The Search For A Cybersickness Dose Value

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1 Introduction

Cybersickness refers to the sickness phenomenon associated with the use of virtual reality systems. When a user views a wide field-of-view moving scene inside a virtual environment, an illusion of self-motion (vection) in the opposite direction can occur and the experience can be nauseogenic. This paper presents the initial development of a Cybersickness Dose Value (CSDV) and explores how this CSDV can be used to predict the severity of cybersickness.

2 Problems of Cybersickness

A virtual reality (VR) system enables a user to interact with a computer-generated 'virtual' environment (Furness and Barfield, 1995) and is useful in operator training applications (e.g., driving simulation: Bayarri *et al.*, 1996; flight simulation: Haas, 1984; equipment simulation: Lin *et al.*, 1996). However, symptoms of motion sickness (e.g., nausea and headache) have been reported among users who navigate through a virtual simulation for 20 minutes or longer (e.g., passive navigation: So, 1994; active navigation: Regan, 1995; Finch and Howarth, 1996; Stanney and Kennedy, 1997, 1998; Kolasinski and Gilson, 1998; Draper, 1998). Some studies reported sickness occurrence even after 10 minutes of exposure (e.g., Wilson *et al.*, 1997). This type of sickness has been referred to as 'cybersickness' (McCarley and Sharkey, 1992) and its occurrence has hindered the widespread applications of VR simulators. A review of literature indicates that cybersickness has been the subject of many studies (see Table 1). The results of these studies have provided a body of knowledge, which can be used to predict levels of cybersickness. The rest of the paper will explore the possibility of formulating a Cybersickness Dose Value (CSDV) for predicting the levels of cybersickness.

Table 1 Summary of experimental studies of cybersickness (excluding studies of simulator sickness in a non-VR environment, adapted from Lo and So, 1998).

Variables investigated	**References**
Duration of exposure (including with / without exposure)	Bliss *et al.* (data from Kennedy and Stanney, 1997); Lampton *et al.* (1994a,b); Lo and So (1998); Kennedy *et al.* (1995); Kolasinki and Gilson (1998); Regan and Price (1993a,b,c); Regan (1995); Salzman *et al*. (1995); So (1994); Stanney and Kennedy (1997, 1998); Wilson *et al.* (1997)
Types of VR displays	Costello and Howarth (1996); Howarth and Costello (1997); Lampton *et al.* (1994); Wilson *et al.* (1997)
Display's field-of-view	DiZio and Lackner (1997)
Display lags	DiZio and Lackner (1997); So (1994)
Stereoscopic presentation	Ehrlich (1997)
Method of navigation	Finch and Howarth (1996); Rich and Braun (1996);
Age, gender, posture stability	Ehrlich (1997); Ehrlich *et al*. (1998); Kolasinski (1996); Regan & Price (1993b,c); Rich & Braun (1996)
Sitting Vs Standing	Regan and Price (1993b)
Amount of head movement interactions	Regan (1995); So (1994)
Drug treatment	Regan (1995)
Axes of scene movement (rotational axes)	Lo and So (1998); So and Lo (1998a)
Types of scene	Draper, 1998; Kennedy *et al.*, 1994; Kennedy *et al*., 1996; Slater *et al* (1996); So and Lo (1998b,c)

3 Previous studies of Motion Sickness Dose Value

Predicting levels of motion sickness with a dose value is not new. The development of Motion (sea) Sickness Dose Value (MSDV) for predicting sea sickness can presently be used to predict the percentage of sea passengers who will vomit for a given voyage (British Standard 6841). A review of literature indicates that at the center of the MSDV, there is a basic unit, acceleration, which quantifies the physical motion that is responsible for symptoms of motion sickness (Griffin, 1990, British Standard 6841). The MSDV is essentially a time integral of this basic unit (i.e., frequency weighted vertical ship acceleration):

$$MSDV = \left[\int a^n(t)\, dt \right]^{1/n}$$

where a is the frequency-weighted vertical ship acceleration (ms^{-2})
n is 2 or 4

Griffin (1990) reported that for n = 2 or 4, a good correlation has been found between the values of the MSDV and the percentage of vomit incidence among sea passengers.

