Case Report

Acrophobia and Pathological Height Vertigo: Indications for Vestibular Physical Therapy?

Background and Purpose. Acrophobia (fear of heights) may be related to a high degree of height vertigo caused by visual dependence in the maintenance of standing balance. The purpose of this case report is to describe the use of vestibular physical therapy intervention following behavioral therapy to reduce a patient's visual dependence and height vertigo. Case Description. Mr N was a 37-year-old man with agoraphobia (fear of open spaces) that included symptoms of height phobia. Exposure to heights triggered symptoms of dizziness. Intervention. Mr N underwent 8 sessions of behavioral therapy that involved exposure to heights using a head-mounted virtual reality device. Subsequently, he underwent 8 weeks of physical therapy for an individualized vestibular physical therapy exercise program. Outcomes. After behavioral therapy, the patient demonstrated improvements on the behavioral avoidance test and the Illness Intrusiveness Rating Scale, but dizziness and body sway responses to moving visual scenes did not decrease. After physical therapy, his dizziness and sway responses decreased and his balance confidence increased. Discussion. Symptoms of acrophobia and sway responses to full-field visual motion appeared to respond to vestibular physical therapy administered after completion of a course of behavioral therapy. Vestibular physical therapy may have a role in the management of height phobia related to excessive height vertigo. [Whitney SL, Jacob RG, Sparto PJ, et al. Acrophobia and pathological height vertigo: indications for vestibular physical therapy? *Phys Ther.* 2005;85:443–458.]

Key Words: *Acrophobia, Dizziness, Height phobia, Physical therapy, Vestibular rehabilitation, Virtual reality.*

Susan L Whitney, Rolf G Jacob, Patrick J Sparto, Ellen F Olshansky, Gail Detweiler-Shostak, Emily L Brown, Joseph M Furman

A link between dizziness and phobic avoidance of certain environments has been discussed for millennia, but interest waned after the identification of agoraphobia as a psychiatric disorder in 1874.[1] Recent research, however, has re-established links between this avoidance pattern and vestibular dysfunction.[2] Specifically, patients with vestibular or balance disorders often report fear of heights.[3–5] This fear tends to be embedded in a larger symptom pattern that has been labeled "space-and-motion discomfort" (SMD).[3,6,7]

Space-and-motion discomfort occurs in patients with anxiety disorders, particularly agoraphobia,[8] a disorder in which fear of heights is common. Patients with agoraphobia have been found to have an increased prevalence of vestibular or balance dysfunction.[9–12] In a study by Jacob et al,[6] patients with anxiety plus fear of heights and other symptoms of SMD were found to be unusually sensitive in their body sway to full-field visual motion (ie, optic flow). The subjects stood in front of a large screen on which patterns of black and white squares or stripes were projected that created the illusion of vection ("subjective self-motion") while postural sway was recorded. The results suggested that people with anxiety plus fear of heights were visually dependent in a manner similar to that of patients with vestibular disorders examined in an earlier study.[13]

Height vertigo occurs when a critical distance between a person and the closest stationary visible object is exceeded.[14] The long visual distances in high places lead to a lack of visual information used to maintain balance.[15] In high places, sway increases, perhaps in part as an exploratory behavior aimed at increasing visual balance feedback.[16] Body sway in high places approaches that of sway during eye closure.[17] With increased sway, the center of gravity at times may approach the boundary of support, and when this happens, instability increases even further, in particular when visuospatial cues remain absent.[18]

The case report examines the link between dizziness and phobic avoidance of certain environments.

In individuals with vestibular dysfunction, one way of compensating for the vestibular deficit is to rely primarily on information from nonvestibular inputs.[19,20] This process is referred to as "sensory reweighing."[21(p86)] If preference is given to visual inputs, the affected individuals will become more sensitive to perturbations in their visual surround and will become visually dependent.

Space-and-motion discomfort may be a symptomatic expression of visual dependence. Bronstein[22,23] found that 5 of 15 patients who had symptoms triggered in supermarket aisles or moving visual surroundings showed increased sway responses to full-field visual motion (ie, when an artificial environment is made to move relative to the person), creating an illusion of self-motion (vection) induced by a moving room. Eagger and colleagues,[24] in a longitudinal study of people with

SL Whitney, PT, PhD, NCS, ATC, is Assistant Professor, Departments of Physical Therapy and Otolaryngology, University of Pittsburgh, Pittsburgh, Pa, and Program Director of the Physical Therapy Department Centers for Rehab Services, Pittsburgh, Pa. Address all correspondence to Dr Whitney at Department of Physical Therapy, University of Pittsburgh, 6035 Forbes Tower, Pittsburgh, PA 15260 (USA) (whitney@pitt.edu).

RG Jacob, MD, is Professor, Departments of Psychiatry and Otolaryngology, University of Pittsburgh.

PJ Sparto, PT, PhD, is Assistant Professor, Departments of Physical Therapy, Otolaryngology, and Bioengineering, University of Pittsburgh.

EF Olshansky, DNSc, RNC, FAAN, is Professor and Chair, Department of Health and Community Systems, University of Pittsburgh School of Nursing, Pittsburgh, Pa.

G Detweiler-Shostak, RN, MSN, CS, is Psychiatric Nurse Specialist, Department of Psychiatry, University of Pittsburgh.

EL Brown, BS, is research associate, Department of Psychiatry, University of Pittsburgh, and is currently a medical student at the University of Pittsburgh.

JM Furman, MD, PhD, is Professor, Departments of Otolaryngology, Physical Therapy, and Bioengineering, University of Pittsburgh.

Dr Whitney, Dr Jacob, and Dr Furman provided concept/idea/project design, project management, and fund procurement. All authors provided writing. Dr Whitney, Dr Jacob, Dr Sparto, Dr Olshansky, and Ms Brown provided data collection and analysis; Ms Detweiler-Shostak also assisted with data collection. Dr Jacob and Ms Detweiler-Shostak provided the behavioral treatment. Dr Whitney, Dr Jacob, Dr Sparto, and Dr Furman provided facilities/equipment. Dr Jacob and Dr Furman provided institutional liaisons. Dr Whitney and Ms Brown provided clerical support. Dr Whitney provided consultation (including review of manuscript before submission).

This work was supported in part by National Institutes of Health grants DC 05384 to Dr Whitney and P01-DC011 to Dr Jacob and Dr Furman.

This article was received August 13, 2004, and was accepted October 12, 2004.

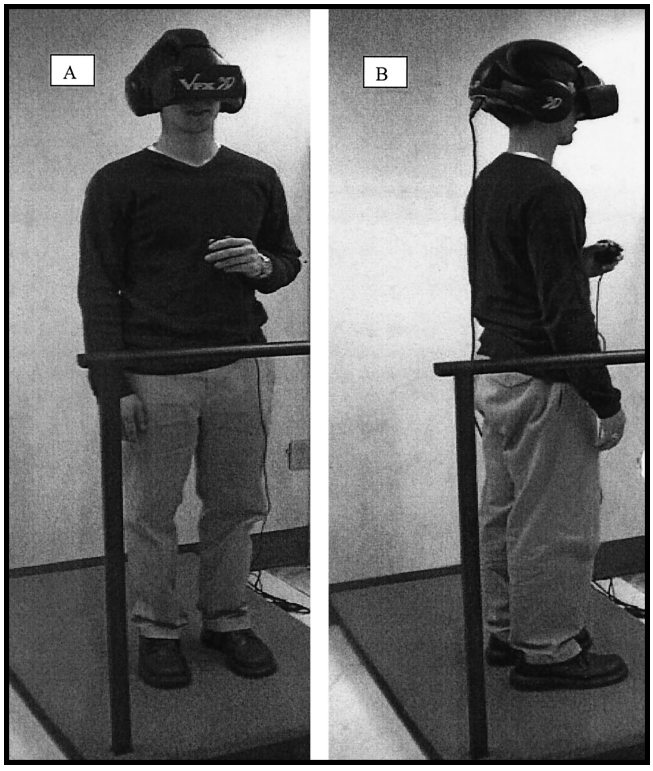

Figure 1.
A person demonstrating the use of the virtual reality head-mounted device while standing (A). Note the controller of the scene movement in his left hand. The session started with the bar in front of him, but he was free to move in any direction relative to the bar during the training session (B).

peripheral vestibular disorders, found that the subjects often developed a fear of darkness and heights.

