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Driving disability and dizziness

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Abstract

Problem: People with dizziness caused by vestibular (i.e., inner ear) disorders complain of difficulty driving. Physicians occasionally warn their patients with vestibular disorders not to drive. Few studies have asked patients about their driving performance, so little data are available. *Method:* Using the *Driving Habits Questionnaire*, the authors did structured interviews with people with several different vestibular disorders and with normal subjects. The self-reported crash rate and rate of citations for moving violations did not differ between the subject groups. *Results:* Patients report reduced driving skills, particularly in situations when visual information is reduced, rapid head movements are used, and specific path integration or spatial navigation skills are needed.
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1. Introduction

Dizziness is one of the most common reasons for a visit to a physician, particularly among senior citizens (Weindruch, Korper, & Hadley, 1989). At least 50% of people over 65 years of age who complain of dizziness have disorders of the vestibular system (Baloh, Sloane, & Honrubia, 1989), which is the special sense with receptors in the inner ear that detect head acceleration. Vestibular signals ascend to the brain via the vestibular branch of Cranial Nerve VIII, carrying velocity signals that are then converted to position signals. The nervous system uses vestibular input in several ways: (a) it contributes to control of balance by generating postural reflexes in response to head movement, which keep the body upright during a perturbation such as stepping on a pebble or slipping on ice on a sidewalk; (b) it contributes to gaze stabilization by generating the vestibulo–ocular reflex, so that the individual can see clearly while moving through the environment; (c) it contributes to spatial orientation so that the individual knows his/her position with reference to gravity and contributes to egocentric navigation skills (i.e., the ability to plot a course with reference to the starting position); (d) it modulates autonomic responses such as heart rate, respiration, and stomach motility, so that these basic life functions respond appropriately when the individual's movements through space change during perturbations.

The structures of the vestibular system undergo morphological changes across the life span, which become particularly evident in older age. For example, aging causes loss of cells in the tissues of the inner ear (Bergstrom, 1973; Nakayama, Helfert, Konrad, & Caspary, 1994), changes in the organelles within the remaining cells (Rosenhall, 1973), and reduced capillary size and blood flow to the inner ear (Lyon & Wanakaer, 1993). Furthermore, the brain centers that receive input from the vestibular labyrinths show degenerative changes with age (Lopez, Honrubia, & Baloh, 1997). These changes may all be involved in the well-documented decrements in vestibular function that occur with aging (Cohen, Heaton, Congdon, & Jenkins, 1996; Paige, 1992).

People with various impairments of the vestibular system complain of disorders with the functions of the vestibular system. The hallmark of vestibular impairment is vertigo—the illusion of self-motion, sometimes described as a sense of spinning or falling. Many people also complain of poor balance, blurred vision, bumping into walls or corners while walking, and nausea. These problems cause discomfort and decreased independence in activities of daily living, including driving a car (Cohen, 1992; Cohen & Kimball, 2000).

Physicians in the United States, Canada, and Great Britain have expressed concern about the safety of patients with vestibular disorders while driving motor vehicles (Jonathan & McKiernan, 2000; McKiernan & Jonathan, 2001; Parnes & Sindwani, 1997; Sindwani & Parnes,

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1997). One paper describes the cases of people who drove off the side of the road and were subsequently diagnosed with vestibular impairments (Page & Gresty, 1985). Despite the potential impact on public safety, very little data are available on this problem.

The available data from surveys of patients' own perceptions provide cause for concern. On the Vestibular Disorders Activities of Daily Living scale, subjects who had vestibular impairments of the peripheral vestibular labyrinth rated their independence on a range of functional tasks, including driving, using a 10-point scale where 1 is Independent and 10 is Too Difficult/Stopped Trying to Perform the Task (Cohen & Kimball, 2000). Responses on the Driving a Car question were trimodal; patients with either benign paroxysmal positional vertigo (BPPV) or chronic vestibulopathy of unknown etiology (CV) indicated either Level 1, Level 4 (more slowly than usual), or Level 10. Cohen, Ewell, and Jenkins (1995) reported previously that 60% of patients with Meniere's disease said that driving was difficult, dangerous, or both. Sindwani, Parnes, Goebel, and Cass (1999) reported that 56% of patients with vestibular disorders in Canada and the United States said they would continue to drive even if their physicians warned them not to drive. They further reported a relationship between having a "dizzy spell" and having difficulty driving.

To study this problem we looked to the previous work on drivers with visual processing impairment. Owsley, Stalvey, Wells, and Sloane (1999) developed the Driving Habits Questionnaire (DHQ) as an interviewer-administered, 34-item questionnaire, intended for use with visually impaired patients. They found that older drivers with cataracts drive less often than normal drivers, drive more slowly than the general flow of traffic, and have difficulty driving in challenging situations. We used the DHQ in the present study, modified by adding several questions about driving problems likely to be challenging to people with vestibular impairments.

