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A visual display enhancing comfort by counteracting airsickness

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ABSTRACT

A simulator study has been conducted demonstrating a positive effect on airsickness by utilizing a 3D artificial Earth-fixed visual pattern. Participants were exposed to the same turbulent physical aircraft motion in a simulator three times in a row, each time using a different visual cue. In one condition only the interior of the simulator cabin was visible. In another condition an Earth-fixed star field moving opposite the simulator cabin was projected in front of the participant. In a third condition the same star field was used, however with additional anticipatory information by means of a rollercoaster like track showing the trajectory to go. Participants were asked for their misery and joyfulness ratings at fixed time instants using an 11-points misery scale (no problems–vomiting) and joyfulness scale (unpleasant–pleasant). The results showed that viewing an Earth-fixed visual frame moving instantaneously opposite the cabin motion did reduce motion sickness significantly by a factor of 1.6, thereby improving comfort. This condition could be applied in air transport, where often a monitor is available in the back of the seat ahead. The largest effect, i.e., a reduction by a factor of 4.2 was realized by adding anticipatory information. Although it is not possible to predict the effect of turbulence on the aircraft motion yet, an anticipatory display might already be applicable in other domains, such as at sea by using a wave radar and a ship motion model.

1. Introduction

Cybersickness describes a type of motion sickness users of virtual–reality systems or games may experience [9]. Typically, the users of such systems are not moving while they are viewing a moving pattern. Such a situation can cause a sense of self-motion or vection, possibly resulting in cybersickness. However, the perceived motion in the visual field (further simply referred as visual motion) may not only cause sickness, it may also counteract sickness by presenting an artificial Earth-fixed visual frame moving opposite the subject's vehicle, for example in the case of seasickness, carsickness and, as studied in this paper, airsickness.

In regular commercial flights, Turner et al. [15] found 16% of all passengers reporting some illness, 8% reported nausea, and 0.5% even reported vomiting, Although not substantiated by experimental evidence, we expect passenger discomfort to be even worse in small aircraft due to the larger effect of turbulence, especially at low altitudes. Besides variations in the susceptibility of airsickness among passengers [15], vertical and lateral (sway) motion are specifically known to be nauseogenic at a frequency of about 0.2 Hz [6,11].

The prevention of a discrepancy between physical and visual motion (a sensory conflict) may play an important role in counteracting airsickness and motion sickness in general. In cars, for example, less sickness is generally observed when the passenger looks outside, preferably ahead, instead of looking inward by, e.g., reading a map or book [13]. Looking at the horizon at sea is also known to be beneficial with respect to seasickness, and the positive effect of an artificial horizon has been proven before, see e.g., [12]. An artificial horizon, that is used in aviation as a flight instrument (not to counteract airsickness), indicates only pitch and roll (banking) angles (2 Degrees-of-Freedom, DoFs) and does not indicate, e.g., vertical and lateral motion. We therefore assume a larger preventive effect when an artificial imagery includes more DoFs). This assumption is also motivated by the opposing fact that in gaming higher cybersickness levels were reported when including more degrees of visual motion [7]. Besides theory relating to sensory conflict, also expectation or anticipation seems to be an issue. Usually drivers and pilots – being in control of (self-)motion – do not get sick, whereas passive passengers do [1–3,13,14]. Therefore our hypothesis is that the level of airsickness can be reduced by (1) displaying an artificial imagery that moves coherently with the physical motion (i.e., opposite the self-motion) and (2) this reduction can be enhanced by adding anticipatory information.

The objective of the study was to validate these hypotheses by demonstrating a reduction in airsickness severity by exposing subjects to a physical sickening aircraft motion in a motion simulator

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(Desdemona, see below) and adding to that an artificial Earth-fixed visual motion suggesting 6 degrees of freedom. In this experiment, we used a within subjects design with the same physical motion being presented in three different visual conditions. In a control condition, no visual pattern was shown. The participants just looked inside the illuminated simulator cabin. In another condition testing hypothesis (1), a visual pattern was presented consisting of randomly positioned 3D stars providing yaw, pitch, roll, heave, surge and sway information, showing 6 degrees of freedom except for a scaling factor (see below). This pattern was projected in front of the participants inside and effectively moving opposite to the moving simulator gondola. This is a condition that could be realized using current commercial off the shelf technology, i.e., by using inertial sensors, possibly augmented by position, altitude, attitude and velocity information from the aircraft instruments, and a monitor that is often available in front of most passengers in the back of the seat ahead. In a third condition testing hypothesis (2), additional anticipatory information was added to the 3D star field, by showing a roller coaster like path to be flown.