Preliminary evidence suggests that vestibular physical therapy may be of value for patients with agoraphobia and laboratory evidence of vestibular dysfunction.[25] Furthermore, in a recent study, Rahko[26] found that close to half of the patients with benign positional vertigo had acrophobia and that, in all of the patients, these symptoms had remitted after vestibular rehabilitation. Similarly, Pavlou and colleagues[27,28] showed that vestibular rehabilitation could reduce SMD and visual dependence in patients with vestibular disorders.

Both the professions of physical therapy and psychotherapy use forms of exposure therapy as part of patient management.[29] Behavioral management of phobias is based on therapeutic exposure, a procedure in which patients face the feared stimulus repeatedly for a prolonged period. The therapeutic benefit derives from habituation and breaking the association between the anxiety and the stimulus. Such therapy can use actual exposure (in vivo) or conjured feared stimuli in imagination. Recently, a third method has become technically feasible: virtual reality. One type of virtual reality involves presenting an immersive phobic stimulus to a patient via a head-mounted display (Fig. 1).[30–33] Virtual reality exposure is safer and more practical for office treatment than in vivo exposure.[33] In addition, it does not depend on patients' capacity for imagination, although it requires that they be able to immerse themselves within the virtual environment.

Clinical experience among behavior therapists suggests that the behavioral management of acrophobia presents difficulties especially in those patients who seem to sway excessively during height exposure (Barbara Rothbaum, personal communication). Such excessive sway may be due to visual dependence. This case report describes a patient whose dizziness and body sway responses to moving visual scenes did not decrease following behavioral exposure therapy. We surmised that vestibular physical therapy would specifically target visual dependence and thus provide a needed addition to behavioral exposure treatment.

Case Description

Mr N was a 37-year-old man who reported having had a fear of heights and dizziness since childhood. He was initially seeking consultation from his primary care physician for dizziness. He was referred to the balance and vestibular laboratory for vestibular testing. The test battery, consisting of an oculomotor screening battery, static positional testing, Dix-Hallpike maneuvers, binaural bithermal caloric irrigations, and rotational chair testing, showed no abnormalities. However, physical examination by the otoneurologist (JMF) suggested mild imbalance. The patient was prescribed 0.25 mg of clonazepam twice daily and 10 mg of imipramine at bedtime, a standard initial treatment combination for chronic dizziness in our clinic. Clonazepam is used as a vestibular suppressant, and imipramine is used as a means of moderating noradrenergic influences on the vestibular system.[34] Because of his imbalance, Mr N was referred for vestibular physical therapy, which was not approved by his insurance company. The patient also was referred to a psychiatrist (RGJ) for his anxiety and agoraphobia.

At the psychiatric evaluation, the patient's psychiatric diagnosis was panic disorder with agoraphobia, with comorbid social anxiety disorder, and generalized anxiety disorder according to DSM IV-TR criteria.[35] As part of his agoraphobic avoidance spectrum, the patient had a marked degree of acrophobia. The patient reported that imipramine was no longer helpful. Therefore, imipramine was discontinued, and he was prescribed fluoxetine, 20 mg per day, an antidepressant commonly used for anxiety disorders. The fluoxetine dose was later increased to 40 mg per day, and his clonazepam dose was increased to 0.5 mg 3 times daily. He remained on stable doses of these medications throughout the remainder of the intervention.

Although his dizziness partially decreased with this medication regimen, the acrophobia persisted. Six months later, he was referred to a combined behavior therapy and physical therapy program that was part of a research pilot study.

Overview of Sequence of Interventions and Examinations

Mr N's treatment proceeded in 2 phases. The first phase was an 8-week behavioral therapy program, referred to as "virtual reality exposure treatment," in which he was exposed to height scenes presented in virtual reality. The second phase was an 8-week physical therapy program, referred to as "vestibular physical therapy." Mr N was examined on 3 occasions: (1) before treatment (ie, before virtual reality exposure treatment), (2) after virtual reality exposure treatment, which also served as a prevestibular examination by the physical therapist, and (3) after vestibular physical therapy. In addition, a physical therapist examination was performed before vestibular physical therapy. After both interventions, the patient was interviewed by an expert in qualitative data analyses (EFO). In what follows, we will present the results of assessments and interventions chronologically as the patient experienced them.

Outcome Measurement Instruments and Pretreatment Examination Results

Self-report measures. The primary outcome measure was the Cohen Acrophobia Questionnaire (CAQ), which is designed specifically to assess a person's fear of heights.[36] The Pearson *r* for test-retest reliability of data for the fear and avoidance subscales was estimated to be .82.[36] As expected from the known loose associations between the different domains of anxiety (eg, behavioral, self-report), the CAQ data were moderately correlated with behavioral measures of fear of heights in a behavioral avoidance test (the behavioral avoidance test will be described in the next section) ($r=.46$ for CAQ–avoidance, $r=.32$ for CAQ–anxiety). Mr N's pre–virtual reality intervention score on the fear subscale of the CAQ was 91, a score that exceeded the average pretreatment score of people with height phobia treated by Rothbaum et al[33] by 1.8 standard deviations.

Another questionnaire that focused on fear of heights was the Attitudes Towards Heights Questionnaire as adapted by Rothbaum et al.[33] Internal consistency (alpha) for data obtained with this measure has been reported as .81. Validity of data for this measure is supported by the fact that it is responsive to treatment effects.[32] Mr N's responses on the Attitudes Towards Heights Questionnaire indicated a maximal or close-to-maximal negative attitude on all items.

The Situational Characteristics Questionnaire[8] was used to assess SMD. The questionnaire consists of 2 subscales that measure SMD: the Space and Motion Discomfort, Part I (SMD-I), and the Space and Motion Discomfort, Part II (SMD-II). The differences between the SMD-I and SMD-II stem from the mechanics of scoring, which render the SMD-I scores less influenced than the SMD-II scores by a patient's overall tendency to report symptoms, a problem frequently observed in patients with anxiety disorders.[37] Test-retest reliability of data for the SMD-I was estimated using Pearson *r* to be .66, and internal consistency (alpha) was .74 to 76.[8] The validity of data for the SMD-I was reflected in its ability to discriminate between patients with dizziness and hearing disorders and to identify individuals with laboratory evidence for vestibular dysfunction among patients with anxiety disorders.[10,11] The SMD-II included items specifically chosen to identify people with vestibular disorders. Test-retest reliability of data for the SMD-II was estimated using Pearson *r* to be .87. It did not discriminate between patients with anxiety with or without vestibular dysfunction but was even more powerful than the SMD-I for discriminating between patients with balance disorders and patients with hearing disorders.[8]

Comparative data for patients with anxiety disorders, patients with vestibular disorders, and control subjects without SMD were reported by Jacob et al.[8] This database for control subjects without SMD has been expanded as further data were collected for other studies, and these data constitute our laboratory norms. Mr N's scores were compared with those of control subjects without SMD in this database. Mr N's pretreatment score on the SMD-I was 4.4—higher than 98% of unpublished norms based on 101 control subjects without SMD evaluated in previous research studies; his SMD-II score was 12.8, which was much higher than the range of scores for subjects without SMD, whose scores are generally under 2.[8]

Mr N also completed instruments focused on his quality of life. The Illness Intrusiveness Ratings Scale[38] measures impairment in social function specifically attributable to a particular disorder (in this case, fear of heights). Internal consistency in a recent study was .88, and test-retest reliability corresponded to an intraclass correlation coefficient of .89.[39] Cina and Clase[39] also reviewed previous research, which indicated values for internal consistency ranging from .80 to .88 and values for test-retest reliability of .79 to .85. Illness Intrusiveness Rating Scale scores for various aspects of quality of life have been published for patients with anxiety disorders.[40] Mr N's total score was 58, which was somewhat higher than the published average of 53.3 (95% confidence interval=46.75–55.90) for people with panic disorders. The patient's profile was similar to the published

