gaze stabilization in the horizontal plane may not allow for adequate gaze stabilization in the vertical plane. This may not become apparent unless a vertical VOR task is performed. Naturally, it would be important to assess function in both planes posttherapy to demonstrate appropriate outcome.

Effect of Font Size

Results of the current investigation revealed an effect of font size that interacted with the variables of condition and group. Font size had little effect on performance for any group during the baseline condition. The greatest effect was observed during the dynamic horizontal condition. Performance decreased with decrease in font size for the IVF group. Performance was significantly poorer at size 12 compared to all other sizes for the dynamic horizontal condition for the NVD group, but no other differences were observed. No effect of font was observed for the NVF group.

Roberts et al (2006) reported decreased performance for font size 12 for their control group with normal vestibular function and their group with impaired vestibular function. The group with impaired vestibular function had decreased performance for font size 14 as well, reflecting the impact of impaired VOR. Interestingly, this same pattern of results was observed for the NVD and IVF groups in the current study. A similar effect of font size was also reported by Hillman et al (1999). Their normal group only had degradation at font size 12, but the group with bilateral vestibular dysfunction had degradation at all font sizes.

The group with IVF had degradation at all font sizes except 20 during the dynamic horizontal condition. This certainly suggests that incorporation of all the font sizes is important for clinical testing. Normal participants and even participants with nonvestibular dizziness may have decreased performance at font size 12, but participants with impaired vestibular function are more likely to demonstrate degradation at other font sizes. A practical reason to include these other font sizes is that the clinician can be more certain that the patient understands and is performing the task correctly by monitoring performance at the easier (larger) font sizes.

Effect of Group

Performance on our DVA task was dependent on group, as well as the interaction with the factors of condition and font size. Although the three groups performed similarly during the baseline condition, performance during the dynamic conditions varied. The NVF group performed the same for all conditions. There was no significant difference between baseline and dynamic vertical for the NVD group. For the IVF group, DVA was poorer for the dynamic vertical condition compared to baseline for the smallest two font sizes. This finding is in

agreement with Roberts et al (2006) and Hillman et al (1999), who both reported significant degradation in vertical DVA for their groups with impaired vestibular function.

Both patient groups had significantly degraded DVA with horizontal head movement, but as described above, this varied with font size. The IVF group had degraded DVA across font sizes except 20, while the NVD group only degraded at font size 12. As previously explained, there is evidence that degraded DVA for a range of font sizes would be expected for the IVF group, but only at the smallest font size for normals or patients with nonvestibular dizziness (Hillman et al, 1999; Roberts et al, 2006).

In their report on horizontal DVA, Herdman et al (1998) indicated an increase in missed optotypes from 0.4 to 2.4 when results from their static (baseline) condition were compared to their dynamic horizontal condition for their normal group. Their group with unilateral vestibular dysfunction had an increase in missed optotypes from 0.9 to 15.6. This is in agreement with the current study because even normals or patients with nonvestibular dizziness may have some degree of difficulty with the dynamic task, just not to the extent observed for patients with impaired vestibular function.

CONCLUSIONS

Dynamic visual acuity testing allows the clinician to measure the functional impact of VOR impairment. The current study compared performance on a baseline condition with no head movement to performance with volitional head movement in the vertical and horizontal planes. Results were obtained for participants with normal vestibular function, nonvestibular dizziness, and impaired vestibular function. Results indicate that (1) there is no effect of DVA task on participants with normal vestibular function and no effect of vertical head movement on DVA for participants with nonvestibular dizziness; (2) there is greater difficulty with tasks of DVA than the baseline task with no head movement for participants with impaired vestibular function; (3) there is greater sensitivity to impaired vestibular function for horizontal DVA compared to vertical DVA; and (4) participants with impaired vestibular function exhibited a decrease in performance as font size decreased for both dynamic conditions, although both patient groups had difficulty for the smallest font size used (12) for the dynamic horizontal task.

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