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Influence of video content type on users' virtual reality sickness perception and physiological response

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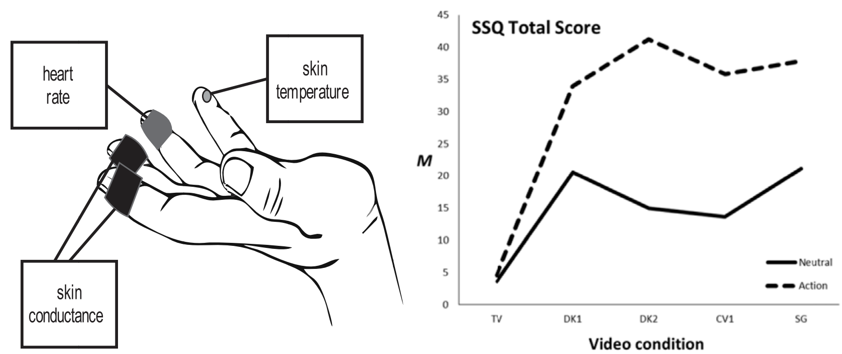
HIGHLIGHTS

- Confirmed influence of the video content type on the users' VR sickness response.
- Confirmed influence of participants' background and preferences on the VR sickness response.
- VR sickness response assessment by the SSQ, SUDS and physiological response methods.
- Evaluation of the experiment procedure (NASA-TLX).

GRAPHICAL ABSTRACT



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ABSTRACT

Virtual Reality (VR) sickness (Cybersickness) is an affliction and a challenge, common to users of virtual environments. We therefore asked ourselves this research question: "Can video content type influence users' VR sickness and physiological response?" We conducted a study with 26 participants, who watched two omnidirectional videos of different content types (neutral and action content) on five distinct video conditions: 2D TV screen, three generations of Oculus Rift VR HMDs (DK1, DK2 and CV1) and on the mobile Samsung GearVR HMD. The Simulator Sickness Questionnaire and the Subjective Units of Distress Scale in combination with the measurement of the physiological parameters (electrodermal activity and skin temperature, respiratory frequency and heart rate) were used to assess the VR sickness effects. The results show that video content type as well as users' background preferences (preference to adrenaline sports) affected the users' VR sickness perception. Considering various video conditions, significantly less VR sickness effects were reported with the TV condition than with any VR devices. The results of the subjective questionnaires were correlated with the objective physiological measurements, whereby skin conductance strongly correlated with the VR sickness effects. The effects were also more pronounced in cases of action video content type. Furthermore, we show there is a strong correlation when assessing the VR sickness effects using subjective questionnaire-based methods (the Simulator Sickness Questionnaire and the Subjective Units of Distress Scale) of various complexity, indicating the simple methods (only one question), can effectively be used as well.

1. Introduction

Virtual Reality (VR) technologies are emerging as a mature technology according to the Gartner Hype Cycle for Emerging

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Technologies [1]. According to [2] the virtual reality can be described as "The illusion of participation in a synthetic environment rather than external observation of such an environment. VR relies on three-dimensional (3D), stereoscopic, head-tracked displays, hand/body tracking and binaural sound. VR is an immersive, multi-sensory experience". Recent technological advances combined with economic viability have led to widespread use of VR solutions in entertainment, business, education and healthcare segments as well as research areas [3].

The core component of the VR system is a VR head-mounted display device (VR HMD). It primarily consists of high spatial and temporal resolution dual displays (typically 1080 × 1200 pixels per eye with 90 Hz to 120 Hz refresh frame rate frequency) allowing for high fidelity stereoscopic image rendering, stereo binaural speakers and precise head/body tracking system. The overall low latency of the system is especially important for achieving a good user experience. Key examples of the current VR generation are the Oculus Rift CV1 [4], HTC Vive [5], Sony PSVR [6] and the OSVR [7]. The last solution is especially interesting as it presents an open source approach alternative to the VR systems. Mobile VR solutions, such as the Google Cardboard/Daydream VR [8] or Samsung Gear VR [9], present a more affordable and mobile alternative, sacrificing some of the fidelity of the desktop solutions. Mobile VR solutions are especially interesting for users, because of high mobility and economic affordability, requiring modern high bandwidth and low latency 5G networks [10–12]. Furthermore, combining VR solutions with IoT [13] and multimedia IPTV [14], opens new possibilities.

