

Cybersickness Affects the Affective Appraisal of a Virtual Environment

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Abstract. It is well known that navigation through VEs may have a negative effect on the physical well-being of observers, by inducing cybersickness. In this study we investigated if cybersickness interacts with the appraisal of a simulated environment. Using the Half-Life 2 level editor we created a VE representing fictitious rural and urban areas. This environment was displayed by means of back projection onto a semi-transparent (frosted) screen, and was viewed from 1 m distance. For a 17 minute period, 32 subjects passively watched a walk through this VE, where the visual scene continuously performed a quasi-sinusoidally frontal roll oscillation. Immediately after the exposure, the remaining subjects filled out an appraisal questionnaire rating the environment on 4 dimensions: arousing-sleepy, pleasant-unpleasant, exciting-gloomy and distressing-relaxing. Two subjects were unable to complete the experiment due to severe nausea. When we divide our subject population into two categories: “non-sick” when the physical well-being ratings were below 2 (19 subjects), and “sick” for ratings of 2 or higher (11 subjects), we find a statistical significant effect of sickness on appraisal ($p < 0.003$). A post hoc test contributes this to the arousing-sleepy dimension ($p < 0.05$) and the pleasant-unpleasant dimension ($p < 0.06$): sick subjects typically rate more sleepiness and unpleasantness than non-sick subjects. We conclude that cybersickness may be a confounding factor in the affective appraisal of VEs.

Introduction

Planners and architects like to assess the affective appraisal evoked by their designs before they are actually being built. Computer visualizations are an important means to this end. They are not only relatively cheap, but also facilitate a viewpoint through the eyes of an actual visitor. As a result an appraisal evoked by viewing a VE is supposed to be more similar to the real situation than that elicited by viewing for instance a maquette. However, simulation restrictions inherent in the medium, such as the use of a 2D screen and

the absence of olfactory and tactile sense input, may cause the affective appraisal of a virtual environment to differ from that of the real environment it simulates. Differences in the affective appraisal of virtual and real places have in fact been found, for instance by Bishop and Rohrmann (2003), Wernemyr *et al.* (2003) and De Kort *et al.* (2003). This decreases the transfer validity of the obtained knowledge in the virtual environment to the real world. To increase the validity of VEs for planning and design purposes it is therefore essential to know the factors that influence an affective appraisal. We hypothesize that cybersickness is one of these factors. No experiments have been

done that specifically link the physical wellbeing of a person to the perceived affective qualities of an environment. However, it is known that an affective appraisal is influenced by environmental stressors, 'chronic and intractable environmental conditions that, although nonurgent, are negatively valued and place adaptive demands on people' (Holahan, 1986). For instance, helicopter noise was found to negatively influence the perceived aesthetic qualities of the Grand Canyon (Mace *et al.*, 1999) and crowding in store environments to detriment the affective experience of shopping, resulting in people actively avoiding the environment in the future (Machleit *et al.*, 1994). Additionally, when malodorous scents were dispersed into a museum room, the paintings present received lower scores on aesthetics than in the unpolluted instance (Rotton, 1983).

These are all external stressors however, whereas cybersickness may be considered an internal stressor. As said, there is no direct evidence of a person's wellbeing influencing the affective appraisal of an environment, but Russell (2003) states evidence that a person's internal affective state could influence the appraised affective qualities of an object by misattribution. The argument then proceeds thusly: people feeling unpleasant could mistakenly attribute this to the environment and appraise it as being unpleasant.

Research methodology

Design. For the purpose of this and future research a virtual environment was created with the Half-Life 2 Source SDK level editor. The virtual environment comprises rural, mostly coastline, areas, an industrial vista and an urban area, depicting a city with mixed European architecture (Figs.1-4). Due to the use of a contemporary game engine, the graphics are up to modern day standards.

The navigation through the virtual space was passive, i.e. without user control, in order to assure that every person had the same impression of the environment. The

walk through the environment started from a beach and ended in the city, and lasted approx. 12 minutes. At the end of the first walkthrough, the presentation would start over, run for another five minutes and stop at a designated part in the city, after which the participant was asked to appraise the environment (s)he was looking at.



Figure 1. Area to be appraised.



Figure 2. Example of a coastline area in the VE.



Figure 3. Example of a cityscape in the VE.



Figure 4. Another cityscape in the VE.

Stimuli. The stimuli pertaining to the induction of cybersickness were: a geometric field of view (GFOV) of 60 degrees, an oscillatory motion around the forward axis, a large screen projection and the walk through the environment itself.