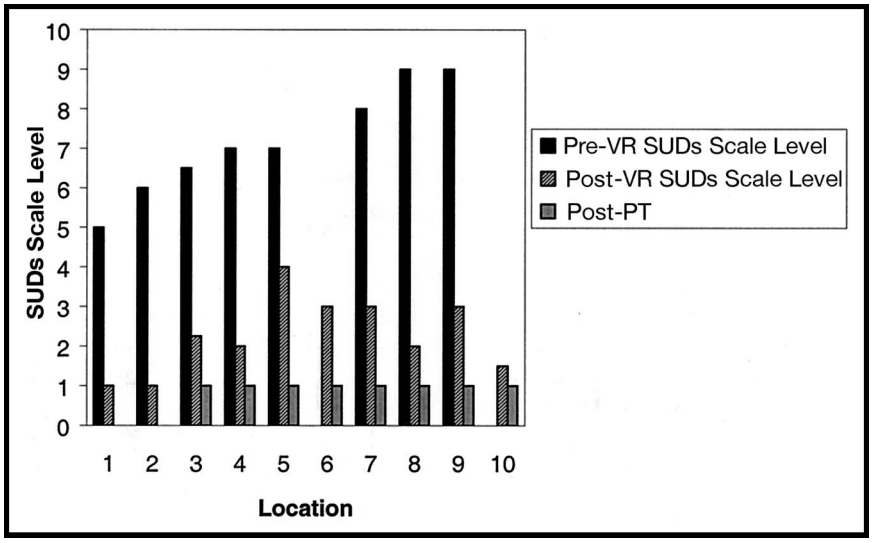

Figure 2.
Mr N's "Subjective Units of Discomfort" (SUDs) Scale levels reported during behavioral avoidance test in 10 different locations. The locations included various high places in the surrounding area where he was asked to look down over a railing, stand on an elevated platform, or stand on the stairs of a fire escape. Locations 1 and 2 received a score of 0 after physical therapy and therefore are not visible in the figure. VR=virtual reality exposure treatment, PT=vestibular physical therapy.

data on patients with panic disorders, with the exception of religious expression, where his score was above the mean for people with panic disorders by an estimated 1.8 standard deviations. One of the patient's treatment goals was to be able to go back to church, an activity that he had avoided.

General quality of life was assessed with the Medical Outcomes Study 36-Item Short-Form Survey questionnaire (SF-36), version 1.[41,42] This instrument contains 8 subscales: Physical Function, Role–Physical, Bodily Pain, General Health, Vitality, Social Function, Role–Emotional, and Mental Health. When the SF-36 was used in a psychiatric outpatient setting, the authors reported internal consistency reliabilities of .80 to .94. The profile of data on individual subscales differentiated in a clinically meaningful manner between patients with psychiatric problems and patients seen for surgery, suggesting validity.[43]

Mr N's SF-36 scores fell below the one-tailed 90% confidence limit for normative data[44] in several domains: General Health, Social Function, Role–Emotional, and Mental Health. His scores indicated better functioning compared with the average group values of people with varied vestibular disorders.[45] Because of the availability of normative data for the SF-36 as well as information on reliability,[46] our assessment of general quality of life could be refined with the aid of a method to establish the clinical significance of questionnaire changes in individual subjects.[47] We used 2 complementary indicators: (1) clinically reliable improvement and (2) recovery. "Clinically reliable improvement" was coded if the "Reliable Change" index (RC)[47] exceeded 1.96 standard deviations. To obtain the RC, the standard error of the measurement of a difference between 2 individual test scores (S_{diff}) was first calculated:

$$S_{diff} = \sqrt{(2\,S^2(1-r))}$$

where r denotes the reliability of data obtained for the scale and S denotes the population standard deviation. For the SF-36, both r and S are available from normative data.[44] The RC value is calculated as: RC=(score−[average of normative data])/S_{diff}. We defined a clinically significant improvement as RC >1.96, which means that the difference in test score is due to a true change, as opposed to measurement error, with a 2-tailed probability of 95%. Similarly, we defined RC >1.65, representing the 90% probability of a true difference, as a "trend" toward improvement.

"Recovery" was defined as: (1) having had a pretreatment score outside the normal range and (2) having a posttreatment score within the normal range. Mr N's standing compared with the normative population was calculated as a z score ([score−mean of norm]/standard deviation). We defined a score to be outside of the normal range if the z score was less than −1.28, because it corresponded to the lower (more impaired) 10th percentile of the population.

Behavioral avoidance test. A behavioral avoidance test is often used by behavioral therapists to document a patient's anxiety reactions when they are actually exposed to their phobic situations.[48] Mr N received a behavioral avoidance test that involved exposure to a sequence of 10 successively more difficult high locations, such as ascending an outdoor stairway or looking over a railing of an open courtyard 3 floors below. At each location, he was asked to report his anxiety level, expressed on a "Subjective Units of Discomfort" (SUDs) scale[32] that ranged from 0 ("no discomfort") to 10 ("maximal discomfort"). The SUDs measure has been widely used in behavior therapy since its inception as a self-report of anxiety experienced at the moment. As an indicator of validity, SUDs measures obtained during virtual exposure in people with height phobia were correlated with the scores on the CAQ[36] (Pearson

Figure 3.
Silhouette view of a person demonstrating the use of the Balance Near Automatic Virtual Reality Environment (BNAVE) laboratory with the checkered optic flow stimulus. The patient is standing on a movable force platform, and an electromagnetic motion transmitter is behind the patient.

$r = .48$).[49] Before treatment, Mr N reported high SUDs levels (Fig. 2); during the 2 most difficult stations, he reported levels of 9/10 at stations 8 and 9, which both involved looking down a stairwell inside a 40-story building.

Optic flow testing. Sway responses to optic flow stimuli were recorded before and after virtual reality exposure treatment. Mr N stood upright on a force platform in the center of a visual theater with a wide field of view (Fig. 3). While standing, an optic flow stimulus that pitched forward and back from upright ±2 degrees was projected onto the walls. The optic flow stimulus consisted of a checkered pattern presented in his peripheral field of view (from 35° to 90° on each side of midline). Mr N was asked to keep his direction of gaze straight ahead. Instrumentation included electromagnetic position and orientation sensors on Mr N's head and pelvis. In addition, center of pressure was measured from the force platform data. Anterior-posterior (A-P) and medial-lateral (M-L) translation data were extracted from these measurements. The root mean square (RMS) and average velocity were computed during the period of optic flow in both the A-P and M-L directions.

Six conditions were tested: 2 frequencies of optic flow for each of 3 surface conditions. Black and white rectangles moved toward the patient at 0.05 and 0.20 Hz (1 cycle per 20 and 5 seconds, respectively) while he was instructed to stand as steady as possible. The force platform upon which the patient stood could be: (1) fixed, (2) pitched toes up and down to maintain constant ankle angle (sway-referenced), or (3) pitched toes up and down in synchrony with the visual stimulus (driven). The stimulus profile of each trial consisted of a period of either 120 seconds (0.05 Hz) or 60 seconds (0.20 Hz) of optic flow, which was immediately preceded and followed by periods of 30 seconds without optic flow.

Mr N's center-of-pressure data from the sway-referenced conditions at 0.05 Hz are shown in Figure 4. At his pretreatment assessment, Mr N exhibited large-amplitude, high-frequency oscillations that were quantified by analyzing the signal power in different frequency bands. These high-frequency recordings were seen particularly during the sway-referenced and driven platform conditions. Biomechanically, the oscillations could be produced by a stiffening of the body in an attempt to control the trajectory of the center of mass.[50] He also showed increases in RMS total sway. During the destabilized platform conditions, Mr N abducted his upper extremities in an apparent attempt to help control his balance.

Virtual Reality Exposure Treatment

The psychiatric nurse (GDS) provided the treatment. She taught the patient about SMD and its mechanisms to facilitate his understanding of his situational symptom triggers. He was given written materials to study at home,[3] which provided the rationale for the behavioral and vestibular rehabilitation therapy. This information was reinforced and elaborated on during the behavioral intervention and later during physical therapy.