2. Methods

2.1. Participants

Every subject had a valid drivers license in his or her state of residence and was a current driver. Normal subjects were all recruited from visitors who accompanied patients to the senior author's laboratory. Patient subjects had all been diagnosed with impairments of the peripheral vestibular system and all complained of vertigo. They fell into several diagnostic groups.

Patients with BPPV were recruited from the senior author's caseload after they had been referred for vestibular rehabilitation by their physicians. They were all participants in a larger study of vestibular rehabilitation for benign paroxysmal positional vertigo. BPPV subjects had all been diagnosed with unilateral BPPV of the posterior semicircular canal, as indicated by classical (up beating and laterally beating) nystagmus on the Dix-Hallpike maneuver and vertigo elicited by the maneuver (Dix & Hallpike, 1952). This disorder is characterized by vertigo when making pitch rotations of the head (i.e., when looking up or down, or when rolling over in bed toward the involved side).

Patient subjects with CV were also recruited from the senior author's caseload after they were referred for vestibular rehabilitation. These patients had vertigo for a 2-month duration or more and either significant unilateral weakness on bithermal caloric tests or decreased vestibulo–ocular reflex gains on low frequency sinusoidal tests in the rotatory chair in darkness, with eye movements recorded by electrooculography. This pattern of results on diagnostic tests of the vestibular system is consistent with impairment in the peripheral vestibular apparatus in the inner ear. These patients did not meet the criteria for Meniere's disease, BPPV, or acute vestibular neuronitis. CV is characterized by brief episodes of vertigo when making sudden head rotations (e.g., when looking to the right to check for oncoming cars before changing lanes while driving). People with CV also often have balance problems, spatial disorientation, and sometimes nausea.

Patient subjects with Meniere's disease met the criteria for Meniere's disease of documented, progressive sensorineural hearing loss, repeated episodes of vertigo, and possible tinnitus and sense of pressure in the ear (Monsell et al., 1995). These subjects were recruited from the caseloads of the referring neurotologists. Meniere's disease subjects were not referred for vestibular rehabilitation and had not had surgery. They were being followed by their physicians with standard medical care. This disorder is characterized by decreased hearing on the affected side, sudden and unexpected episodes of vertigo lasting minutes to hours accompanied by nausea, poor balance and noise in the affected ear, and the inability to function during vertigo attacks. Many patients have normal motor skills in between attacks, although some people do have brief episodes of vertigo during head rotations and balance problems.

The postoperative (PostOp) patient subjects were recruited from the caseloads of the neurotologists in the senior author's department. These individuals fell into two

Table 1
Age, history of vertigo and sex for each diagnostic group

Diagnosis (number of subjects)	Mean age (*SD*)	History of vertigo (years)	Sex (females/males)
Normal control (51)	51.9 (15.3)	none	27/24
BPPV (34)	54.8 (12.21)	0.92 (2.2)	23/11
Chronic vestibulopathy (27)	53.4 (13.0)	4.0 (7.1)	19/8
Meniere's disease (48)			
From Houston (18)	50.9 (12.2)	6.7 (10.0)	13/5
From Birmingham (30)	54.4 (13.0)	7.3 (10.3)	21/9
PostOp (9)			
Acoustic Neuroma (7)	49.1 (7.4)	3.5 (8.1)	3/4
Nerve section (2)	40.3 (11.8)	7.2 (1.7)	1/1

Table 2
Speed, seatbelts and driving quality: percent of subjects by diagnostic groups

Question	Percent of subjects					Patients vs. normal s (p value)	Diagnostic groups differ (p value)
	Normal ($n=51$)	BPPV ($n=34$)	CV ($n=27$)	Meniere's ($n=48$)	PostOp ($n=9$)		
Relative speed							
Slower than traffic	16	12	30	23	0		
Same as traffic	65	62	41	67	78	.816	.064
Faster than traffic	19	26	29	10	22		
Seatbelt use							
Always	98	94	93	96	89	.438	.693
Sometimes	2	6	7	4	11		
Driving quality							
Poor/Fair/Average	22	6	26	14	22		
Good	39	65	52	40	67	.282	.055
Excellent	39	29	22	46	11		

groups: postoperative acoustic neuroma resections and postoperative vestibular nerve section. In the acute phase of recovery, both groups of PostOp patients often have brief episodes of vertigo during head rotations, blurred vision, decreased spatial orientation, and nausea. PostOp patients usually recover within a few weeks.

Normal subjects were recruited while sitting in the waiting room. BPPV and CV subjects were recruited when they came for their first visits for vestibular rehabilitation. Meniere's subjects from Houston were recruited after they had completed their clinic visits with their physicians. Meniere's subjects from Birmingham were recruited through a letter from their neurotologist describing the study. PostOp patients were initially approached prior to their surgery and then were recruited during postoperative visits with their surgeons. This study was approved by the Institutional Review Boards for Human Subjects Research at our institutions.