Besides technological maturity and economical affordability, one of the key factors for success and user acceptance of VR solutions is the overall user experience (UX). The user experience can be described as the users' entire interaction with the device or service, as well as the thoughts, feelings and perceptions that result from that interaction. The process involves the user who is interacting with the device or service (or anything with the user interface) and whose experience is of interest, observable or measurable [15].

One of the inhibiting factors when using VR systems is the phenomenon of VR sickness. It is known by several names, including motion sickness, cybersickness, and simulator sickness. These terms are often used interchangeably, but are not completely synonymous, being differentiated primarily by their causes [16]. Motion sickness refers to adverse symptoms and readily observable signs, associated with exposure to real (physical or visual) and/or apparent motion [17]. Cybersickness is described as visually induced motion sickness resulting from immersion in a computer-generated virtual world [18]. Cybersickness is distinct from motion sickness in that the user is often stationary, but has a compelling sense of self motion through moving visual imagery. Simulator sickness (SS) is sickness that results from shortcomings of the simulation, but not from the actual situation that is being simulated [19].

According to [16] there is currently no generally accepted term that covers all sickness symptoms resulting from VR usage. A general term is needed and proposed that is not restricted by specific causes. Thus the term VR sickness or simply "sickness" can be used when discussing any sickness caused using VR, irrespective of the specific cause of that sickness.

VR sickness effects can be observed and measured by different approaches. These include the use of standard questionnaires and/or the measurement of physiological parameters.

The Simulator Sickness Questionnaire (SSQ) [20] presents a standardized method of measuring the effects of the simulator/motion sickness. It has been originally used to assess the simulator sickness in aviation simulations [21] and has been successfully applied to other areas, such as driving simulators [22] and rehabilitation in VR environments [23]. Another, much simpler, yet also effective measure of personal discomfort or distress represents the Subjective Units of Distress Scale (SUDS) method [24]. Whereas the SSQ is a multi-question based method, the SUDS comprises only of one linear scale question, typically in a range from 0 to 100, 0 indicating no distress and 100 indicating maximum distress. It is thus easy to implement and a non-time-consuming method, that has been successfully applied to various fields of research, including distress measurement in VR applications [25].

Measurement of users' psychophysiological parameters, such as heart rate, breathing rate and amplitude, skin temperature and skin conductance response (SCR), can give another insight into VR sickness [26]. The effect is especially apparent when measuring the skin conductance response [27].

In this research we present the influence of video content type (neutral content, action content) on the perceived VR sickness, showing the effects of watching panoramic 3D video content in different conditions. Five video conditions were used—a 2D TV set, three generations of the Oculus Rift VR HMD and the mobile VR solution Samsung Gear VR. We furthermore explore the physiological response of the participants (heart rate, respiratory rate, skin temperature and SCR). We were also interested in the influence of the participants' preferences (e.g. adrenaline sports preferences) on the VR sickness effects. Finally, the usage of different VR sickness measures is explored (SSQ, SUDS) including the participants' perception and evaluation of the experiment procedure (NASA-TLX, [28]).

Key contributions of the paper are:

- Confirmed influence of video content type on users' VR sickness response;
- Confirmed influence of participants' background and preferences on the VR sickness response;
- VR sickness response assessment by the SSQ, SUDS and physiological response methods;
- Evaluation of the experiment procedure (NASA-TLX).

The rest of the paper is organized as follows: related work is presented in Section 2; followed by research hypotheses and questions, and a detailed experiment setup and procedure described in Section 3; results are presented and discussed in Sections 4 and 5 respectively; while key conclusions and future work references are drawn in the last section.

2. Background and related work

We present the related works relevant for our research. We focus (2.1) on the VR devices and their influence on the user, (2.2) on the panoramic video in VR, and finally (2.3) on the review of the VR sickness based research.

2.1. VR devices and the influence on the user

The authors in [29] present a comprehensive review of the chronological development as well as the current state of the art of the VR technology and accompanying input devices. A detailed taxonomy of various input/output VR devices is presented. The authors expose current hardware limitations and challenges in terms of resolution, improvement of optics and add per-user lens positioning capabilities, as well as mobility limitations, as the current high-end VR solutions are tethered. The issue of VR sickness is emphasized, which is closely related to the overall system (especially rendering and interaction) latency.

Long-term use of fully immersive VR technologies and the impact on the users is not yet fully understood. The study in [30] reports findings of a self-experiment in which a subject was exposed to an immersive VR setup for 24 h. While only one participant was involved in the study, the results are still important for the sheer