



Perceived Anxiety and Simulator Sickness in a Virtual Grocery Store in Persons with and without Vestibular Dysfunction



Susan L. Whitney, PhD, PT
Patrick J. Sparto, PhD, PT
Sabarish V. Babu, MS
Larry F. Hodges, PhD
Joseph M. Furman, MD, PhD
Mark S. Redfern, PhD





University of Pittsburgh Department of
Physical Therapy

University of Pittsburgh Department of
Otolaryngology

University of Pittsburgh Department of
Bioengineering

University of North Carolina at Charlotte,
Department of Computer Science

DEPARTMENT OF COMPUTER SCIENCE

UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE



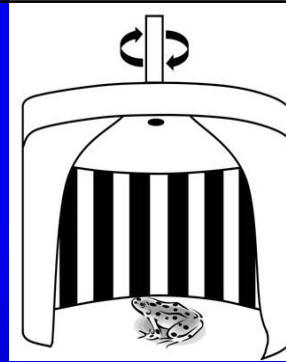
Collaborators

- ◆ Jim Cook, BS
- ◆ Rolf G. Jacob, MD
- ◆ Plus all of our talented staff



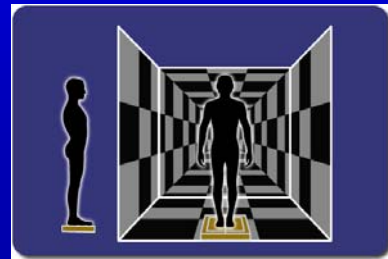
Background

- ◆ Visual motion and flow can cause patients with vestibular disorders to feel disoriented and nauseous.
- ◆ Anxiety and simulator sickness is evident during virtual reality exposures with persons with vestibular disorders (Sparto et al, 2004; Whitney et al., 2005; Whitney et al., 2002; Whitney et al., 2006)



Background

- ◆ People with vestibular disorders may have greater reliance on visual cues, resulting in increased sway in visual provocative situations (Redfern et al, 2002; Whitney et al., 2005).



Background

- ◆ It has been reported that patients with vestibular disorders are sensitive to optic flow (Redfern & Furman, 1994), similar to what has been reported in persons with anxiety disorders who were sensitive to body sway during full-field visual motion from an optic flow stimulus (Redfern, Furman, & Jacob, 2006).





Subjects

- ◆ Twenty healthy subjects with no evidence of neurological disease (10 female, mean age 45 y, range 21 to 79 years)
- ◆ 10 patients with unilateral vestibular hypofunction, UVH (4 female, mean age 58 y, range 37 to 69 years)

Subjects

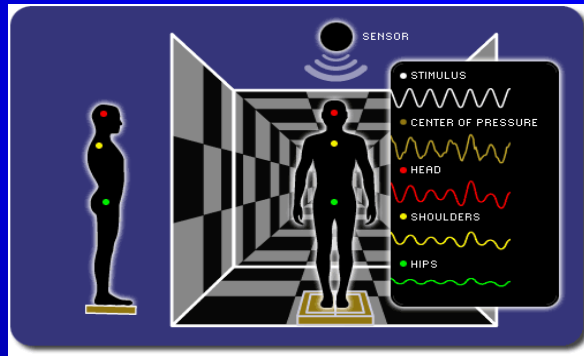
- ◆ All healthy subjects had undergone a neurologic screening and had a normal vestibular test battery that included electronystagmography (positional testing, calorics and oculomotor), rotational chair, and computerized dynamic posturography.
- ◆ Patients underwent the same test battery and all were diagnosed with unilateral peripheral vestibular hypofunction.

Instrumentation

- ◆ A single-aisle virtual grocery store was displayed in a full field-of-view CAVE-like virtual environment (2.4 m high, 2.4 m wide, 1.5 m deep (Sparto et al, 2004))
- ◆ Three 2.4 m X 1.8 m (vertical X horizontal) back-projected screens

Instrumentation

- ◆ The front screen is 1.5 m from the user, and the opening of the BNAVE at the location of the subject is approximately 2.9 m.
- ◆ The update rate of the images is consistently at least 30 frames per second.
- ◆ Perspective was not updated based on head location.



BNAVE



Subjects walked through a virtual grocery store while pushing on a grocery cart instrumented with force transducers.

The speed of the treadmill and movement through the store was proportional to the amount of force applied to the cart handle.

Speed was limited to 1.2 m/s.

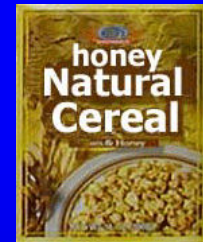
Procedures

- ◆ Navigated down the aisle by:
 - a) standing and pushing forward on a joystick
 - b) walking on a custom-made treadmill placed within the environment.



Procedures

- ◆ Subjects performed 6 trials divided into 2 blocks: a walking block (3) and a standing block (3) of trials
- ◆ The order was counterbalanced across visits
- ◆ During two trials (i.e. one in each block), subjects were asked to search for common cereal boxes (Frosted Flakes and Cheerios) that had been pseudo-randomly placed 20 times along the length of a 120 m aisle.



Procedures

- ◆ The aisle was a repeating pattern of shelves that were 5 m long with a 2 m inter-shelf break
- ◆ There were 30 other brands of products in the “full” store
- ◆ The ratio of the number of “target” products to the number of “distractor” products was approximately 8%

Procedures

- ◆ During 2 of the trials, subjects searched for the 2 target products, but half of the shelf space was empty, resulting in a target-to-distractor product ratio of approximately 16%
- ◆ On 2 other trials, subjects moved down the aisle without searching for any products (No Search condition).