Behavioral therapy consisted of a patient-paced, psychotherapist-aided exposure to a hierarchy of increasingly fearful virtual height scenes. The scenes were presented in virtual reality, using a head-mounted display. The hardware, software, and virtual reality scenes were originally developed by Rothbaum and colleagues.[33]

The first session consisted of the patient education already described, familiarization with the equipment, and organizing scenes into a hierarchy of increasing anxiety. During the subsequent 7 sessions, Mr N faced the items in the height hierarchy. Mr N was in control of his location and movements via a hand-held joystick (Fig. 1). He also wore a cloth over the head-mounted device to ensure that no additional light was perceived during virtual reality height

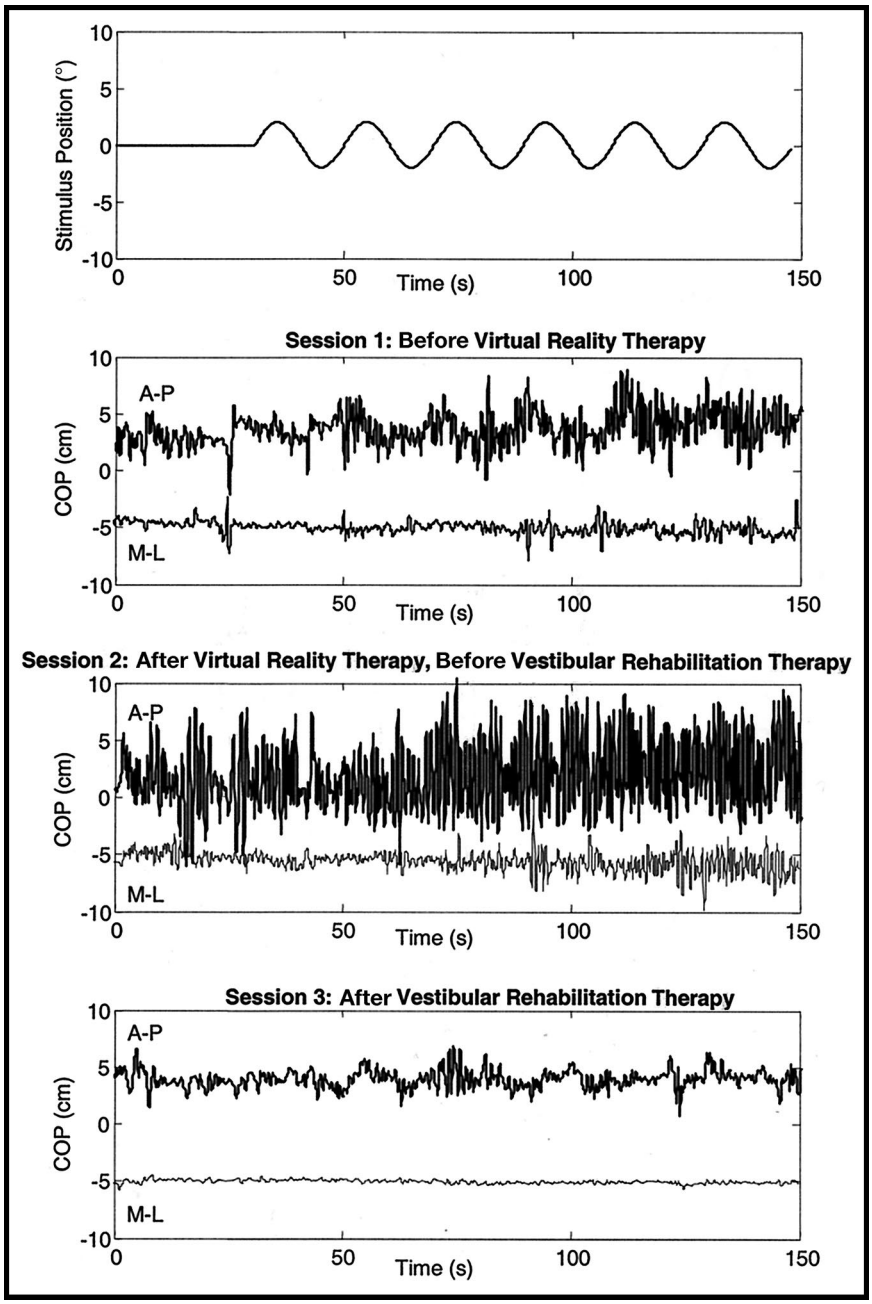

Figure 4.
Recordings of anterior-posterior (A-P) and medial-lateral (M-L) center of pressure (COP) obtained during the 3 sessions of optic flow testing. The stimulus (frequency=0.05 Hz, sway-referenced platform) is shown in the top panel. Notice the large reduction in the high-frequency sway during session 3 in both the A-P and M-L directions.

exposure, an intervention similar to one that Jang et al[30] described. The psychiatric nurse encouraged Mr N to report his experiences by eliciting Mr N's ratings of discomfort (SUDs scale) at regular intervals and by inquiring about his thoughts and physical sensations. To forestall the development of simulator sickness, session duration was limited to 45 minutes, as recommended by Rothbaum et al.[33] Jang and colleagues[30] limited their virtual reality sessions to 25 to 30 minutes for the management of acrophobia, yet Emmelkamp et al[51] provided virtual reality sessions of 1 hour without patient complaint, with breaks of a few minutes. An overview of Mr N's behavioral intervention sessions is presented in Table 1.

During virtual reality exposure treatment sessions, Mr N showed levels of distress consistent with anxiety that decreased across successive sessions. After completion of his virtual reality exposure treatment, Mr N demonstrated improvements in anxiety and quality of life, but not with SMD or visual dependence. During the behavioral avoidance test (Fig. 2), Mr N's SUDs scale levels decreased from a maximum of 9/10 to 4/10. On the CAQ, Mr N's score decreased from 91 to 37, which was only 1.1 standard deviations below the pretreatment levels that Rothbaum et al[32] reported. Therefore, it could not be claimed that Mr N had "recovered" from his acrophobia.[47]

On the Situational Characteristics Questionnaire (Tab. 2), the patient's score decreased from 4.4 to 3.8 on the SMD-I, a change that did not bring him into the normal range (97% of control subjects scored lower).[8] On the SMD-II, his score decreased from 12.2 to 11.1, which was still higher than 100% of control subjects. Furthermore, his postural responses to optic flow stimuli increased rather than decreased (Fig. 4), and his SUDs scale level during the test decreased only slightly (from a maximum of 9/10 to 8/10 [Fig. 5]). The patient expressed surprise as well as disappointment after the optic flow tests.

On the Illness Intrusiveness Rating Scale,[38] Mr N reported diminished intrusiveness from the height phobia by at least 2 steps (an arbitrarily chosen criterion) on the 7-point (1–7) scales in the following domains: health, self-expression/self-improvement, religious expression, and community and civic involvement (Tab. 3).

Mr N's condition following the behavioral therapy can be summarized as follows: he had reduced anxiety, reduced avoidance of heights, and increased quality of life; however, symptoms of dizziness and SMD persisted.

Table 1.
Overview of the Head-Mounted Virtual Reality Device Behavioral Therapy Sessions and the Physical Therapy Sessions[a]

Session No.	Content	Virtual Scene Category	Peak SUD Scale Rating	Therapist's Comments
Behavioral visit 1	Individual self-rated height hierarchy Familiarization with VR equipment	Room		
Behavioral visit 2	Exposure to VR scenes according to hierarchy	Glass elevator	6	Shaking, dizzy
Behavioral visit 3		Balcony/walkway Facing hotel lobby	5	Dizzy, difficulty looking over handrail
Behavioral visit 4	Measures: SUD every 5 min		7	Slightly dizzy, tense
Behavioral visit 5	Recording of Mr N's ongoing reports and body sensations		4	Tense
Behavioral visit 6			2	Looking up caused imbalance
Behavioral visit 7		Footbridges	4	Minimally improved
Behavioral visit 8			2	Much improved

Physical Therapy Interventions	Exercises Performed in Physical Therapy Sessions	Home Exercises Provided
Visit 9 (physical therapy visit 1)	Function was assessed (see Tab. 2 for his functional outcome scores and how he perceived his dysfunction)	Sitting–rock a cylindrical roll under the foot (shoes off) Sitting–place rice in the shoe and rock the foot back and forth Sitting–VOR×1 with a blank background Sitting–VOR cancellation with a blank background
Visit 10 (physical therapy visit 2)	Standing on a pillow Marching in place with eyes open and closed Walking with up and down head movements Standing weight shifts Bending while standing and moving from sitting to standing position	Walking with head movements in the pitch plane (up and down) Standing with feet together on a pillow Weight shifts forward and backward in standing position VOR cancellation with the card moving up and down in standing position
Visit 11 (physical therapy visit 3)	Standing on a cushion, eyes closed Marching in place Standing weight shifts Standing on a tiltboard and catching a ball while the board was oriented in the M-L and A-P directions Walking with pitch-and-yaw (right/left) head movement while walking backward and counting Standing on 2 cushions, eyes closed with feet together Standing on 2 cushions with eyes open in semi-tandem stance and in single-leg stance	Single-leg standing on a cushion One foot up on a stool, pitch-and-yaw head movement Feet in partial heel-to-toe position while standing on the foam VOR cancellation exercise in standing position

(continued)