2.2. Procedure

The DHQ was administered as a structured interview. This instrument is a normed survey with several parts: current driving safety habits such as use of a seatbelt, driving exposure or the amount of driving the subject does per week, driving space or where the subject drives, and questions about the difficulty of driving in various challenging situations (Owsley et al., 1999). Both the instrument and the psychometric properties are described in the paper by Owsley et al. (1999). We added six extra questions about problems specific to people with vestibular disorders (see the Appendix A). Face validity of those questions was established by showing them to 15 occupational therapists (mean years in practice = 15). Eight respondents thought that all additional questions had good face validity. Three respondents thought that Question 3, staying in lane while driving, was unnecessary, because they assumed that drivers do stay in lane. Three other respondents liked Question 3 but thought that Question 4, traffic checks before entering an intersection, was unnecessary. Both of these questions were retained because most respondents thought they were appropriate.

Reliability based on internal consistency for the 13 questions regarding difficulty of driving tasks was 0.90 with a 95% lower confidence limit of 0.88. Item-rest correlations ranged smoothly from .53 to .79; no item appeared to be a

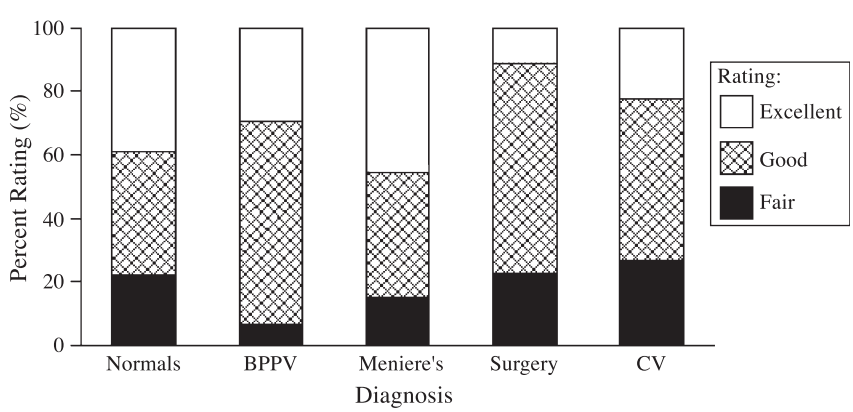

Fig. 1. Quality of driving in individual patient groups.

Table 3
Percent of subjects having difficulty with particular driving challenges, by diagnostic groups

Driving challenge	Percent of subjects having difficulty					Patients vs. normal subjects (p value)	Diagnostic groups differ (p value)
	Normal ($n=51$)	PostOp ($n=9$)	BPPV ($n=34$)	CV ($n=27$)	Meniere's ($n=48$)		
Rain	35	50	36	67	40	.024	.019
Alone	0	67	26	67	29	<.001	.001
Parallel parking	33	50	41	62	45	.101	.594
Left turns across traffic	4	57	15	46	30	.001	.086
Freeway driving	12	62	15	67	26	.011	<.001
High traffic local roads	13	43	13	58	33	.022	.028
Rush hour driving	21	57	19	59	31	.004	.063
Night	22	43	37	73	57	.002	.108
Parking spaces	10	56	15	44	21	.037	.015
Changing lanes	12	50	18	59	30	.007	.006
Staying in lane	2	56	12	44	17	<.001	.005
Traffic checks	4	56	26	52	33	<.001	.105
Ramped garages	10	43	29	61	35	.003	.333

misfit. Items regarding staying in their lane and parallel parking were slightly less consistent with the other items, whereas items about driving in rush hour and ramped garages were the most consistent items.

After the initial interview, BPPV subjects were treated with standard Epley or Semont maneuvers, which are widely used to treat this disorder by relocating the displaced calcium carbonate particles that are the putative cause of this disorder (Brandt, Steddin, & Daroff, 1994; Cohen & Jerabek, 1999; Epley, 1992; Semont, Freyss, & Vitte, 1988). BPPV subjects were reinterviewed after 3-months. The other subjects were given the DHQ only once.

2.3. Statistical analyses

Cronbach's alpha coefficient was used to assess reliability based on internal consistency of the DHQ items on difficulty while performing driving tasks. Item-rest correlations were used to evaluate how well items fit the rest of the items on the scale.

Responses to each question on the DHQ from the normal and patient groups were compared. Fisher's Exact Tests were used for categorical variables, and Kruskal–Wallis tests were used for continuous variables. Responses among the diagnostic groups were compared in the same manner.

Responses in BPPV patients before and after treatment for vertigo were compared to determine whether driving ability improved. Tests for asymmetry (disagreement) between the baseline and 3-month trials were used for the categorical variables, and paired t tests were used to evaluate differences in the continuous variables.

All tests were two-tailed. *Stata statistical software: Release 7.0* software was used for the analyses (StataCorp., 2001).