Procedures

- ◆ Subjects were “taught” what they were to search for in the virtual store
- ◆ They were instructed to move through the scene at their comfortable speed



Procedures

- ◆ All subjects completed the Subjective Units of Discomfort (SUDS) and the Simulator Sickness Questionnaire before and after each trial



Subjective Units of Discomfort

- ◆ Subjects rated their level of anxiety/discomfort on a 0-100 scale with 0 indicating no discomfort and 100 indicating that they needed go to the emergency room

Simulator Sickness Questionnaire (Kennedy et al, 1993)

- ◆ Subjects rated the intensity of 16 symptoms from 0 (none) to 3 (severe)
- ◆ The number of symptoms that had an intensity greater than 0 for the SSQ was computed for each trial



Data analysis

- ◆ Differences in SUD and SSQ between healthy controls and subjects with UVH were examined with the non-parametric Mann-Whitney U test, using the median of each subject's scores as the estimate of central tendency

Patient walking- full store



Older control walking with a full
grocery store



Percentage of trials in which controls (CON) and subjects with unilateral vestibular hypofunction (UVH) reported Subjective Units of Discomfort (SUD) greater than zero, or reported at least one symptom on the Simulator Sickness Questionnaire (SSQ).

% non-zero events	SUD	SSQ
CON	39%	29%
UVH	81%	81%

Results

- ◆ There were no differences in SSQ or SUD scores by day (visits were approximately one week apart)

Range of median Subjective Units of Discomfort (SUD) scores reported before and during exposure to virtual grocery store. Median scores for “Pre-Test” computed from 2 trials (2 visits X 1 trial). Median scores for “Test” computed from all 12 trials (2 visits X 6 trials).

SUD	Pre-Test	Test
CON	0 for 11 subjects 2.5, 3.5, 4, 4, 5, 9, 12.5, 30	0 for 11 subjects 1, 2.5, 4, 4, 6.5 10, 10.5, 20
UVH	0 for 1 subject 1, 9, 10.5, 12.5, 15, 25, 25, 30, 30	0 for 2 subjects 10, 11.5, 17.5, 22.5, 22.5, 27, 29, 60

Subjects with UVH had greater median SUD scores compared with controls during both the pre-test assessment and virtual reality exposure, $p = 0.002$.

Range of median Simulator Sickness Questionnaire (SSQ) scores reported before and during exposure to virtual grocery store. Median scores for “Pre-Test” computed from 2 trials (2 visits X 1 trial). Median scores for “Test” computed from all 12 trials (2 visits X 6 trials).

SSQ	Pre-Test	Test
CON	0 for 15 subjects 0.5, 0.5, 0.5, 0.5, 1	0 for 14 subjects 0.5, 1, 1, 1, 2, 2
UVH	0 for 2 subjects 0.5, 1, 2, 4, 4.5, 6, 8, 9	0 for 2 subjects 1, 1.5, 2, 2, 4, 9, 9.5, 12

Subjects had greater number of symptoms reported on the SSQ than controls ($p < 0.002$)

SSQ and SUD correlation

- ◆ Among the subjects with UVH, a significant correlation existed between the median SUD and median number of symptoms reported on the SSQ (Spearman $\rho = 0.850$, $p = 0.002$). No such relationship existed for the control subjects (Spearman $\rho = -0.09$, $p = 0.72$), probably due to the large number of scores equal to zero.

Discussion

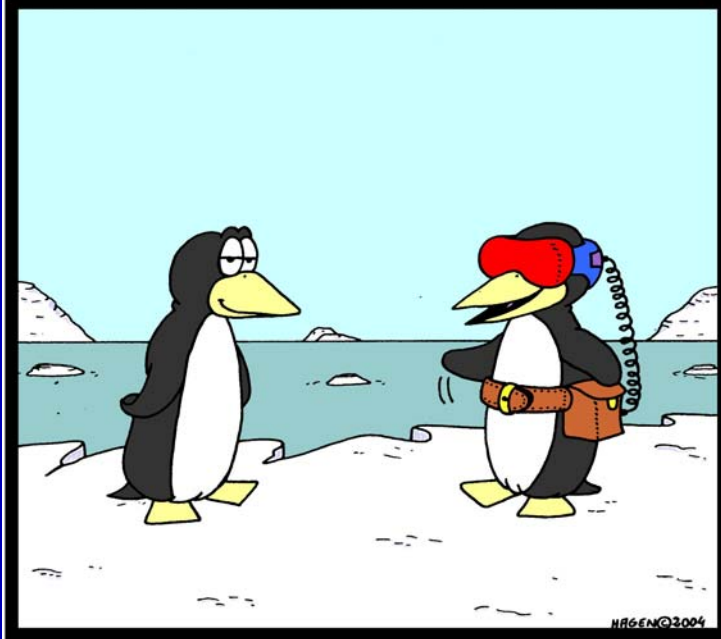
- ◆ Subjects with and without vestibular abnormalities were able to complete all trials when navigating through a virtual grocery store, except for one patient

Discussion

- ◆ Patients and control subjects seems to be equally able to manage this somatosensory-visual conflict and resolve it, as no patients fell or reported problems with the visual scene

Conclusion

- ◆ Subjective measures recorded after virtual reality exposure suggest that there were no differences between visits, making changes demonstrated from virtual reality exposure more likely to be a change in perceived health status versus learning of the virtual reality task
- ◆ Subjective measures recorded after exposure to the virtual reality grocery store are stable over time



These virtual-reality goggles are great!
Right now, I'm sun-bathing in Tahiti...