The choice for these stimuli is a result of a number of considerations. Primarily, we wanted to induce cybersickness without hindering the formation of an affective appraisal. The picture consequently had to be relatively stable without distorting the environment greatly. We therefore chose a gentle swaying motion of the camera over one axis. However, it also needed to induce cybersickness within a relatively small amount of time, before participants would get bored which might confound the affective appraisal as well. Previous research indicated that motion sickness related symptoms are most prevalent when either a roll or pitch motion is performed (Bles *et al.*, 2000; Lo and So, 2001). As the roll motion ensures a better look at the scenery to be appraised, this was deemed the best option. See Figure 6 for a pictorial example of the roll axis.

However, an extensive pilot study showed that the roll motion alone was not enough to effectively induce cybersickness. Therefore, a polygenic measure (i.e. the large screen and slightly smaller than average GFOV) was implemented which had sufficiently proven to be effective (see Bos *et al.*, Internal and external field of view and cybersickness, these proceedings).

During the pilot it also became apparent that participants were able to accustom to the roll motion when a normal sinusoid was implemented. Therefore an unpredictable complex harmonic motion, a linear combination of three sinusoids, was used. The function was defined as

$$\varphi = a \sin\left(\frac{2\pi}{a}\right) + b \sin\left(\frac{2\pi}{b}\right) + c \sin\left(\frac{2\pi}{c}\right). \quad (1)$$

$$amp(t) = 8 \left(\frac{\varphi}{\max \varphi} \right). \quad (2)$$

where $a = 7.2$, $b = 4.1$ and $c = 4$. These constants were selected in order to get the highly erratic oscillation as shown in figure 5.

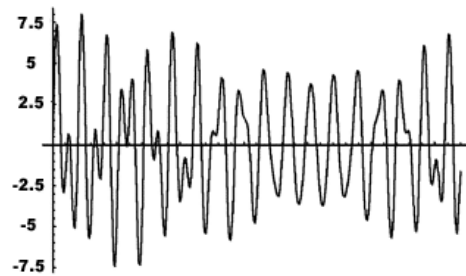


Figure 5. Unpredictable roll oscillation of the camera, ranging from +8 to -8 degrees.

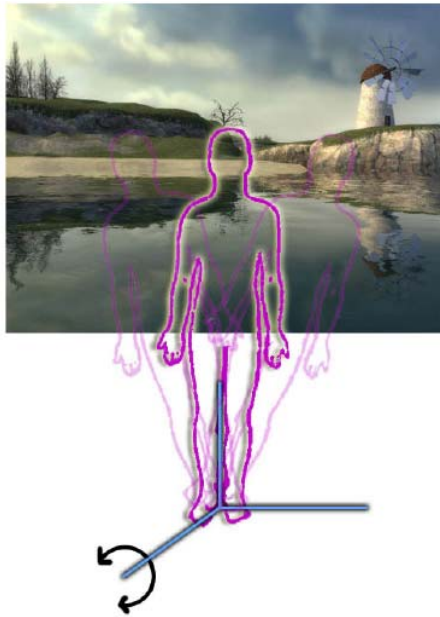


Figure 5. Frontal roll axis, resulting in swaying camera.

Measurement scales. As So *et al.* pointed out after evaluating 50 different experiments, nearly all research on motion, simulator and cybersickness makes use of the Simulator Sickness Questionnaire (SSQ) (So *et al.*, 2001), a subjective self-report scale first introduced by Kennedy and Lane (1993). The SSQ, while giving an accurate depiction of cybersickness, is a rather long questionnaire however. As the average affective appraisal questionnaire is also comprehensive, there were fears that cybersickness could subside over the course of the final appraisal task. Furthermore, this is an exploratory research and the effect of cybersickness was deemed more important than the cybersickness itself. Consequently for the evaluation of cybersickness a short 0-10 index score scale, the Misery Scale (MISC) was used, as good results had already come from this in previous in-house research, by Bos *et al.* (2004). MISC scores range from no symptoms (0), undeterminable symptoms (1) and slight determinable symptoms (2) gradually upwards to vomiting (10).

A number of different measurement scales for the affective appraisal were considered, most notably the Semantisk Miljö Beskrivning (Semantic Environment Description, SMB) by Küller (1977) and a scale by Russell and Pratt (1980). Both are in the form of a self-report scale, where participants rate a list of affective adjectives on a seven and eight point scale respectively, which are then grouped into different dimensions comprising the appraisal. The SMB-scale provides a broader appraisal of the environment, comprising both cognitive and affective descriptors, while Russell and Pratt's scale focuses solely on affective adjectives. We suspected that the cognitive perception of the environment would remain unaffected by the cybersickness, and therefore the increased nuance of the latter score was preferred. Additionally, a shorter version of Russell and Pratt's scale made it possible to do more tests without tiring the participants.

Russell and Pratt's scale describes the affective qualities of a molar environment as a 2D space, with the independent dimensions unpleasant-pleasant and arousing-sleepy on the two main axes. Diagonally through these axes are the dimensions exciting-gloomy and distressing-relaxing, which can optionally be inferred from the two main axes.

