Effects of Manipulated Zeigebers and Cognitive Load on Time Estimation and Presence

HAODONG LIAO, University of Electronic Science and Technology of China, UESTC
HUIYUAN LI, University of Electronic Science and Technology of China, UESTC
JIANPING SU, University of Electronic Science and Technology of China, UESTC
NING XIE, University of Electronic Science and Technology of China, UESTC

Fig. 1. Drumheller Fountain, The University of Washington, Seattle WA.

According to their needs, researchers building virtual environment are able to set the time in the immersive virtual environments (IVEs) in a variety of ways, which enables the environment builder to influence or even change the users' perception of the time while experiencing computer-generated IVEs.

In this paper, we further expolre the effects of manipulated multimodal information such as visual sitimuli representing illumination intensity or audio stimuli representing ticking of a clock as zeitgebers and cognitive load on time estimation and presense as yet not well studied factors of spatiotemporal perception in IVEs based on previous work [Schatzschneider et al. 2016]. We presented an experiment in which we made attempts to explore human's ability in estimating temporal duration.. We found that ...

CCS Concepts: • **Human-centered computing** → **Virtual reality**; • **Computing methodologies** → **Perception**; *Virtual reality*;

Additional Key Words and Phrases: time perception, cognitive load, immersive virtual environment

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1 INTRODUCTION

In 1968, Ivan Sutherland, with the help of his students including Bob Sproull, created what was widely considered to be the first head-mounted display system applied to immersive simulation: the sword of Damocles [Sutherland 1968]. Since then, researchers have started their continuous exploration of virtual reality (VR) technology. Thanks to the development of computer graphics and VR technology, some VR products for consumers such as HTC VIVE [1] and Oculus Rift [2] began to be better known. For one thing, it benefits more people by bringing them the experience of the wonderful feeling of "being there" [Barfield and Weghorst 1993; Bystrom et al. 1999; Draper et al. 1998; Held and Durlach 1992; Sanchez-Vives and Slater 2005; Sheridan 1992; Slater and Wilbur 1997] or "feeling real" [Parola et al. 2016]. For another, many unsolved problems limited by software and hardware get back to public attention, and the answer to this question that "is there a way to control the temporal perception of user when they are in the IVEs" is exciting.

The characteristics contributing to VR technology to which people often referred are "Immersive, Interactive and Imaginative", [Burdea and Coiffet 1994], however, there is no generally accepted theory of presence [Birkenbusch and Christ 2013; Darken et al. 1999; IJsselsteijn et al. 2000; Skarbez 2016]. In 2009, M.Slater put forward a widely accepted theory of place illusion (PI) and plausibility illusion (Psi) to the question that why participants tend to respond realistically to situations and events portrayed within an immersive VR system. They argue that when both PI and Psi occur, participants will respond realistically to the virtual reality. [Slater 2009] Different from infuluencing factors of "immersion" which address more on objective technical condition of VR system, [Bowman and McMahan 2007; Riva et al. 2011; Slater 1999; Slater and Wilbur 1997] the user's subjective experience is more concerned in VE when refers to presence, which includes the perception of time.

The idea of time controlling seems to be a fantasy in the real world, but VR has the potential to make it possible. In the context of time perception, light is the most important synchronizers of biological rhythms in nature, which is referred to as zeitgebers. [Aschoff 1965; Roenneberg et al. 2007] Zeitgebers is a term that describes external or environmental cues that function to entrain the human circadian rhythms and synchronizes our biological rhythms to the Earth's 24-hour day-night cycle and 12-month cycle. [Aschoff 1965; Pittendrigh 1981] Such cues help people determine what time they are at in the day or to mark the elapsed time, namely the speed of time. The study of zeitgebers was derived from the study of biological rhythms in chronobiology. Aschoff concluded that *Under natural conditions, the circadian period is synchronized with (or entrained to) the period of the earth's rotation by means of periodic factors in the environment, called Zeitgebers.* [Aschoff 1965] In 2016, Schatzschneider et al. used various virtual sun movement speeds as zeitgebers for their experiments. In order to test the influences of the cognitive load on time perception, dual-task studies were used. They had proved that it is feasible to manipulate such zeitgebers to affect time judgments. Moreover, they found that increased spatial and verbal cognitive load resulted in a significant shortening of judged time as well as an interaction with the external zeitgebers. [Schatzschneider et al. 2016]