Table 1.
continued

Physical Therapy Interventions	Exercises Performed in Physical Therapy Sessions	Home Exercises Provided
Visit 12 (physical therapy visit 4)	VOR cancellation was slowed because it was too difficult for him Practiced standing in single-leg stance Practiced standing on foam with eyes closed with head movement Walking with head movements in the pitch plane	Standing on foam, feet apart, eyes closed while moving the head in the pitch (up/down) and yaw (right and left) planes VOR cancellation in single-leg stance Walking with head movements in the pitch plane
Visit 13 (physical therapy visit 5)	Standing and marching on foam VOR cancellation in sitting position Standing, marching on foam, tossing balls, and counting Tossing balls while standing on a balance board Walking down the hallway with eyes closed	VOR cancellation exercise in single-leg stance While standing on a futon, marching in place and having the children throw a ball to him Standing and marching on a futon, having the children throw a ball to him back and forth, and counting backward at the same time Playing Twister[b] with the children
Visit 14 (physical therapy visit 6)	Walking with ball toss in the pitch plane Stepping up and down from a 20.3-cm (8-in) step Stepping up to the left and down and to the right Ball toss while saying the alphabet backward Ball toss on the foam pad Rocking on a half roller and catching a ball Rocking on a half roller in tandem Romberg position	Stepping up onto a stool with both feet, then stepping off to the left Step onto the stool and then step backward off the stool Walking, doing a 360° turn, and catching a soft ball thrown to him Performing 4–5 turns but walking straight between turns; repeating with 360° turns in the opposite direction Standing on a futon on one leg and having the children toss a ball to him
Visit 15 (physical therapy visit 7)	Walking with ball toss in the pitch plane Stepping up and down from a 20.3-cm (8-in) step Stepping up to the left and down and to the right and down Ball toss while saying the alphabet backward Ball toss on the foam pad Rocking on a half roller and catching a ball Rocking on a half roller in tandem Romberg position	Stepping up onto a stool with both feet, then stepping off to the left Step back up onto the stool and then step backward off the stool Walking, doing a 360° turn, and catching a soft ball thrown at him; doing about 4–5 turns but walking straight between turns; resting and letting things settle, then repeating with 360° turns in the opposite direction Standing on the futon on one leg and having the children toss a ball to him
Visit 16 (physical therapy visit 8)	Focused on an object in the periphery when he was turning Walking forward and backward while turning in 360° turns on command of the therapist	Playing with his son by spinning son 2–3 times in a circle

[a] The content of the session, the virtual reality scenes used, Mr N's "Subjective Units of Discomfort" (SUDs) scale ratings, and the psychologist's comments about the session are included. For the physical therapy sessions, the content of the session, the home exercise program, and the patient's comments are detailed. VR=virtual reality, VOR=vestibulo-ocular reflex, M-L=medial-lateral, A-P=anterior-posterior. All physical therapy clinic sessions were 45 minutes and the home program was designed to last 20–30 minutes per day.
[b] Hasbro Inc, PO Box 200, Pawtucket, RI 02862.

Table 2.
Mr N's Outcome Measures at Baseline, After Behavioral Therapy, After 4 Weeks and 8 Weeks of Physical Therapy Intervention, and After the Completion of Both Physical Therapy and Behavioral Therapy and Normative Values, if Available

Measurement Tool[a]	Before Behavioral Therapy	After Behavioral Therapy	Before Physical Therapy	4 Weeks Later	8 Weeks Later	Percentage of Change Over the 8 Weeks of Physical Therapy	After Both Behavioral Therapy and Physical Therapy	Normative Values
CAQ	91	37					20	Undefined
Attitudes toward height (average item score, 1–10)	7.6	5.3					4.7	Undefined
SitQ: SMD-I subscale	4.4	3.8					1.9	Undefined, but see text
SitQ: SMD-II subscale	12.2	11.1					3.3	Undefined, but see text
SOT composite			65	86	87	+34		Normal scores are 70 (EquiTest System, Version 8)[b]
TUG (s)			10.7	10.0	9.5	−11		Elderly controls were under 10 s[59]
BBS			56	56	56	No change		Median score (±SD) for people with vestibular disorders was 48±8 (n=70)[62]
DGI			23	23	23	No change		In older adults, the mean score (±SD) was 21±3[64]
Gait speed (m/s)			1.13	1.22	1.2	+7		1.3–1.5 m/s[66]
Space and motion symptoms			60–70	60–70	0	−100		Not available
DHI			60	38	18	−70		Median DHI score of people with vestibular disorders was 52 (n=71)[54]
ABC			35	36	81	+131		Median ABC score of people with vestibular disorders was 55 (n=71)[54]

[a] CAQ=Cohen Acrophobia Questionnaire; SitQ=Situational Characteristics Questionnaire; SMD-I=Space and Motion Disorders, Part I; SMD-II=Space and Motion Disorders, Part II; SOT=Sensory Organization Test of Computerized Dynamic Posturography; TUG=Timed "Up & Go" Test; BBS=Berg Balance Scale; DGI=Dynamic Gait Index; DHI=Dizziness Handicap Inventory; ABC=Activities-Specific Balance Confidence Scale.
[b] NeuroCom International Inc, 9570 SE Lawnfield Rd, Clackamas, OR 97015.

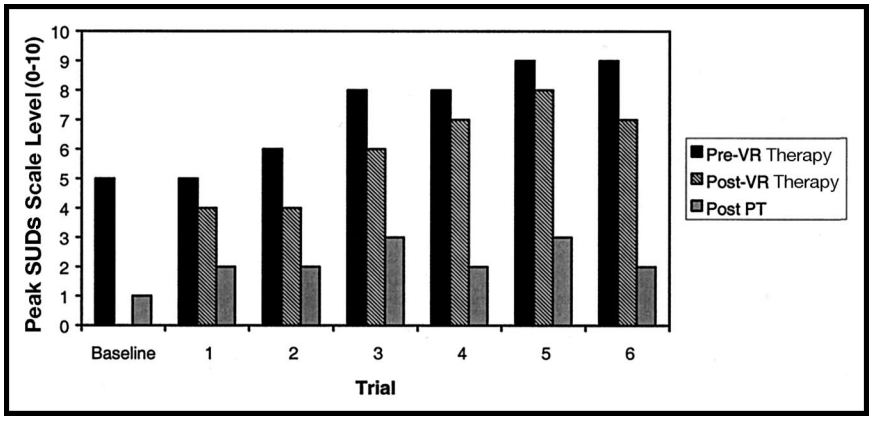

Figure 5.
Mr N's "Subjective Units of Discomfort" (SUDs) Scale levels were recorded during optic flow trials in the Balance Near Automatic Virtual Reality Environment (BNAVE) laboratory before the virtual reality (VR) behavioral therapy and before and after physical therapy (PT) intervention. The baseline post-VR exposure therapy SUD level was 0 and therefore is not visible in the figure. The visual scene was composed of a checkerboard pattern. Trial 1: frequency of visual scene oscillation=0.05 Hz, fixed platform; trial 2: frequency of visual scene oscillation=0.20 Hz, fixed platform; trial 3: frequency of visual scene oscillation=0.05 Hz, sway-referenced platform; trial 4: frequency of visual scene oscillation=0.20 Hz, sway-referenced platform; trial 5: frequency of visual scene oscillation=0.05 Hz, driven platform; trial 6: frequency of visual scene oscillation=0.20 Hz, driven platform.

Table 3.
Illness Intrusiveness Rating Scale Ratings[a] for This Patient With Acrophobia and Pathological Height Vertigo

How much does your height phobia or its treatment interfere with your:	Before Intervention	After Behavioral Therapy	After Physical Therapy
Health	5	3	1
Diet (ie, the things you eat and drink)	4	3	1
Work	4	3	2
Active recreation (eg, sports)	4	4	2
Passive recreation (eg, reading, listening to music)	4	3	2
Financial situation	2	3	2
Relationship with your spouse (girlfriend or boyfriend, if not married)	4	3	1
Sex life	4	3	1
Family relations	4	3	2
Other social relations	4	3	2
Self-expression/self-improvement	6	3	3
Religious expression	6	3	1
Community and civic involvement	7	3	1
Total	58	40	21

[a] Illness Intrusiveness Rating Scale ratings range from 1 ("Not Very Much") to 7 ("Very Much").

Results of Physical Therapist Examination After Virtual Reality Exposure Treatment and Before Vestibular Physical Therapy

After having completed virtual reality exposure treatment, Mr N was referred for physical therapy by the psychiatrist for his remaining fear of height and his dizziness. He began physical therapy approximately 2 weeks after completing his virtual reality exposure treatment. Mr N described 2 types of dizziness that could occur simultaneously. He described the first type as dizzy spells that felt like spinning and almost like falling. These dizzy spells occurred 6 to 7 times per day and lasted 30 to 45 minutes. The second type was a sensation of fogginess that included difficulty concentrating. The 2 types of dizziness often occurred together and were associated with sweating, nausea, and shortness of breath.

