# Internal and external Field of View: computer games and cybersickness

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**Abstract.** In an experiment with a computer game environment, we studied the effect of Field-of-View (FOV) on cybersickness. In particular, we examined the effect of differences between the internal FOV (IFOV, the FOV which the graphics generator is using to render its images) and the external FOV (EFOV, the FOV of the presented images as seen from the physical viewpoint of the observer). We hypothesized that incongruent IFOVs and EFOVs would lead to a larger incidence of cybersickness. However, this was not found, and the opposite seems to be true instead. The unexpected result may be explained by the relative large differences between IFOV and EFOV we used.

## Introduction

Studies of visually induced motion sickness mainly involve vehicle simulators and other forms of virtual environments (e.g., Kennedy et al., 1994). A relatively underexposed category in this context is made up by computer games, in which case the term cybersickness is often used. Computer games have become more and more sophisticated, with graphics that match or even exceed those of military simulators costing millions of dollars only a couple of years ago. With the advancement of computer games, the phenomenon of cybersickness raises its ugly head to a larger public than ever before, as a short search on the internet may attest. The problem is also growing due to the increasing number of game players potentially afflicted. The relevance of this topic is furthermore given by the importance of virtual reality and games for training and simulation (also called *serious gaming*).

For many years it has been known that training simulation may cause sickness in pilots, drivers, or sailors. Sometimes this is inevitable as the scenarios that have to be trained are provocative even in real life. In other cases, however, it seems to be due to the use of inappropriate image presentation. By using commercial-of-the-shelf software (games) serious gaming can be a relatively low-cost approach reaching many people. Its success is considered to depend on the attractiveness of games combined with a smart didactic approach. Cybersickness would be contributing negatively to this, and therefore deserves special attention

It appears that cybersickness is a multifactor problem (McCauley & Sharkey, 1992; Stanney et al, 1998; Viola, 2000). One issue studied relatively frequently concerns that of vection, i.e., a sense of self-motion induced by optic flow in physically stationary subjects (e.g., Cheung et al., 1991; Brandt et al., 1973; Dichgans and Brandt, 1978; Hu et al., 1997; Lo and So, 2001; Stanney et al., 1998). Here, a discrepancy between different inputs to the different senses seems to cause the problems (Reason and Brand, 1975; Bos et al., 2007). Besides vection, more contributing factors have been defined, many of them having been studied in a merely qualitative way. Some of these factors are related to technical features (optical distortion, field-of-view, flicker, motion platforms, refresh rate, resolution, transport delays, update rate). Other factors are related to user characteristics (experience, gender, field independence, age, illness, mental rotation ability, postural instability, susceptibility to motion sickness); and again others related to exposure schedules (duration, repetition).

In the current research we focus on the role that Field-of-View (FOV) plays in cybersickness. With smaller displays, vection is less powerful, which results in lower SSQ scores (Simulator Sickness Questionnaire, Kennedy et al., 1989). According to Brandt et al. (1973), displays smaller than 30° are not very effective in inducing vection. In a literature review, Stanney et al. (1998) note that both small and wide FOV's may induce nausea.

It should be noted that optic flow of two classes of movement (rotation and translation) behave radically different for low and high FOVs. If a game uses a low FOV for its image calculations, rotations around a player's vertical axis cause a large translational flow in the image. For instance, with a horizontal FOV of 10 degrees, a head rotation with a speed of 180 deg/s causes 18 screens to zip by each second. Translations of the player in the same low-FOV game cause a relatively low, divergent optic flow. The opposite is true for high-FOV games. In this case, rotations of the player cause a smaller translational optic flow onscreen (with a horizontal FOV of 60 degrees and a rotation of 180 deg/s only 3 screens/s), but translations of the player yield a higher (divergent) optic flow pattern.

Depending on the nature of the game and the playing style of the player the size of the FOV may or may not play a role. In general, vehicle simulators will have a large translational component. Airplanes have yaw motions that are typically in the order of 3 deg/s, whereas players of first person shooter (FPS) games may have yaw speeds of several hundreds of deg/s. This implies that results obtained for simulators may not be generalisable to games and vice versa.

Another notable difference between simulators and games is that whereas in the simulator case utmost care is taken to position the user in the correct design location, nothing of the sort is done for the player of games. To our knowledge, no game instruction booklet provides information on the game's internal FOV, nor is anything stated about optimal viewing distance in relation to the player's screen size. In fact, given typical viewing distances and screen sizes a typical player's FOV (which we will call in this article the *external* FOV or EFOV) is 30 deg vertically, whereas game engines typically use a calculated FOV (which we will call in this article the *internal* FOV or IFOV) of 75-90 deg vertically. That means that unless displays triple in size, IFOV and EFOV will be different for most games and gamers.

For the above reasons we decided to study the effect of FOV magnitude in gaming situations together with the effect of congruency of IFOV and EFOV. With Kolasinsky (1995), we hypothesize that the design viewpoint of the imagery should coincide with the actual viewpoint in order to lower the chance of cybersickness to occur. In our case this would imply that equal IFOV and EFOV would give less sickness than incompatible FOVs.