3. Results

3.1. Participants

The final sample was 62 male and 107 female adults, with a mean age of 53 years ($SD=13.3$, range 20 to 83). See Table 1 for descriptive data. There were no differences among the diagnostic and control groups in age ($p=.607$) or gender ($p=.224$), however they differed in history of

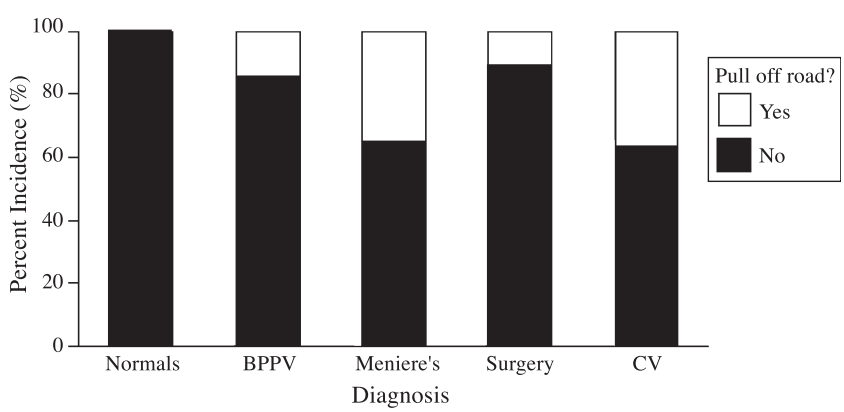

Fig. 2. Number of subjects who had to pull off the road due to vertigo.

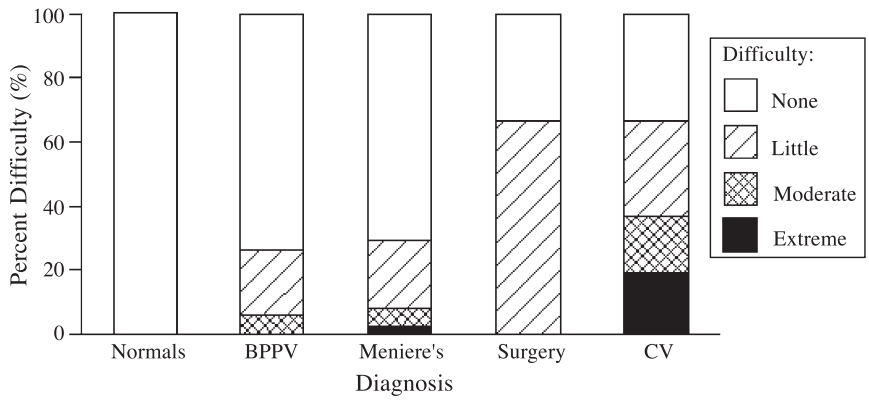

Fig. 3. Percent of subjects reporting difficulty when driving alone.

vertigo ($p = .0001$). Median (and range) of years of vertigo were 0.21 (0.04 to 20) years for surgery patients, 0.16 (0.02 to 12) years for BPPV patients, 0.57 (0.04 to 30) years for chronic vertigo patients, and 3 (0.06 to 42) years for Meniere's patients.

3.2. Current driving habits

Control subjects and patients gave similar responses to most questions on current driving habits. On the question about the number of people available to give the respondent a ride, normal subjects reported that they had significantly more people they could call if they needed a ride (7.1 ± 5.0) than patient subjects (5.8 ± 4.8, $p = .03$). Patients and normal subjects did not differ significantly on the relative speed of driving ($p = .82$); 20.3% of patients said they drive faster than the general flow of traffic and 9.5% said they drive slower. One patient commented that she drives as fast as possible over a certain overpass on a local highway where few visual cues are available to help her orient to gravity, because the experience is so disorienting. Other subjects indicated that they drive more slowly in particularly disorienting situations. Table 2 shows data on driving safety in patients compared to normal subjects.

Comparisons of current driving habits among the diagnostic groups indicated that none of the BPPV subjects were advised against driving by their physicians, but 56% of the postoperative patients, 22% of the chronic vestibulopathy patients, and 15% of the Meniere's patients were advised against driving ($p < .0001$), indicating that they ignored their physicians' advice. On the question about quality of driving, illustrated in Fig. 1, more CV and PostOp patients than Meniere's and BPPV patients rated themselves as poor to fair drivers ($p = .055$). None of the PostOp patients, 12% of BPPV, 23% of Meniere's, and 30% of chronic vestibulopathy patients reported that they drive slower than usual ($p = .064$).