Fast head movements could trigger the dizziness. While standing, he might lose his balance and have to compensate with a step or by holding on to something. On escalators, he would hold on to the railing so as not to stumble when getting off. He experienced discomfort when rinsing his hair in the shower with his eyes closed, looking up at tall buildings, moving from a supine to a sitting position, bending over, turning while walking, viewing rotating ceiling fans, or even lying in bed with his eyes closed. When the dizziness was the most severe, he had to keep the lights on in the bedroom. He found that stabilizing his head by folding his hands behind the back of his head helped. Going to church elicited dizzy and foggy feelings. He felt uncomfortable and disoriented in grocery stores or the mall, particularly when they were crowded, and he avoided buses, trains, crowds, and standing in line.

The results on the optic flow test suggested that his visual dependence had not decreased. These changes were reflected in Mr N's report that he was able to help hang Christmas lights on his neighbor's roof; however, he experienced feelings of dizziness and imbalance while doing so.

Mr N's Dizziness Handicap Inventory (DHI)[52] score was 60, and his Activities-Specific Balance Confidence (ABC)[53] scale score was 35%. A Spearman correlation coefficient of .97 has been reported for test-retest reliability of scores on the DHI in people with vestibular disorders.[52] Both the DHI and the ABC have been shown to yield data with concurrent validity in people with

vestibular disorders, with a Spearman rank-order correlation coefficient of .64.[54] Scores on the DHI[55] range from 0 to 100, with higher scores indicating greater handicap. A score of greater than 60 has been related to falls in the 6 months prior to the start of physical therapy in people with vestibular disorders.[55] The ABC has been used with people with vestibular disorders, and the median score of people under the age of 65 years has been reported to be 58.[54]

Mr N also rated his symptoms related to visually complex scenes. He rated his discomfort at 60 to 70 out of 100, with 100 representing the worst discomfort, when he was in rich visual environments such as grocery stores or large hardware stores with high walls. The 0-to-100 verbal analog scale has been used previously with people with vestibular disorders to assist in determining their level of discomfort with visually complex scenes.[56] We asked the patient to report how distressed he became after being exposed to complex visual scenes as a global marker of his visual discomfort.

An upper- and lower-quarter screen revealed that muscle force, sensation, and range of motion appeared to be normal for his age. Mr N reported no falls in the previous 6 months. He said that he had great difficulty walking in the dark.

Mr N had moderate symptoms with vestibulo-ocular reflex (VOR) cancellation and had mild to moderate symptoms when asked to rate symptoms as "a little" (mild), "medium" (moderate), or "a lot" (severe) with VOR × 1. The patient had been asked to focus on an object while moving his head and eyes at the same time as the object (VOR cancellation) and to focus on a stable business card at arm's length as he moved his head to the right and left (VOR × 1). Mr N had a negative Halmagyi head-thrust test,[57,58] and he had no spontaneous nystagmus, no gaze-evoked nystagmus, and a normal head-shaking nystagmus test.

His Timed "Up & Go" Test (TUG) score was 10.7 seconds.[59] He almost fell into the wall after turning toward the left while performing the TUG, and his score on the Berg Balance Scale was 56/56.[60,61] Both the Berg Balance Scale and the TUG have been used to assess balance in young people with vestibular disorders.[62,63]

During the Sensory Organization Tests of Computerized Dynamic Posturography, Mr N had a composite score of 65. Scores below 70 are considered abnormal. Specifically, his score was below normal on one trial of condition 3 (standing on a firm surface with the visual surround sway referenced), he fell during one trial of condition 5 (standing with eyes closed on a sway-referenced platform), and his scores were below normal for all 3 trials of condition 6 (standing with eyes open, sway-referenced surface, and visual surround).

Table 4.
Root Mean Square (RMS) and Average Velocity (VEL) Measurements Computed for the Anterior-Posterior (A-P) Center of Pressure (COP) During the Period of Optic Flow Stimulation

	Session		
Sway Measure	**1**	**2**	**3**
RMS A-P COP (cm)	1.2	2.2	0.8
RMS M-L COP (cm)	0.5	0.8	0.2
VEL A-P COP (cm/s)	3.2	7.9	1.8
VEL M-L COP (cm/s)	1.1	1.9	0.3

Mr N's Dynamic Gait Index (DGI)[64,65] score was 23 out of 24. His gait speed was 1.13 m/s.[66] A gait speed of 1.22 m/s is necessary to walk across a signaled intersection.[67]

Mr N was able to stand on foam with eyes open and closed for 30 seconds,[68,69] although his dizziness increased after standing on the foam. He was able to stand on a firm surface in the Romberg position for 60 seconds with eyes open and in the tandem Romberg position for at least 30 seconds.

In general, Mr N was stable while walking and with static balance activities, and he had normal abilities to stand on compliant surfaces. He did have complaints with eye/head movements (VOR cancellation and VOR × 1), and his posturography findings showed a vestibular pattern. The response profile directed our choice of vestibular exercises. He seemed to complain of symptoms with head movement, especially when he was also standing on a compliant surface.

Vestibular Physical Therapy

Table 1 includes a description of the physical therapy interventions within each physical therapy session, the home exercises that were provided, and how the patient felt about his home exercise program. He was given activities that challenged his balance or that made him dizzy. The exercises were designed to increase his symptoms, but he was told that the symptoms should not last longer than 20 to 30 minutes after performing his exercises. He was instructed to perform all exercises twice a day, each day of the week.

Outcomes

On the CAQ, the patient's score following vestibular physical therapy was 20, which is only 0.25 standard deviation above (ie, more phobic than) the average post-intervention level reported by Rothbaum et al[33] (Tab. 2). It is 1.7 standard deviations below (ie, less acrophobic than) that of Rothbaum and colleagues' untreated control group. On the Attitude Towards

Table 5.
Quality-of-life Scores on the Medical Outcomes Study 36-Item Short-Form Health Survey Questionnaire (SF-36)

SF-36 Subscale	Before Behavioral Therapy		After Behavioral Therapy		After Vestibular Physical Therapy		Reliable Change Indices[a]		
	Score	z[b]	Score	z	Score	z	2–1	3–2	3–1
Physical Function	80	−0.18	90	0.249	95	0.464	1.15	0.574	1.72[c]
Role–Physical	100	0.56	100	0.562	100	0.562	0	0	0
Bodily Pain	84	0.37	100	1.05	84	0.371	1.51	−1.51	0
General Health	42	−1.47[c]	47	−1.23	57	−0.734	0.4	0.799	1.2
Vitality	50	−0.52	65	0.196	70	0.435	1.36	0.452	1.81[c]
Social Function	50	−1.47[c]	75	−0.366	100	0.736	1.38	1.38	2.75[d]
Role–Emotional	33.3	−1.45[c]	100	0.567	100	0.567	3.37[d]	0	3.37[d]
Mental Health	44	−1.70[d]	84	0.514	88	0.735	3.91[d]	0.391	4.3[d]

[a] Reliable change index (RCI)=change/standard error of change (positive=improvement), 2–1=before behavioral therapy compared with after behavioral therapy, 3–2=after behavioral therapy compared with after vestibular physical therapy, 3–1=effect of 2 interventions combined.
[b] *z* score=(norm mean–Mr N's score)/standard deviation of norm.
[c] $P<.10$.
[d] $P<.05$ (1-sided test for *z* scores, 2-sided test for RCI).

Heights Questionnaire, the patient's item responses, ranging between 4 and 5, indicated a neutral attitude toward heights. His SMD decreased from 3.8 to 1.9 on the SMD-I, corresponding to the 75th percentile of controls. His SMD-II score decreased from 11.1 to 3.3, corresponding to the 89th percentile of controls without SMD.

Measures of gait, balance, or perceived handicap either stayed the same or improved over the 8-week physical therapy intervention period (Tab. 2). On the optic flow test (Tab. 4, Fig. 4), the large-amplitude, high-frequency oscillations were reduced. There was a large reduction from post–behavioral therapy training to post–physical therapy, with the final values lower than at the start of behavioral therapy. These findings, along with the improvement in SMD scale level, suggest that the patient had become less visually dependent. Furthermore, examination of the SUDs scale ratings (Fig. 5) revealed lower ratings than during the first 2 test occasions. The administrator of the test noted that the patient no longer used arm movements to maintain balance during the optic flow testing.