Apparatus. The experiment was conducted on two different computers. One was a Dell XPS700 desktop pc with an Intel Core2 Duo 6600 chipset, running at 2.4 GHz and with 2GB of RAM. The video card was a GeForce 7950 GX2 in dual SLi mode, with 1024MB of RAM. The other computer was a Dell XPS600, with an Intel Pentium 4 processor, running at 3.6 GHz and containing 1GB of internal RAM. This computer's video card was a GeForce 7800GTX in dual SLi mode, with 256MB RAM. Both computers used a beamer to back-project the generated virtual environment on a semi-transparent ('frosted') screen 1.46 by 1.09 meters in dimensions, at a resolution of 1024 by 768, with a screen refresh rate of 75Hz.

Participants were seated in a chair with a headrest, at approximately 1.2 meters viewing distance. Occasionally, when a participant got highly nauseous, they were allowed to sit slightly further away from the screen, as this probably wouldn't influence the mental representation of the virtual world much.

Participants. The test group consisted of $N = 32$ persons, but 2 persons had to forfeit prematurely because they reached a MISC score of 8 or higher after 7 and 9 minutes, which was the preset ceiling of this experiment. Imposing the participants to continue while feeling very sick was considered unethical, thus for the end result the Valid $N = 30$. The average age was $\mu = 45.8$, with the minimum age being 20, the maximum age 68 and $\sigma = 15.2$. However as a possibly confounding factor, the ages aren't evenly distributed, with participants being either a college student, or normally distributed around the age of fifty. 15 Persons were male and 17 persons female. The persons that quit prematurely were a 68 year old man (also the oldest participant), and a 47 year old woman.

Procedure. The participants first filled in a questionnaire where they stated how proficient they were with virtual environments, first person shooters and Half-Life 2 in particular. This was important, as people who recognize the scenery from the game may recall the set pieces in the game from the corresponding environments, which could in turn influence their affective appraisals. However, only two people reported having played Half-Life 2 and when prompted after the experiment neither said they recognized any locale. After this they appraised the affective qualities of a picture of a neo-renaissance building that resembled the target area of figure 1, according to Russell and Pratt's shortened scale. This was done to accustom the participants with the measurement scale, and to ascertain the participant's affective appraisal of this type

of cityscape. The scores are plotted in the scatterplot of figure 7, showing a homogeneous liking of this architectural style. After completing these three questionnaires, the participants were delegated to the darkened experiment room and seated in the setup. There they watched the tour of the virtual environment, during which they were occasionally prompted to note down their MISC scores. At the end of the presentation the camera froze on the area depicted in figure 1. Here, the lights in the room were turned on dimly, and the participants appraised this particular part of the environment with Russell and Pratt's affective scale.

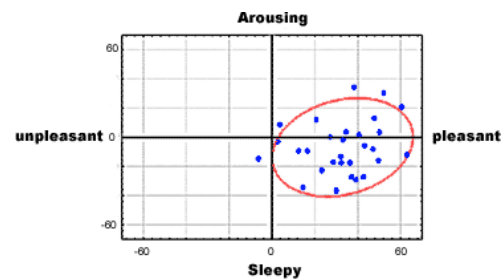


Figure 7. Scatterplot with 95% confidence ellipse detailing the affective appraisals of the photograph.

Hypothesis

As figure 7 shows, prior to the experiment nearly all participants found an exemplary neo-renaissance style architectural cityscape to be pleasant and, for the greater part, slightly sleepy. Given the unpleasant effects of cybersickness, we expected that the cybersick participants would find the environment less pleasant as well.

Results

30 People finished the experiment. Of these, 7 reported no effect at all during the whole exposure, and 13 ended feeling fine. The last MISC report was used as the criterion for the following statistical analysis, as it most accurately described the person's wellbeing during the appraisal task. 16 Participants reported different degrees of

cybersickness, although the MISC scores they reported were unevenly distributed over the spectrum, with 19 participants scoring a 0 or a 1, and a nearly even distribution of the remaining MISC scores. The small number of people per MISC score meant that an accurate decomposition of the effect of different degrees of cybersickness on the affective appraisal of virtual environments was problematic. This was further complicated by the fact that people could stop after reporting an 8, while the onset of nausea, which would hypothetically lead to the highest change in affective appraisal, doesn't start until level 6. Although a simple multivariate regression did return a significant result, the small amount of people that ended with cybersickness and the apparent high variation per MISC score, gives the model a low fidelity.

Therefore the participants experiencing cybersickness were pooled into a single group, which makes for a more robust comparison. The MISC score can be divided into four categories: participants experiencing no effect (0), participants experiencing undeterminable symptoms (1), and participants experiencing determinable symptoms in varying amounts of severity (2-10).