3.3. Driving space

Nearly all of the patients and normal subjects were able to drive inside and beyond their immediate neighborhoods; however, only 77% of patients compared to 92% of normal subjects drove to nearby towns ($p = .029$), and to distant towns ($p = .005$). The PostOp patients were the least likely patients to have driven to nearby towns ($p = .062$), to more distant towns ($p = .060$), and outside the state ($p = .017$). The questionnaire includes a question about driving to

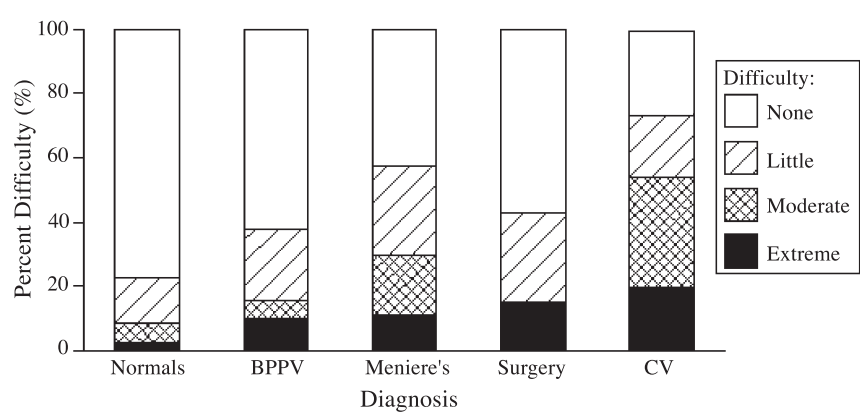

Fig. 4. Percent of subjects reporting difficulty when driving at night.

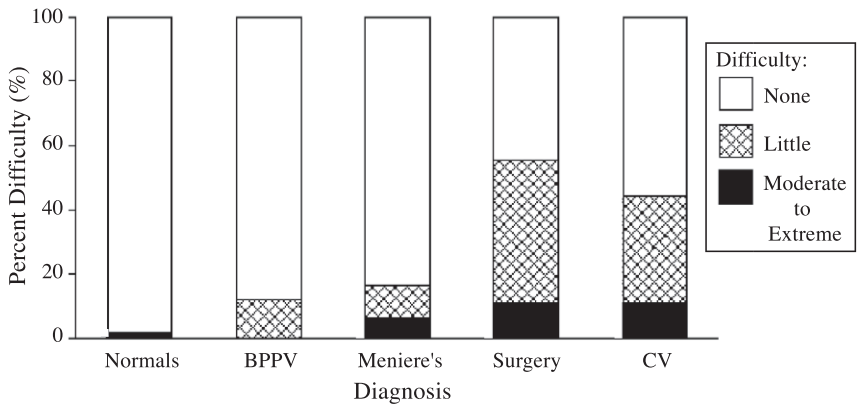

Fig. 5. Percent of subjects reporting difficulty staying in lane.

towns out of state, but very few normal subjects or patients reported driving out of state, which was not surprising. Most of our subjects lived in Texas, a state so large that driving out of state is an unusual event for most residents.

3.4. Crashes and citations

Significantly fewer patients (10%) than normal subjects (26%) reported having been pulled over by the police for moving violations ($p = .017$). Fewer patients (6%) than normal subjects (16%) reported receiving tickets for moving violations in the past year although this finding only approached statistical significance ($p = .072$). Patient groups did not differ significantly on these measures.

3.5. Driving exposure

The Driving Exposure section of the questionnaire asked subjects about how much and how far they drive. Patients reported that they drove 5.9 ± 1.8 days per week, but normal subjects reported that they drove 6.5 ± 1.3 days ($p < .006$). Meniere's patients reported that they drove 5.5 ± 1.9 days per week; other patient groups reported that they drove from 5.8 to 6.4 days per week ($p = .033$). Some subjects had difficulty estimating the distances they drove on a regular basis.

3.6. Driving challenges

The Driving Challenges section asked subjects about their performance in specific situations that might be problematic. Compared to normal subjects, patients reported having considerably more difficulty driving in the rain, alone, making left turns across traffic, during freeway driving, on high traffic roads, during rush hour, and at night. On additional questions we thought were more specific to vestibular disorders, patients reported significantly more difficulty than normal subjects when pulling into or out of parking spaces, changing lanes in traffic, staying in lane while driving, checking for traffic before pulling into an intersection, and driving around a ramped parking garage. The additional questions are provided in Appendix A (see Table 3). Significantly more patients reported having to pull off the road due to vertigo (28%) than normal subjects (0%, $p < .001$).