On the Illness Intrusiveness Rating Scale,[38] his ratings in the domains of relationship with spouse, sex life, and diet changed positively for the first time after physical therapy; in addition, further improvements occurred in most of the domains that had begun to improve after behavioral therapy. After the 2 programs combined, only his rating in the financial situation domain remained unimproved, but Mr N had not judged this to be affected by the fear of heights. His rating in the religious expression domain, one of Mr N's treatment goals, improved.

On the SF-36, the patient showed further increases on a number of subscales that, however, fell below our RC requirement (Tab. 5). Nevertheless, improvement on the Social Function and Vitality subscales occurred only after both interventions combined. In addition, there was a trend for his level of physical function to improve, as he had reported pretreatment limitations in participating in vigorous exercise, bending over, or walking more than a mile. With respect to the Vitality subscale, which had not been abnormally low before intervention, the posttreatment value was within the upper half of the population.

A coauthor (EFO) who had not provided his physical therapy interviewed Mr N about his experience with both virtual reality and physical therapy. He said that both interventions were "successful" and that he was able to "function better in my daily activities." He described going to a hockey game and being able to sit in seats that were high up, something he could not do previously. He said that he really wanted "to beat this" and therefore had been motivated to go through the intervention.

He had some difficulty comparing one intervention with the other, because he viewed them as complementing one another. He did say that, during the last few sessions of the virtual reality, he was more aware (or convinced that) it was not real, but that at the beginning it was frightening and he was able to overcome much of his fear.

The patient reported, "vestibular physical therapy helped both my balance problems and my height problem." At the time of the interview, he was not performing vestibular exercises at home, but said he knew how to do them and felt that he had strategies available to him to help him with his height phobia.

Discussion

The use of vestibular physical therapy for anxiety disorders has only recently been examined.[9,25,29] In this case

report, physical therapy was provided for a patient with height phobia without laboratory evidence for vestibular dysfunction but with clinical signs of imbalance. The physical therapy exercises addressed the hypothesized underlying mechanism, namely increased visual dependence resulting in an increase in height vertigo. The outcomes suggested that, whereas anxiety and avoidance improved following behavior therapy, SMD and self-reported balance scores improved only after vestibular physical therapy. Exercises were provided that attempted to increase the weighting of his somatosensory inputs so that he could use somatosensation more effectively when stressed in a height situation. The addition of exercises to promote awareness of somatosensory inputs may have enhanced his confidence in height situations, as suggested by Brandt et al.[70]

Mr N initially had an excellent Berg Balance Scale score (56/56) and DGI score (23/24). Most physical therapists would probably not have treated this person; he was not at risk for falls based on his Berg Balance Scale and DGI scores, although his perception of handicap and balance confidence was impaired. We are not aware of any reports of vestibular physical therapy intervention used to manage a person with acrophobia and pathologic height vertigo.

The most difficult head/eye movement that he was asked to perform was VOR cancellation. This is evident based on the number of weeks (n=5) that VOR cancellation was assigned as an exercise. The visual movement in the background when performing VOR cancellation increased his dizziness. The VOR cancellation exercise was provided as a form of habituation exercise.[71] By the sixth visit, Mr N reported that VOR cancellation was much easier to perform. The VOR cancellation in the pitch (up and down movement) plane remained difficult for him longer than in the horizontal plane, as observed by his physical therapist.

Based on his reports, Mr N's ability to function in the community and within his family improved after the combination of virtual reality and physical therapy. The changes probably were not the result of spontaneous recovery because he had been fearful of heights for 19 years. Clearly, a controlled trial is needed to determine whether vestibular physical therapy is helpful in the management of people with height phobia and dizziness.

Conclusion

Mr N demonstrated moderate improvement in his perception of his handicap and a decrease in his fear-avoidance behavior after virtual reality behavioral therapy, but his SMD and postural sensitivity to optic flow stimuli did not decrease. These variables improved by the end of an 8-week vestibular physical therapy intervention program. It appears that vestibular physical therapy might be a valuable adjunct to virtual reality behavioral training in people with acrophobia related to excessive height vertigo. It is possible that some of the observed changes were actually sequelae of the virtual reality behavioral training, and not a result of the subsequent physical therapy intervention. Further study is needed to determine whether vestibular physical therapy is useful in the management of acrophobia and pathological height vertigo.

References

1 Balaban CD, Jacob RG. Background and history of the interface between anxiety and vertigo. *J Anxiety Disord.* 2001;15:27–51.

2 Duncan B, Clark D, Leslie MI, Jacob JG. Balance complaints and panic disorder: a clinical study of panic symptoms in members of a self-help group for balance disorders. *J Anxiety Disord.* 1992;6:47–53.

3 Jacob RG, Lilienfeld SO, Furman J, et al. Panic disorder with vestibular dysfunction: further clinical observations and description of space and motion phobic stimuli. *J Anxiety Disord.* 1989;3:117–130.

4 Pogany E. Height vertigo. *Monatsschr Ohrenheilkd Laryngorhinol.* 1958; 92:209–213.

5 Staab JP, Ruckenstein MJ. Which comes first? Psychogenic dizziness versus otogenic anxiety. *Laryngoscope.* 2003;113:1714–1718.

6 Jacob RG, Redfern MS, Furman JM. Optic flow-induced sway in anxiety disorders associated with space and motion discomfort. *J Anxiety Disord.* 1995;9:411–425.

7 Furman JM, Jacob RG. A clinical taxonomy of dizziness and anxiety in the otoneurological setting. *J Anxiety Disord.* 2001;15:9–26.

8 Jacob RG, Woody S, Clark DB, et al. Discomfort with space and motion: a possible marker of vestibular dysfunction assessed by the situational characteristics questionnaire. *Journal of Psychopathology and Behavioral Assessment.* 1993;15:299–324.

9 Yardley L, Britton J, Lear S, Bird J, Luxon LM. Relationship between balance system function and agoraphobic avoidance. *Behav Res Ther.* 1995;33:435–439.

10 Jacob RG, Furman JM, Durrant JD, Turner SM. Panic, agoraphobia, and vestibular dysfunction. *Am J Psychiatry.* 1996;153:503–512.

11 Jacob RG, Furman JM, Durrant JD, Turner SM. Surface dependence: a balance control strategy in panic disorder with agoraphobia. *Psychosom Med.* 1997;59:323–330.

12 Perna G, Dario A, Caldirola D, et al. Panic disorder: the role of the balance system. *J Psychiatr Res.* 2001;35:279–286.

13 Redfern MS, Furman JM. Postural sway of patients with vestibular disorders during optic flow. *J Vestib Res.* 1994;4:221–230.

14 Brandt T. Visual vertigo and acrophobia. In: Dix M, Hood JD, eds. *Vertigo.* London, United Kingdom: John Wiley & Sons Ltd; 1984:439–466.

15 Brandt T, Arnold F, Bles W, Kapteyn TS. The mechanism of physiological height vertigo, I: theoretical approach and psychophysics. *Acta Otolaryngol.* 1980;89:513–523.

16 Gatev P, Thomas S, Kepple T, Hallett M. Feedforward ankle strategy of balance during quiet stance in adults. *J Physiol.* 1999;514 (pt 3):915–928.

17 Bles W, Kapteyn TS, Brandt T, Arnold F. The mechanism of physiological height vertigo, II: posturography. *Acta Otolaryngol.* 1980;89:534–540.

18 Duarte M, Zatsiorsky VM. Effects of body lean and visual information on the equilibrium maintenance during stance. *Exp Brain Res.* 2002;146:60–69.

19 Darlington CL, Smith PF. Molecular mechanisms of recovery from vestibular damage in mammals: recent advances. *Prog Neurobiol.* 2000; 62:313–325.

20 Horak FB, Henry SM, Shumway-Cook A. Postural perturbations: new insights for treatment of balance disorders. *Phys Ther.* 1997;77:517–533.

21 Redfern MS, Yardley L, Bronstein AM. Visual influences on balance. *J Anxiety Disord.* 2001;15:81–94.

22 Bronstein AM. Visual vertigo syndrome: clinical and posturography findings. *J Neurol Neurosurg Psychiatry.* 1995;59:472–476.

23 Bronstein AM. Visually induced body sway in patients with visual vertigo, in vestibular and neural front. In: *Proceedings of the 12th International Symposium on Posture and Gait.* Amsterdam, the Netherlands: Elsevier; 1994:569–572.

24 Eagger S, Luxon LM, Davies RA, et al. Psychiatric morbidity in patients with peripheral vestibular disorder: a clinical and neuro-otological study. *J Neurol Neurosurg Psychiatry.* 1992;55:383–387.