## Method

**Apparatus.** The experiment took place in an almost dark room with dimmed fluorescent lamps at the ceiling. Two virtually identical experimental set-ups were placed in this room, separated by black curtains. Each set-up consisted of a Toshiba TDP-P6 projector, which projected at the back of a frosted rear-projection screen. Subjects sat at the other side of the screen. Both screens measured 1.46 cm (h) by 1.09 cm (v). The screen resolution was 1024 x 768 pixels. Screen refresh rate was 75 Hz.

The projectors were connected to fast gaming PCs. One PC was an XPS700 with Intel Core2 Duo 6600 chipsets running at 2.4 GHz, 2 GB memory, and dual NVIDIA GeForce 7950 GX2 graphics cards. The other PC was an XPS600 which uses a

Pentium 4 running at 3.6 GHz, 1 GB memory, and dual NVIDIA GeForce 7800 GTX graphics cards. Though the specs differ, both machines were easily able to provide the frame rate of 75 Hz at which the projector was running. Frame rate measurements of our computer generated movies showed that both were able to achieve mean frame rates of at least twice this rate. Only in some very rare occasions did the XPS600 appear to drop below 75 Hz, resulting in a slight tearing.

**Subjects.** After consulting the TNO Human Factors Ethics Committee for consent, twenty volunteer subjects (15 male and 5 female) were recruited from the TNO database. Subjects were between 19 and 31 years of age, with a mean age 22.8 years and a standard deviation of 3.1 years. All subjects were college or university students. Only 6 participants were avid FPS players: 70% had little or no experience in playing FPS games.

All subjects participated in three sessions on separate days over a period of one week, always at the same time of the day. Between each session at least 48 hours were kept to minimize aftereffects of a previous session.

To assess the susceptibility of the subjects to motion sickness, a simplified version (Bos et al., 2005) of the Motion Sickness Susceptibility Questionnaire was used (Reason and Brand, 1975; Golding, 1998).

**Experimental task.** Subjects were positioned in a comfortable office chair with their head resting against a raised headrest. Their viewpoint corresponded with the centre of the screen and they were located at such a distance from the screen that the vertical EVOF was either 30º (a distance of 203 cm) or 60º (at 58 cm). At these distances the horizontal EFOV was 49.6º and 103.1º, respectively. The internal FOV (IFOV) was chosen equal to either of these values, i.e., 30 and 60º (called the *congruent* conditions, or precisely the other value (called the *incongruent* conditions; see Table 1). Games usually have a vertical IFOV in the order of 75-90º, but enlarging the FOV that we used to get in this range was not feasible, as it required the subjects to sit so close to the screen that their knees would touch it.

Subjects viewed a tour through a virtual environment. To generate the imagery, we used the graphics engine of the game HalfLife 2 (the so-called 'Source' engine). A varied set of environments were constructed using the Source developer's kit. Scenes included open coastal environments and more up-close city areas. A selection of these environments can be seen in Figure 1. The virtual tour took place at a simulated speed of 13.6 km/h. An erratic swaying movement with a maximum amplitude of 16º was superposed on this translation to increase the imagery's potential to provoke sickness. The tour lasted for about 12 minutes and was repeated about four times to get a movie with a total length of 50 minutes.

**Procedure.** Before the experiment commenced, participants filled out a questionnaire about their physical and mental state, their experience with computer games, and their past susceptibility to motion sickness and related phenomena.

The participants were then seated at the correct distance from the screen and the virtual tour started. Just before the start of the tour the participants wrote down their MISC score (MIsery Scale: 0 = no problems at all, 1-5 = any symptom except nausea, 6-9 = nauseated, 10 = vomiting; see Wertheim et al., 2001 and Bos et al., 2005). After two minutes the tour was interrupted for a few seconds allowing the participants to rate their MISC level again. This was then repeated every multiple of five minutes. Hence, a total of 12 MISC scores was obtained. After the end of the tour (i.e., after 50 minutes) they assessed their MISC level for one more time.

The participants were instructed that they could interrupt the experiment at any time when they felt too sick to continue, which would generally be at a MISC level of 6 or higher. This happened in 12 sessions and involved 8 subjects.

Figure 1. Some locations from the virtual tour.

**Independent variables.** The IFOV and EFOV were combined to create the following four conditions (see also Table 1.):

1. Wide angle image; viewed from near by (congruent condition)
2. Wide angle image; viewed from far away (incongruent condition)
3. Tele lens image; viewed from near by (incongruent condition)
4. Tele lens image; viewed from far away (congruent condition)

Table 1. Condition numbering scheme.

| FOV | | Internal | |
|---|---|---|---|
| | | 30° | 60° |
| External | 30° | 4 | 2 |
| | 60° | 3 | 1 |

**Dependent variables.** Our primary dependent variable was the MISC rating. From all MISC scores the subjects wrote down during an experimental session the maximum value was taken (dubbed MaxMISC).