Exploratory analyses of driving difficulty by diagnostic group indicated that patient groups had statistically significant differences on questions about driving in the rain,

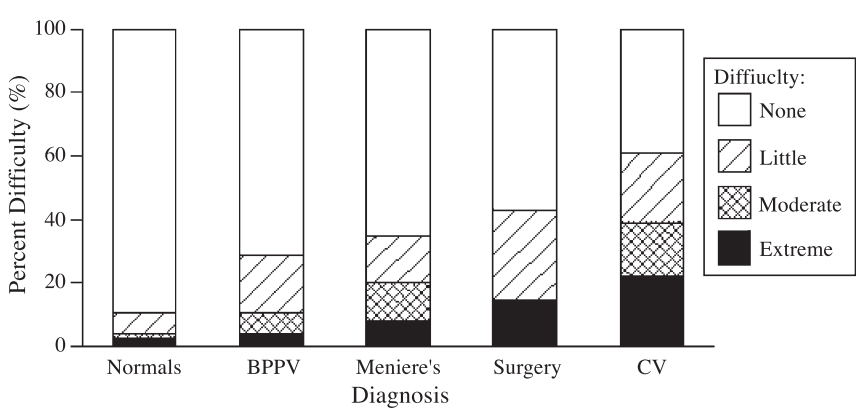

Fig. 6. Percent of subjects reporting difficulty when driving up or down a ramped parking garage.

driving alone, freeway driving, driving on local high traffic roads, pulling into and out of parking spaces, changing lanes, and staying in lane. These differences indicated that in general, patients with chronic vestibulopathy and patients who were postoperative had the most difficulty. All of the diagnostic groups reported that they have had to pull off the road due to vertigo, but differences among the diagnostic groups were not statistically significant ($p = .084$; see Fig. 2). One third of Meniere's and CV patients reported this problem compared to 11% to 15% of other subjects. All patient groups reported difficulty driving in ramped parking garages, although they did not differ significantly from each other. Thirty-nine percent of CV, 20% of Meniere's, and 14% of PostOp patients reported that this task was moderately to extremely challenging or they avoided it completely. Figs. 3–6 show the findings for particularly problematic driving challenges. Table 3 lists all of the driving challenges and the magnitude of significant differences from normal subjects, if any.

BPPV patients were the least impaired of all patient groups. Therefore, not surprisingly, their scores did not change significantly after treatment for BPPV.

4. Discussion

In general, normal subjects and patients drove approximately the same distances on a regular basis. During the initial therapy evaluation for vestibular rehabilitation, patients often report that they try to limit their driving. People must, however, go to work, run errands, attend religious services, and perform other activities of daily living. Patients report that they cannot delegate these tasks to other people because no one else can do those tasks, or because other people depend on them for assistance. Therefore, most patients do not actually limit the distance they drive. They may have reduced numbers of driving days, however, in an effort to reduce their driving exposure. In the Houston and Birmingham metropolitan areas, no equally convenient, alternative methods of transportation are available. Therefore, despite their physicians' advice not to drive, patients with vestibular disorders continue driving. Thus, just being instructed on whether to drive does not keep these people off the roads because the advice is impractical. In cases where driving must be prohibited permanently, patients should be referred to social services to arrange alternative modes of transportation.

The findings about driving space must be viewed in context. Most of our subjects lived in Texas, primarily in the Houston metropolitan area. The nearest state, Louisiana, is a 2.5-hour drive on the interstate highway. Therefore, many people in the area fly to out-of-state destinations. Many small communities abut the city of Houston, however, and many people in the local and distant suburbs commute to Houston for work, health care, and recreation. Therefore, the questions about driving to nearby towns and more distant towns do apply. In response to both questions, patients reported driving less than normal subjects, suggesting that they limit their driving activities as much as possible to nearby areas. Many patients reported that although they are comfortable driving short distances on local roads, they are uncomfortable doing highway driving. This sentiment is reflected in some of their scores on the Driving Challenges section.

Patients reported slightly fewer incidents of being pulled over by the police, and few actual crashes, at a rate that did not differ from normal subjects. This finding probably reflects the caution with which most patients drive. Some patients have reported being pulled over when wandering out of the lane or driving too slowly, indicating other problems that are also reflected in the Driving Challenges section.

People with vestibular disorders rely heavily on visual information for spatial orientation, to reduce vertigo, to tell them when they are steering straight ahead, and to tell them when they are upright. They become disoriented more easily than normal people by extraneous visual stimuli, or visual noise. These problems are reflected in their significant difficulty driving in reduced visual conditions at night or in the rain. Their difficulty making left turns, driving on freeways and other high traffic roads, changing lanes while driving, and driving during rush hour may be partly attributed to increased sensitivity to motion of other objects that they see. These problems may also be related to vertigo that is elicited by rapid motion. Driving performance under these conditions might be improved by better road lighting, use of high-contrast paint for on-road signs, and use of more three-dimensional reflective lane markers.

Other problematic tasks for people with vestibular disorders are those that require good spatial navigation skills, performance of which may be affected by brief, rapid, head motions. Parking a car, maneuvering in a parking space, and staying in the lane while driving require good spatial navigation skills. The type of vestibularly guided navigation, or path integration, that is needed to stay in lane while driving is impaired in people with vestibular disorders (Cohen, 2000; Page & Gresty, 1985). Checking for traffic before entering an intersection requires the kind of rapid head rotations that elicit vertigo in many vestibularly impaired patients, particularly people with chronic vestibulopathy and postoperative vertigo.