2. Method

2.1. Apparatus

The 6 DoF research simulator Desdemona was used as the motion platform in this study (Fig. 1a). The simulator is located at TNO (Soesterberg, The Netherlands) and was built in co-operation with AMST (Ranshofen, Austria). By its modular cabin design the simulator has various application areas such as spatial disorientation research and training, flight, driving and sailing simulation. The platform design is unconventional as compared to standard moving-base simulators, generally being Stewart platforms. The Desdemona cabin is mounted in a gimbaled system (3 DoF, >360°), which as a whole can move vertically along a heave axis (2 m stroke) and horizontally along a linear arm (8 m length). This structure as a whole can rotate around a central Earth vertical axis allowing centrifugation up to 3G.

The out-the-window visuals in the cabin have a maximum width of 120 × 40 degrees visual angle when seen from 1.5 m distance and using three projectors (60 Hz, 1024 × 768 pixels). For the current experiment, only the centre projection was used, resulting in a visual angle of 40 × 40 (see Fig. 1b).

2.2. Conditions

Table 1 shows the three different visual conditions. In condition IN the participant viewed the normal illuminated cabin interior with which they were moving all together. No image was displayed on the projection screen. In this control condition, there is a definite visual-vestibular conflict assumed to give a certain amount of sickness. In condition OUT the participants viewed a pattern of 3D objects (stars) distributed randomly in space moving coherently and opposite to the simulator motion thus realizing an Earth fixed frame of reference (see Fig. 1a). When viewing this imagery, the visual-vestibular conflict is assumed to be minimal, although the future trajectory is unknown, thus inhibiting anticipation. Sickness is therefore assumed to be less than in the control condition, although not minimal. Note that the imagery does not use the full 6 DoF because the scale factor for the translations (*x*, *y* and *z*) was undetermined, i.e., the size of the 'stars' was unknown to the viewer. Therefore this 'scale parameter' was used to create a smoothly moving pattern that could be viewed comfortably. A large scale factor would result in a (too) fast moving pattern, possibly showing discontinuities due to the rendering process, and visual discomfort. A (too) slowly moving pattern could just be ineffective for the purpose of the study. In the third, ANTI, condition, the participants viewed the same pattern as in condition OUT with a stylistic rollercoaster track showing the path to be flown in advance. This anticipatory information could be shown due to the fact that we used a preprogrammed motion profile in this study (see below). To make it intuitively clear to the viewer that this was a truly Earth fixed track, the Earth's surface including the horizon was also shown (Fig. 1b). To further avoid too fast and uncomfortable image motion, the track visibility was gradually reduced when it came in proximity 'of the airplane'. The track visibility was also reduced gradually at a predefined distance, giving the track a fixed visual length. For condition ANTI, the least level of sickness was expected because there is no visual-vestibular conflict and the future trajectory is known (see Fig. 2).

2.3. Motion

The physical and visual motions applied in the study were generated in various steps as outlined in Fig. 3 and described in the next subsections. All three conditions used the same resulting physical motion profile.

2.3.1. Turbulence motion

The flight profile used was initiated by having a certified pilot flying a figure-8 trajectory on a pc-based flight simulator (X-Plane, Laminar Research, Radcliffe, USA). The chosen aircraft model was a small propeller driven passenger or typical 'business' aircraft. The trajectory was flown at a relative low speed and a low altitude to enlarge the effect of turbulence on the aircraft motion. The 6 DoF

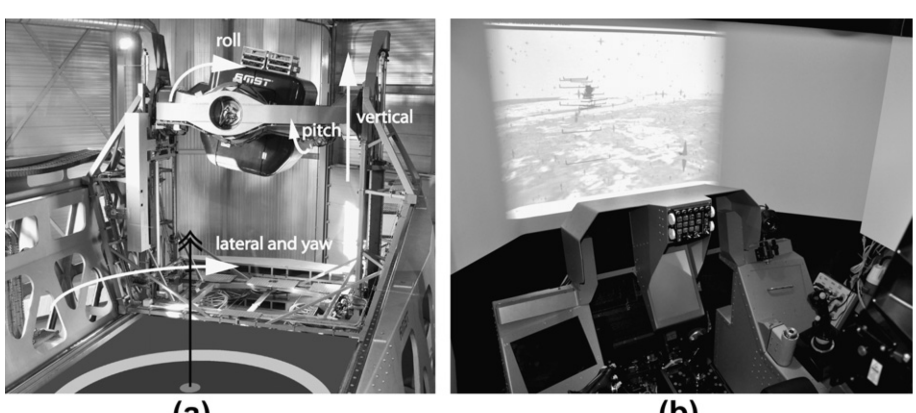

Fig. 1. The Desdemona research simulator. (a) The configuration and DoFs used in the study with the participant's nose pointing inward the paper. (b) The cabin interior with the central visual display as used in the current study.