4 A proposed Cybersickness Dose Value (CSDV)

A literature review on studies of cybersickness indicates that the levels of cybersickness increase with increasing duration of exposure (see row1, Table 1). A Cybersickness Dose Value (CSDV) having a similar structures as the MSDV is, therefore, proposed:

$$CSDV = \int_0^T [basicunit]\, dt$$

Where T is the duration of a VR simulation

As seen from the proposed formula, a basic unit, which quantifies the dominant factors responsible for the generation of cybersickness, has to be identified. According to the sensory conflict theory (Reason and Brand, 1975), cybersickness can be classified as a type of vection-induced motion sickness (Hettinger and Ricco, 1992). This implies that visual scene movements during a Virtual Reality (VR) simulation will introduce illusion of self-motion (i.e., vection). In the absence of appropriate physical motion, the vection will give rise to symptoms of cybersickness. Following this theory, the dominant factor responsible for cybersickness will be visual scene movement. So and Lo (1998b) developed a metric to quantify the visual scene movement during a VR simulation. This metric is called ‘Spatial Velocity (SV)’.

Experimental results have shown that both the rated levels of nausea and the total sickness severity scores measured using the Simulator Sickness Questionnaire developed by Kennedy *et al.* (1993) increased linearly with the ‘spatial velocity’ measurements (Figure 1). Details concerning the ‘Spatial Velocity (SV)’ metric can be found in So and Lo (1998b). Currently, experiments are being conducted to study the effects of frequency of scene movement on the level of cybersickness. Assuming a frequency weighting can be developed for the SV metric, the proposed CSDV formula can be modified as follows:

$$CSDV = \int_0^T [frequencyweightedSV]\, dt$$

Inspection of Table 1 shows that the effects of task-related, display-related, and subject-related parameters on cybersickness have been studied. In particular, the effects of field-of-view (DiZio and Lackner, 1997; Draper, 1998); stereoscopic presentation (Ehrlich, 1997); lags (So, 1994; DiZio and Lackner, 1997); gender (Kolasinski, 1996; Rich and Braun, 1996); and methods of navigation (Rich and Braun, 1996) have been examined. In order to account for these effects, the proposed CSDV can be modified as follows:

$$CSDV = [D]\, x\, [T]\, x\, [S]\, x \int_0^T SV_w\, dt$$

where [D] is the display-related scaling factor
[T] is the task-related scaling factor
[S] is the subject-related scaling factor
SV_w is the frequency weighted Spatial Velocity metric

As the proposed CSDV is intended to predict the 'average' level of cybersickness associated with a particular VR simulation, the subject-related scaling factor would be derived from the average data of a population rather than individuals. On the other hand, both the display and task-related scaling factors can be specified to a particular VR simulation program and apparatus.

5 Final Remarks

Based on the existing knowledge concerning cybersickness, an initial form of a Cybersickness Dose Value (CSDV) is proposed to predict the levels of cybersickness. This CSDV is essentially a time integral of a unit called 'Spatial Velocity, SV' developed to quantify the visual scene movement during a Virtual Reality simulation. With the proposed CSDV, the author intends to stimulate further research towards the modelling and prediction of the occurrence and severity levels of cybersickness.

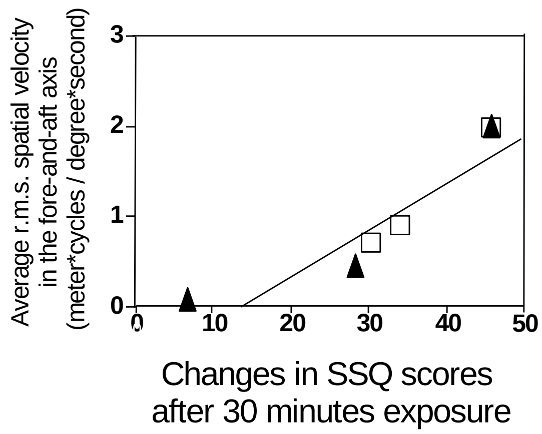

Figure 1 Levels of SSQ Total Sickness Severity scores with different levels of Spatial Velocity (SV). (▲, ❑: data from two experiments) adapted from Lo and So, 1999).

6 References

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