25 Jacob RG, Whitney SL, Detweiler-Shostak G, Furman JM. Vestibular rehabilitation for patients with agoraphobia and vestibular dysfunction: a pilot study. *J Anxiety Disord.* 2001;15:131–146.

26 Rahko T. The test and treatment methods of benign paroxysmal positional vertigo and an addition to the management of vertigo due to the superior vestibular canal (BPPV-SC). *Clin Otolaryngol.* 2002;27:392–395.

27 Pavlou M, Bronstein AM. The use of optic flow for the rehabilitation of visuo-vestibular symptoms. *J Vestib Res.* 2002;11:234.

28 Pavlou M, Lingeswaran A, Davies RA, et al. Simulator-based rehabilitation in refractory dizziness. *J Neurol.* 2004;251:983–995.

29 Beidel DC, Horak FB. Behavior therapy for vestibular rehabilitation. *J Anxiety Disord.* 2001;15:121–130.

30 Jang DP, Ku JH, Choi YH, et al. The development of virtual reality therapy (VRT) system for the treatment of acrophobia and therapeutic case. *IEEE Trans Inf Technol Biomed.* 2002;6:213–217.

31 Ku J, Jang D, Shin M, et al. Development of virtual environment for treating acrophobia. *Stud Health Technol Inform.* 2001;81:250–252.

32 Rothbaum BO, Hodges LF, Kooper R, et al. Effectiveness of computer-generated (virtual reality) graded exposure in the treatment of acrophobia. *Am J Psychiatry.* 1995;152:626–628.

33 Rothbaum BO, Hodges LF, Kooper R, et al. Virtual-reality graded exposure in the treatment of acrophobia: a case report. *Behav Res Ther.* 1995;26:547–554.

34 Balaban CD, Thayer JF. Neurological bases for balance-anxiety links. *J Anxiety Disord.* 2001;15:53–79.

35 *DSM-IV-TR: Diagnostic and Statistical Manual of Mental Disorders.* Arlington, Va: American Psychiatric Association; 1994.

36 Cohen DC. Comparison of self-report and overt behavioral procedures for assessing acrophobia. *Behav Ther.* 1977;8:17–23.

37 Romas RT, Jacob RG, Lilienfeld SO. Space and motion discomfort in Brazilian versus American patients with anxiety disorders. *J Anxiety Disord.* 1997;11:131–139.

38 Devins GM, Binik YM, Hollomby DJ, et al. Helplessness and depression in end-stage renal disease. *J Abnorm Psychol.* 1981;90:531–545.

39 Cina CS, Clase CM. The Illness Intrusiveness Rating Scale: a measure of severity in individuals with hyperhidrosis. *Qual Life Res.* 1999;8:693–698.

40 Antony MM, Brown TA, Barlow DH. Heterogeneity among specific phobia types in DSM-IV. *Behav Res Ther.* 1997;35:1089–1100.

41 Ware JE Jr, Sherbourne CD. The MOS 36-Item Short-Form Health Survey (SF-36), 1: conceptual framework and item selection. *Med Care.* 1992;30:473–483.

42 Ware JE Jr. Using generic measures of functional health and well-being to increase understanding of disease burden. *Spine.* 2000; 25:1467.

43 Adler DA, Bungay KM, Cynn DJ, Kosinski M. Patient-based health status assessments in an outpatient psychiatry setting. *Psychiatr Serv.* 2000;51:341–348.

44 Ware JE Jr, Gandek B. Methods for testing data quality, scaling assumptions, and reliability: the IQOLA (International Quality of Life Assessment) Project approach. *J Clin Epidemiol.* 1998;51:945–952.

45 Enloe LJ, Shields RK. Evaluation of health-related quality of life in individuals with vestibular disease using disease-specific and general outcome measures. *Phys Ther.* 1997;77:890–903.

46 McHorney CA, Ware JE Jr, Lu JF, Sherbourne CD. The MOS 36-Item Short-Form Health Survey (SF-36), III: tests of data quality, scaling assumptions, and reliability across diverse patient groups. *Med Care.* 1994;32:40–66.

47 Jacobson NS, Truax P. Clinical significance: a statistical approach to defining meaningful change in psychotherapy research. *J Consult Clin Psychol.* 1991;59:12–19.

48 Jacob JG, Lilienfeld SO. Panic disorder: diagnosis, medical assessment and psychological assessment. In: Walker JR, Norton TR, Ross CA, eds. *Panic Disorder and Agroaphobia: A Comprehensive Guide for the Practitioner.* Pacific Grove, Calif: Brooks/Cole Publishing Co; 1991: 16–102.

49 Schuemie MJ. *Human-Computer Interaction and Presence in Virtual Reality Exposure Therapy* [dissertation]. Delft, the Netherlands: de Technische Universiteit Delft; 2003.

50 Winter DA, Patla AE, Prince F, et al. Stiffness control of balance in quiet standing. *J Neurophysiol.* 1998;80:1211–1221.

51 Emmelkamp PM, Krijn M, Hulsbosch AM, et al. Virtual reality treatment versus exposure in vivo: a comparative evaluation in acrophobia. *Behav Res Ther.* 2002;40:509–516.

52 Jacobson GP, Newman CW. The development of the Dizziness Handicap Inventory. *Arch Otolaryngol Head Neck Surg.* 1990;116: 424–427.

53 Powell LE, Myers AM. The Activities-Specific Balance Confidence (ABC) Scale. *J Gerontol A Biol Sci Med Sci.* 1995;50:M28–M34.

54 Whitney SL, Hudak MT, Marchetti GF. The Activities-Specific Balance Confidence Scale and the Dizziness Handicap Inventory: a comparison. *J Vestib Res.* 1999;9:253–259.

55 Whitney SL, Wrisley DM, Brown KE, Furman JM. Is perception of handicap related to functional performance in persons with vestibular dysfunction? *Otol Neurotol.* 2004;25:139–143.

56 Whitney SL, Wrisley DM, Brown KE, Furman JM. Physical therapy for migraine-related vestibulopathy and vestibular dysfunction with history of migraine. *Laryngoscope.* 2000;110:1528–1534.

57 Cremer PD, Halmagyi GM, Aw ST, et al. Semicircular canal plane head impulses detect absent function of individual semicircular canals. *Brain.* 1998;121(pt 4):699–716.

58 Halmagyi GM, Curthoys IS. A clinical sign of canal paresis. *Arch Neurol.* 1988;45:737–739.

59 Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc.* 1991;39: 142–148.

60 Berg K. Balance and its measure in the elderly: a review. *Physiother Can.* 1989;41:240–246.

61 Berg K, Wood-Dauphinne S, Williams JI, Gayton D. Measuring balance in the elderly: preliminary development of an instrument. *Physiother Can.* 1989;52:304–311.

62 Whitney SL, Wrisley DM, Furman JM. Concurrent validity of the Berg Balance Scale and the Dynamic Gait Index in people with vestibular dysfunction. *Physiother Res Int.* 2003;8:178–186.

63 Wrisley DM, Whitney SL, Furman JM. Vestibular rehabilitation outcomes in patients with a history of migraine. *Otol Neurotol.* 2002;23: 483–487.

64 Shumway-Cook A, Gruber W, Baldwin M, Liao S. The effect of multidimensional exercises on balance, mobility, and fall risk in community-dwelling older adults. *Phys Ther.* 1997;77:46–57.

65 Shumway-Cook A, Woollacott M. *Motor Control: Theory and Practical Applications.* Baltimore, Md: Williams & Wilkins; 1995.

66 Bohannon RW. Comfortable and maximum walking speed of adults aged 20–79 years: reference values and determinants. *Age Ageing.* 1997;26:15–19.

67 Langlois JA, Keyl PM, Guralnik JM, et al. Characteristics of older pedestrians who have difficulty crossing the street. *Am J Public Health.* 1997;87:393–397.

68 Horak FB. Clinical measurement of postural control in adults. *Phys Ther.* 1987;67:1881–1885.

69 Shumway-Cook A, Horak F. Assessing the influence of sensory interaction on balance. *Phys Ther.* 1986;66:1548–1550.

70 Brandt T, Bles W, Arnold F, Kapteyn TS. Height vertigo and human posture. *Adv Otorhinolaryngol.* 1979;25:88–92.

71 Herdman SJ, Whitney SL. Treatment of vestibular hypofunction. In: Wolf S, ed. *Vestibular Rehabilitation.* 2nd ed. Vol 2. Philadelphia, Pa: FA Davis Co; 2000:387–423.