In fact, scenes with zeitgebers in the reality and non-immersive environments are not rarely seen, a number of which are from video or computer games. [Bruder and Steinicke 2014; Tobin and Grondin 2009] Moreover, people will always report losing their sense of time passing when having fun. [Sanders and Cairns 2010] Accounting for these situations are various explanations, such as attention-based explanation, [Block et al. 2010; 张义芳 and 丁峻 2011] emotion-based explanation, [Angrilli et al. 1997; Droit-Volet and Meck 2007] different estimation paradigms, [Block and Zakay 1997; 赵雪 and 尹艳新 2012] flow theory [Csikszentmihalyi 1997; Nakamura and Csikszentmihalyi 2014] and so on. However, in this paper we try to figure out whether the visual modal information changed by illumination intensity or the audio modal information generated by the ticking of a clock can be used as zeitgebers to affect the user's time perception in IVEs. If so, how much does these zeitgebers affect user's time perception? Does the user's perception of time in IVEs have a relationship with the sense of presence? If so, what kind of relationship?

In this paper, we presented an exploratory qualitative experiment on time estimatiton, in which we combined cognitive load with illumination intensity or ticking speed of a clock in different levels for users in immersive and non-immersive environments. Thus the effects of zeitgebers and cognitive load on time perception and presence were explored. In the experiment, light gains were used to describe the three levels of illumination intensity as the visual modal zeitgebers, namely the bright light, the medium light and the dim light. Clock gains were used to describe the three levels of ticking speed as the audio modal zeitgebers, namely the quick ticking, the medium ticking and the slow ticking. To test the effect of cognitive load, conditions with visual searching task were compared with a baseline condition without a cognitive task. As we know, this is the first experiment so far to evaluate the influence of users' time perceptioin and presence in IVEs by using illumination intensity or ticking speed of a virual clock combined with visual searching task. At the same time, the mutual effects of these factors are also analyzed.

All in all, our article made certain contributions by analyzing the flowing:

- effects of the illumination intensity or ticking speed as an external zeitgebers on the user's perception of time and presence in IVEs and the difference they show in non-immersive environments,
- effects of visual searching cognitive tasks with multimodal information as zeitgebers on time estimation and presence
- feasibility of combining subjective and objective measurement methods to explore the relationship between zeitgebers and cognitive load on temporal perception and presence and
- implications for regulating the user's perception of time in IVEs.

[1]https://www.vive.com/us/
[2]https://www.oculus.com/

The remaining structure of the article is as follows. Section 2 discusses the background and literatures related to this article. Section 3 describes the experiment in which we evaluate the time estimation in IVEs. The result are presented in Section 4, and disscussed in Section 5. Section 6 concludes the article.

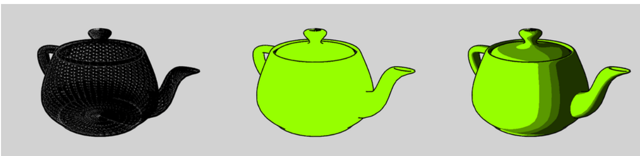

Fig. 2. Cel-shaded teapots. Image by Nicolas Sourd [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], via Wikimedia Commons. (https://goo.gl/5e6tNk).

2 EXPOSITION

Fig. 3. 1907 Franklin Model D roadster. Photograph by Harris & Ewing, Inc. [Public domain], via Wikimedia Commons. (https://goo.gl/VLCRBB).

2.0.1 *Participants.*

3 CONCLUSIONS AND FUTURE WORK

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