The survey included the question about driving around a ramped parking garage because of the prevalence of these structures in urban environments. Many patients commented about having vertigo or feeling disoriented in these garages, probably due to the sharp turns and visual noise in those structures. Some particularly problematic garages have cylindrical ramps on the sides, rather than ramps through the centers of the structures, and their outer walls are covered by regularly spaced, vertical blinds to allow in light without rain. Unfortunately, vertical blinds also create virtual optokinetic drums, or moving visual stimuli, which

can elicit vertigo due to the nature of visual/vestibular interaction in the central nervous system.

Some vestibular neurons in the brain respond to both vestibular input and optokinetic stimuli and many of the other pathways in the brain that respond to vestibular stimuli also respond to moving visual stimuli (Dieterich & Brandt, 2000; Howard, 1997). Therefore, vertigo can be elicited in many of our patients by presenting them with optokinetic stimuli. Virtual optokinetic stimuli plus the slight rapid head rotations elicited while ascending or descending cylindrical ramps may also cause vertigo. Safety might be improved by increasing the number of lower level spaces for visitors with physical challenges and by reconsidering the basic design of these structures.

In all patient groups at least some subjects reported that they sometimes needed to pull off the road due to vertigo. In Meniere's disease, vertigo attacks occur suddenly and without warning. When they occur, patients must pull off the road immediately to avoid accidents. In between Meniere's attacks these people are often free of vertigo. PostOp and CV patients may also have vertigo episodes elicited by sudden head movements and may occasionally need to pull over and wait until the vertigo subsides. All of these people would benefit by having space available on the highway for emergency stops. In some areas, however, no such shoulder space is available. Safety would be improved by designing highways and other roads so that emergency road space is available everywhere and by making viable, alternative means of transportation available.

In the course of doing this study, several subjects also volunteered information about problematic environments and driving challenges that were not included in the list. For example, several patients complained about a landmark at the Texas Medical Center, a large outdoor fountain composed of regularly spaced vertical columns behind which are regularly spaced trees, creating a virtual optokinetic stimulus. Some vestibularly impaired people have vertigo when they drive by it.

Another common complaint of many patients is the difficulty driving on highways when visual cues, such as concrete barriers, suddenly disappear, as when an exit ramp appears on either side, or when a highway forks. In these cases, additional visual cues might be helpful, such as contrasting paint. Other patients complain about highway cloverleaves, which may elicit vertigo in the same way that turns on garage ramps elicit vertigo. The addition of contrasting paint and lights at night might increase safety in these areas.

Many patients commented that if convenient and accessible public transportation was available, they would use it. Despite the discomfort and admitted decline in their driving skills, our patients with vestibular disorders drive because they do not have viable alternatives. In crowded cities where the streets are busy, and little room is available to pull over in case of a vertigo episode, the safety of this specific patient population and the public, in general, would be enhanced if the need to drive individual automobiles could be reduced.

5. Summary

Health care specialists who see patients with vestibular disorders, which cause vertigo, have been concerned with their driving skills for many years. Several studies have reported that physicians believe that patients with some vestibular disorders are not safe drivers. No previous studies, however, have provided data on patients' opinions about their own driving skills. Since vestibular disorders occur frequently in elderly people, this issue is particularly relevant to the older population. This study used a structured interview based on a well-normed instrument to determine how well patients with several different vestibular disorders rate their driving skills compared to normal subjects.

In general, people were aware that their driving performance was not optimal. Although some patients were advised by their physicians not to drive, they continued to drive anyway because they did not have alternative means of transportation. Patients had particular difficulty driving under conditions where useful visual cues were reduced, precise spatial navigation skills were needed, and rapid head movements were elicited. People with Meniere's disease and with chronic vestibulopathies were most affected by these problems. Patients in all groups, however, reported having to pull off the road due to vertigo.

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References

Baloh, R. W., Sloane, P. D., & Honrubia, V. (1989). Quantitative vestibular function testing in elderly patients with dizziness. *Ear, Nose, & Throat Journal*, *68*, 935–939.

Bergstrom, B. (1973). Morphology of the vestibular nerve. II. The number of myelinated vestibular nerve fibers in man at various ages. *Acta Otolaryngologica*, *76*, 173–179.

Brandt, T., Steddin, S., & Daroff, R. B. (1994). Therapy for benign paroxysmal positioning vertigo, revisited. *Neurology*, *44*, 796–800.

Cohen, H. (1992). Vestibular rehabilitation reduces functional disability. *Otolaryngology and Head and Neck Surgery*, *107*, 638–643.

Cohen, H. S. (2000). Vestibular disorders and impaired path integration along a linear trajectory. *Journal of Vestibular Research*, *10*, 7–15.

Cohen, H., Ewell, L. R., & Jenkins, H. A. (1995). Disability in Meniere's disease. *Archives of Otolaryngology, Head, & Neck Surgery*, *121*, 29–33.