Some subjects, however, reached this maximum well within the period of 50 minutes, while others showed persistently increasing ratings, suggesting higher ratings would have been reached if the exposure would have taken longer. As an additional measure we therefore estimated the level that would eventually be reached by fitting the function

$$MISC(t) = A\,(1-\exp(-t/\tau)) \qquad (1)$$

to each set of individually obtained MISC scores. Here A will be the saturated value of the MISC and $\tau$ the time it takes to reach 63% of this value. The parameter A was limited to a value of 10.

**Design.** Due to a limited budged, we used a Balanced Incomplete Block Design in which each subject received three of the four conditions. Therefore, each of the four conditions was measured with a group of 15 subjects. Due to technical problems, strict order balancing could not be maintained throughout the experiment.

**Results**

The MSSQ yielded a mean score of 21.5 ±27 (minimum 0, maximum 84.9, SD 27.3), which is below the 50th percentile of a normal population (MSSQ=37), indicating that most of the test subjects were less prone to motion sickness than average.

A typical time course of the MISC during a session can be seen in Figure 2, together with the exponential fit according to Eq. 1. The crux of the experimental result is summarized in Figure 3. Clearly, the two incongruent conditions (2 and 3) have the lowest scores and the congruent conditions (1 and 4) have the highest scores. An ANOVA revealed the effect of condition to be significant ($F(3,35) = 12.3$, $p < .0001$ for MaxMISC and $F(3,35) = 3.4$, $p = .028$ for A). A post-hoc Tukey test revealed all the MaxMISC differences between the various conditions to be significant, except between conditions 1 and 4 and between conditions 2 and 3. A post-hoc test on A only shows the difference between conditions 1 and 3 to be significant.

To illustrate the effect of habituation, Figure 4 shows the average MISC-ratings for the different sessions. The effect of session order is only significant for MaxMISC ($F(2,35) = 3.9$, $p = .029$) and not for A. A post-hoc Tukey on MaxMISC identifies the difference between session 1 and 3 as significant ($p = .047$).

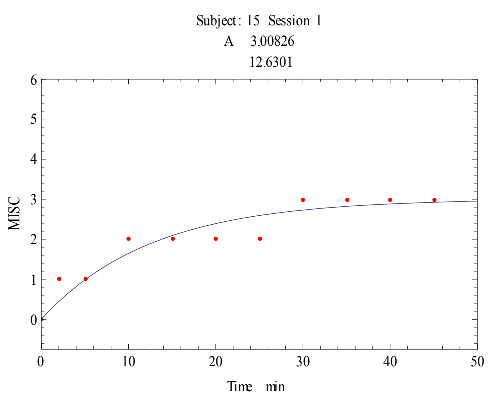


Figure 2. Typical set of MISC scores recorded during the course of a session.

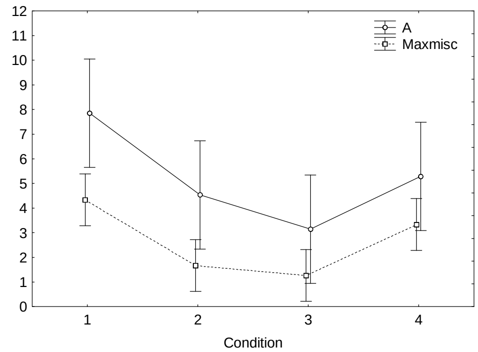


Figure 3. MaxMISC and A as a function of condition (see Table 1 for explanation of the numbers).

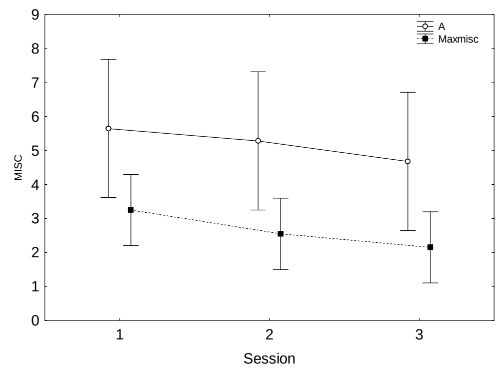


Figure 4. Effect of habituation.

## Conclusions and Discussion

A popular view is that the design viewpoint of simulator imagery should coincide with the actual viewpoint in order to lower the chance of cybersickness to occur (Kolasinsky, 1995).

In this experiment, we have found the opposite to be true: incongruent internal and external FOVs (conditions 2 and 3) led to lower average levels of sickness An explanation may be that the susceptibility to cybersickness is not a monotonous increasing function of the difference between IFOV and EFOV. It may be that for small differences sickness increases with the difference, but decreases at large differences. The current data then suggest a peak in sickness for differences smaller than a factor of 2. If this is true (and experiments with more intermediate IFOV/EFOV values are necessary to confirm this), this leads to the following prediction: The ever increasing display sizes that gamers use tends to decrease the currently existing differences between game IFOV and EFOV. Therefore, gamers will steadily approach the sweet spot of the EFOV/IFOV curve that will cause maximal cybersickness.

In the current experiment we did not find clear (significant) MISC differences between the high and low FOV displays. This suggests that, although vection is known to be "stronger" with larger FOVs, absolute FOV size itself not necessarily affects sickness.

There is, lastly, clear evidence of habituation: On average, misery was less at each succeeding session. This means that there is hope for the unlucky nauseous gamer.

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