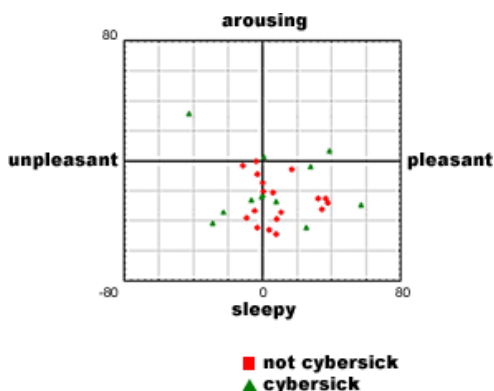


Figure 8. Scatterplot detailing the affective appraisals of the VE.

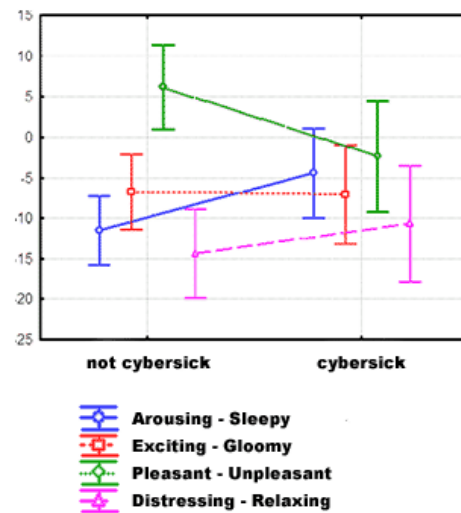


Figure 9. Trends showing the effect of cybersickness on the affective appraisal.

As determinable cybersickness is onset from a score of 2 or higher, this semantic divide was chosen as the demarcation criterion (incidentally nobody scored a three, hence the de facto divide is 0-1 and 3 and higher). Consequently two groups were formed, one consisting of 19 participants who were deemed physically well, and one consisting of 11 participants, who were deemed cybersick. These two groups can then be compared with a One-Way ANOVA, with the cybersickness grouping as categorical predictor and the four different affective dimensions as dependent variables. The plot of this test can be seen in figure 9, where the affective dimensions differ significantly as a result of the cybersickness: $N = 30$, $Wilks\lambda = 0.52$, $F(2,25) = 5.723$, $p < 0.003$.

In this plot, a high score on the arousing-sleepy scale corresponds to a high level of arousal, while a low score indicates a low arousal (or highly sleepy). Likewise, a high score on the pleasant-unpleasant dimension corresponds to a high level of attributed pleasantness; a high score on the exciting-gloomy dimension indicates the participant found the environment exciting; and scoring high on the distressing-relaxing scale means the environment is distressing. The graph shows even more change than

was initially hypothesized. Participants who are cybersick ostensibly not only find the environment less pleasant, but also more arousing, and possibly more distressing.

Examining these scores with a post-hoc Tukey test reveals that the significant result of the four dimensions combined is mostly due to a significant effect on the pleasant-unpleasant dimension ($p < 0.05$), while the effect on the arousing/sleepy scale barely reaches significance ($p = 0.051$). Differences in the exciting/gloomy and distressing-relaxing scale are insignificant however, so the regression line representing distressing-relaxing should be regarded with caution. If the possible outlier in the second quadrant is deleted, Excluding this person from the scores still makes the overall affective appraisal is still significantly different for the cybersickness predictor ($N = 29$, Wilks $\lambda = 0.55$, $F(4,24) = 4.995$, $p < 0.005$), but the singular significance in the post-hoc Tukey tests disappears for both arousal-sleepy and pleasant-unpleasant.

Discussion

The experiment has satisfactorily proven that cybersickness has an effect on the affective appraisal of virtual environments. This therefore has relevant implications for a number of different uses of virtual environments. For instance in urban planning, the designers of a simulation need to take precautions not to induce cybersickness. Moreover, now that it is known that cybersickness not only causes physical discomfort, but also changes the way people appraise the environment, it becomes pressing in the area of training and education as well, and a further understanding of means to alleviate cybersickness an even more relevant research topic. Somewhat undecided remains the matter of how the cybersickness changes the affective appraisal of the virtual environment, however. A significant difference has been found on the pleasant-unpleasant dimension, and a possible significance on the arousing-sleepy dimension. Although this wasn't tested

during this experiment, it gives some circumstantial support to the attribution hypothesis noted by Russell (2003), that a person's affective appraisal of the environment is influenced by the affective state a person is in. It would implicate that people misattribute less pleasantness to the buildings of a city when they're feeling bad themselves. Likewise it is conceivable that due to increased heart rate and sweating from the cybersickness, a person's self-assessment of arousal increases too, and is subsequently misattributed to the environment.

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