Kay M. Stanney and
Robert S. Kennedy

# The Psychometrics of Cybersickness

The aftereffects from exposures to virtual environments have often been evaluated using the Simulator Sickness Questionnaire (SSQ) [1], which was originally devised to evaluate computer-based simulator systems. The SSQ consists of a checklist of 26 symptoms, each of which is related in terms of degree of overall severity (none, slight, moderate, severe), with the highest possible total score (most severe) being 300. A weighted scoring procedure is used to obtain a global score reflecting the overall discomfort level known as the Total Severity (TS) score. The SSQ also provides scores on three subscales representing separable but somewhat correlated dimensions of simulator sickness (i.e., nausea, oculomotor disturbances, and disorientation). In addition to total score differences, results from the SSQ highlight an interesting difference between VE exposures and other disorienting environments. The immediate post-exposure profiles usually indicate that VEs tend to produce more disorientation (D) than neurovegative (N) symptoms, such as nausea, and fewer oculomotor-related (O) disturbances, such as eyestrain. It is important to note that this D>N>O profile does not match the profiles of other provocative environments, including space sickness, which has an O>D>N profile, simulator sickness, which has an O>N>D profile, or seasickness and airsickness, which have N>D>O profiles [2]. This VE profile is reliable, having been replicated in four diverse VE systems, using different HMDs. With flight simulators and VEs both being visually interactive environments, one might expect their symptom profiles to match. However, their diverse profiles indicate quite convincingly these systems produce different symptoms. The differences between these profiles need to be evaluated and understood.

Beyond differences in the pattern of symptoms, VE systems also produce consistently greater TS scores. Whereas simulator systems averaged around 10 on the SSQ, VE systems are averaging above 20, with some systems going as high as 50. The incidence of symptoms is also considerably greater with some VE systems. With flight simulators, 30% to 40% of users reported being asymptomatic. However, the actual incidence could be higher, as pilots

artn (http://www.artn.nwu.edu/Video/Sketch1.html)

are often motivated not to report medical symptoms they may experience as a result of flight-simulation sessions. In early VE studies, only 5% to 10% of users reported no symptoms, indicating adverse symptoms could be common among VE system users. Many current VR systems have had few reports of severe motion sickness. It is important to keep in mind symptoms can range from as little as a slight headache, to emesis (severe nausea) in rare incidences.

With extended or repeated exposures, however, users tend to become less sick as they adapt to the VE. However, this adaptation can create its own problems—when users return to the real world they are still adapted to the virtual world and must readapt to the real world. Because of the anecdotal state of knowledge regarding these phenomena, objective measures of VE aftereffects are currently under development. These include measures of postural stability, hand-eye coordination, and visual functioning [3, 4]. These objective measures will also be used to determine whether the aftereffects from VE exposure dissipate.

There is evidence to suggest cybersickness may be overcome or moderated by providing users with an optimal level of user-initiated control over their movements in the virtual world. This is akin to the phenomenon of the driver of a car being much less susceptible to motion sickness than the passengers in the same car. The following paragraphs briefly describe what is known about user-initiated control in VEs [5].

Users of VEs can be expected to experience a high rate of incidence and severity of cybersickness if they are forced to traverse a virtual world as passive observers with no control over their movements.

Active motion is superior to passive motion in minimizing cybersickness, but it may not be the best solution to the cybersickness problem. Under active control, users can move about a VE with total freedom of motion. Under such conditions, users may not be able to handle efficiently the abundant amount of sensory information that is generated as a result of their unrestricted movements. Thus, while cybersickness may eventually be overcome under active control conditions, because users can predict and thus adapt to their movements in the VE, this process may occur at a slower rate than under coupled control conditions.

Coupled control, where user control is mapped to the needs of the tasks, is an effective method for minimizing cybersickness. By allowing users task-oriented control within a VE, users can adapt quickly to their streamlined movements in the altered world and not be encumbered by the extraneous sensory information associated with active control.

Cybersickness can be further minimized by basic commonsense practices, beginning with a gradual exposure to the VE. Until the user has adapted to the VE, exposure time should be limited and time should be allowed between sessions. We find that intervals of two to five days between sessions are best for adaptation, although each user will adapt at a different rate and should proceed accordingly.

Tasks requiring high rates of linear or rotational acceleration, as well as those requiring unusual maneuvers (such as moving backward) should not be attempted until the user has fully adapted to the VE. Users should be provided with a task-defined amount of user-initiated control at a moderate speed. Scene content should be kept relatively simple, minimizing visual flow.

Users should be informed of potential aftereffects and advised to allow for recovery time after VE exposure before engaging in activities such as driving an automobile. The appropriate recovery time will be directly related to the VE exposure time. By using these general practices, designers of VEs can implement design strategies that minimize the adverse effects of human-VE interaction.

## References


1. Kennedy, R.S., Lane, N.E., Berbaum, K.S., and Lilienthal, M.G. Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The Int. J. Aviat. Psych.* 3, 3 (1993), 203–220.
2. Kennedy, R.S., Lane, N.E., Lilienthal, M.G., Berbaum, K.S., and Hettinger, L.J. Profile analysis of simulator sickness symptoms: Applications to virtual reality systems. *Presence 1*, 3 (1992), 295–301.
3. Kennedy, R.S. and Stanney, K.M. Postural instability induced by virtual reality exposure: Development of a certification protocol. *Inter. J. Human-Comput. Inter. 8*, 1 (1997), 25–47.
4. Stanney, K.M. and Kennedy, R.S. Development and testing of a measure of the kinesthetic position sense used to assess the aftereffects from virtual environment exposure. *Virtual Reality Annual International Symposium*. Los Alamitos, Calif. IEEE Computer Society Press, 1997.
5. Stanney, K.M. and Hash, P. Locus of user-initiated control in virtual environments: Influences on cybersickness. *Presence*. To be published.



**Kay M. Stanney** (stanney@iems.engr.ucf.edu) is an associate professor at the University of Central Florida in Orlando.
**Robert S. Kennedy** (rkennedy@msis.dmso.mil) is vice president of Essex Corporation in Orlando.