Cohen, H., Heaton, L. G., Congdon, S. L., & Jenkins, H. A. (1996). Changes in sensory organization test scores with age. *Age and Ageing*, *25, 39–44.*

Cohen, H. S., & Jerabek, J. (1999). Efficacy of treatments for posterior canal benign paroxysmal positional vertigo. *Laryngoscope*, *109*, 584–590.

Cohen, H. S., & Kimball, K. T. (2000). Development of the vestibular disorders activities of daily living scale. *Archives of Otolaryngology, Head, & Neck Surgery*, *126*, 881–887.

Dieterich, M., & Brandt, T. (2000). Brain activation studies on visual–vestibular and ocular motor interaction. *Current Opinion in Neurology*, *13*, 13–18.

Dix, M. R., & Hallpike, C. S. (1952). The pathology, symptomatology and diagnosis of certain common disorders of the vestibular system. *Proceedings of the Royal Society of Medicine*, *45*, 341–354.

Epley, J. M. (1992). The canalith repositioning procedure: For treatment of benign paroxysmal positional vertigo. *Otolaryngology and Head and Neck Surgery*, *107*, 399–404.

Howard, I. P. (1997). Interactions within and between the spatial senses. *Journal of Vestibular Research*, *7*, 311–345.

Jonathan, D., & McKiernan, D. (2000). Dizziness and driving. *ENT News*, *9*(3), 15–16.

Lopez, I., Honrubia, V., & Baloh, R. W. (1997). Aging and the human vestibular nucleus. *Journal of Vestibular Research*, *7*, 77–85.

Lyon, M. J., & Wanakaer, H. H. (1993). Blood flow and assessment of capillaries in the aging rat posterior canal crista. *Hearing Research*, *67*, 157–165.

McKiernan, D., & Jonathan, D. (2001). Editorial: Driving and vertigo. *Clinical Otolaryngology*, *26*, 1–2.

Monsell, E. M., Balkany, T. A., Gates, G. A., Goldenberg, R. A., Meyerhoff, W. L., & House, J. W. (1995). Committee on Hearing and Equilibrium guidelines for the diagnosis and evaluation of therapy in Meniere's disease. *Otolaryngology and Head and Neck Surgery*, *113*, 181–185.

Nakayama, M., Helfert, R. H., Konrad, H. R., & Caspary, D. M. (1994). Scanning electron microscopic evaluation of age-related changes in the rat vestibular epithelium. *Otolaryngology and Head and Neck Surgery*, *111*, 799–806.

Owsley, C., Stalvey, B., Wells, J., & Sloane, M. E. (1999). Older drivers and cataract: Driving habits and crash risk. *Journal of Gerontology - Medical Sciences*, *54A*, M203–M211.

Page, N. G. R., & Gresty, M. A. (1985). Motorist's vestibular disorientation syndrome. *Journal of Neurology, Neurosurgery and Psychiatry*, *48*, 729–735.

Paige, G. D. (1992). Senescence of human visual–vestibular interactions. 1. Vestibulo–ocular reflex and adaptive plasticity with aging. *Journal of Vestibular Research*, *2*, 133–151.

Parnes, L. S., & Sindwani, R. (1997). Impact of vestibular disorders on fitness to drive: A consensus of the American Neurotology Society. *American Journal of Otology*, *18*, 79–85.

Rosenhall, U. (1973). Degenerative patterns in the aging human vestibular neuro–epithelia. *Archives of Otolaryngology, Head, & Neck Surgery*, *76*, 208–220.

Semont, A., Freyss, G., & Vitte, E. (1988). Curing the BPPV with a liberatory maneuver. *Advances in Oto-Rhino-Laryngology*, *42*, 290–293.

Sindwani, R., & Parnes, L. S. (1997). Reporting of vestibular patients who are unfit to drive: Survey of Canadian otolaryngologists. *Journal of Otolaryngology*, *26*, 104–111.

Sindwani, R., Parnes, L. S., Goebel, J. A., & Cass, S. P. (1999). Approach to the vestibular patient and driving: A patient perspective. *Otolaryngology and Head and Neck Surgery*, *121*, 13–17.

StataCorp, S. P. (2001). *Stata statistical software: Release 7.0*. College Station, TX: Author.

Weindruch, R., Korper, S. P., & Hadley, E. (1989). The prevalence of dysequilibrium and related disorders in older persons. *Ear, Nose, & Throat Journal*, *68*, 925–929.

Appendix A. Additional questions added to the DHQ

1. Since you developed vertigo, have you pulled into or out of a parking space?
2. Since you developed vertigo, have you changed lanes while driving?
3. Since you developed vertigo, have you stayed within the lane where you are driving?
4. Since you developed vertigo, have you had to check for traffic before entering an intersection?
5. Since you developed vertigo, have you driven up or down a ramped parking garage?
6. How many times in the past year (or since the vertigo started if you have had vertigo for less than one year) have you had to pull off the road because of vertigo?

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