Time Perception during Walking in Virtual Environments

Gerd Bruder* Frank Steinicke†

Immersive Media Group (IMG)
Department of Computer Science
University of Würzburg

ABSTRACT

A large body of literature has analyzed differences between perception in the real world and virtual environments (VE) in terms of space, distance and speed perception. So far, no empirical data has been collected for time misperception in immersive VEs to our knowledge. However, there is evidence that time perception can deviate from veridical judgments, for instance, due to visual or auditive stimulation related to motion misperception. In this work we evaluate time perception during walking motions with a pilot study in an immersive head-mounted display (HMD) environment. Significant differences between time judgments in the real and virtual environment could not be observed.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1 Introduction

While differences in the estimation of distances, speed, spatial relations etc. between virtual reality (VR) environments and the real world have been observed in many different experiments [9, 15], the estimation of *time* in immersive virtual environments (IVEs) has not been considered to our knowledge. So far it is unknown whether or not systematic time contraction or expansion occur in IVEs. Experimental studies of time perception in the field of psychology have shown that estimates of stimulus durations do not always match their veridical time intervals, and can be affected by a variety of different factors [3]. Since the absolute time cannot be directly measured at any given moment, the brain is often assumed to estimate time based on internal biological or psychological events, or external signals [4]. Exogenous cues from the local environment have been found to have an effect on endogenous biological clocks [8]. It is possible that differences in exogenous time cues between the real world and IVEs have an effect on internal human time perception. In particular, system latency is known to change the perception of sensory synchronicity [13] and can degrade the perceptual stability of the environment [1].

Space and time are interdependent phenomena not only in physics, but also in human perception [4]. Helson keyed the term *tau effect* for the phenomenon that the variation of the time between spatial events can affect judgments of their spatial layout (cf. [5, 7, 12]). For instance, Helson and King [5] observed for a tactile estimation experiment that stimulating three equidistant surface points p_1, p_2, and p_3 with $||p_2 - p_1|| = ||p_3 - p_2||$ at points in time t_1, t_2, and t_3 for different durations $||t_2 - t_1|| > ||t_3 - t_2||$ that subjects judge the distance between p_1 and p_2 as longer than between p_2 and p_3. The *kappa effect* [2] denotes the phenomenon that the variation of the spatial layout of events can affect judgments of their temporal layout [4, 11]. They observed for a visual bisection task that three successive flashes at spatial points p_1, p_2, and p_3 for different distances $||p_2 - p_1|| > ||p_3 - p_2||$ for points in time t_1, t_2, and t_3 with $||t_2 - t_1|| = ||t_3 - t_2||$ that subjects judge the duration between t_1 and t_2 as shorter than between t_2 and t_3.

*e-mail: gerd.bruder@uni-wuerzburg.de
†e-mail: frank.seinicke@uni-wuerzburg.de

2 Pilot Study

In this section we describe a pilot study in which we evaluate misperception of walking time in an IVE.

2.1 Participants

10 subjects participated in the study (1 female and 9 male, ages 21−36, M=27.4, SD=6.0). The total time per subject was 1 hour and 30 minutes. Subjects were allowed to take breaks at any time; short breaks after every 30 trials were mandatory.

2.2 Material and Methods

Since there is no clear notion of a discrepancy between elapsed time in the real world and VR that could be compared simultaneously with a two-alternative forced-choice task (2-AFCT), we measured values for time estimation separately in the IVE (i. e., with HMD) and in the real world (i. e., without HMD). The trials in the IVE started with an initial stimulus phase in which subjects were presented with a view on an Oculus Rift HMD to a virtual replica 3D model of our laboratory. We tracked the subject with a WorldViz PPT-X4 tracking system. When they felt ready to start, subjects pressed a button on a Wii remote controller, which caused a short acoustic signal, and then walked at their own pace in the direction of a virtual target marker that we displayed at eye height at 10m distance. A second short acoustic signal was displayed after subjects had walked over a time interval that we varied between trials. Then, subjects answered a 2-AFCT question (see below), and were guided back to the start position of the next trial. We replicated the same setup for the trials in the real world without the HMD.

For each trial subjects walked over a time interval that was scaled relative to a reference time. Therefore, we apply time gains $g_t \in \mathbb{R}_0^+$ to determine a subject's walking interval in each trial, describing the relation between the trial's interval and reference time. For $g_t = 1$ the trial's interval $T_v \in \mathbb{R}_0^+$ matches the reference time $T_p \in \{2s, 3s, 4s, 5s\}$ with $T_v = T_p \cdot g_t$. In contrast, gains $g_t < 1$ result in subjects walking over a shorter interval and $g_t > 1$ in a longer interval relative to the reference time. After walking the trial's interval, subjects were asked to answer a 2-AFCT question: "Did you move *longer* or *shorter* than # seconds?" with the # replaced by the corresponding reference time. We used an interleaved staircase approach [10] and applied gains in the range between $g_t = 0.4$ and $g_t = 1.6$, i. e., the walked interval differed by up to ±60% from the reference time. After answering the question, subjects were guided back to the start position of the next trial. They did not receive feedback about the elapsed time.

2.3 Results

Figure 1 shows the results for the tested within-subjects reference times in the real world and VR. The x-axis shows the actual times, and the y-axis shows the judged times. The vertical bars show the standard error of the mean.

In the real world subjects judged an elapsed time as matching the reference time that was approximately 2.10s (g_t=1.051, 5.1% longer) for a reference time of 2s, 3.05s (g_t=1.017, 1.7% longer) for a reference time of 3s, 4.06s (g_t=1.016, 1.6% longer) for a reference time of 4s, and 5.04s (g_t=1.007, 0.7% longer) for a reference time of 5s. In contrast, for the experiment trials in the IVE, subjects judged an elapsed time as matching the reference time that was approximately 2.16s (g_t=1.081, 8.1% longer) for a reference time of 2s, 3.22s (g_t=1.073, 7.3% longer) for a reference time of 3s, 4.24s (g_t=1.061, 6.1% longer) for a reference time of 4s, and 5.23s (g_t=1.046, 4.6% longer) for a reference time of 5s.

Over all reference times, subjects judged an elapsed time as identical to the reference time that was approximately 6.5% increased (g_t=1.065) in the IVE, and approximately 2.3% increased (g_t=1.023) in the real world. The difference between the PSEs in the real world condition and the IVE indicates that times were overestimated in the IVE by approximately 4.2% compared to estimates in the real world. Considering the PSEs of individual subjects, 7 of the 10 subjects judged a longer elapsed time in the IVE compared to the real world, whereas 3 subjects judged a shorter elapsed time.

We analyzed the results with a repeated measure ANOVA and paired-samples t-tests. The results were normally distributed according to a Shapiro-Wilk test at the 5% level. The sphericity assumption was supported by Mauchly's test of sphericity at the 5% level. We found a significant main effect of reference time on the judged PSEs in the real world (F(3, 27)=224.65, p<.001, η_p^2=.961) and in the IVE (F(3, 27)=169.14, p<.001, η_p^2=.949). We observed a trend for a difference between the judged PSEs in the real and virtual world (t(9)=−1.98, p=.07). We observed no significant difference between the judged PSEs over all subjects and veridical results with $g_t = 1$ (t(9)=−1.49, p=.17).

2.4 Discussion

The results show that subjects were able to perform the task in the real world quite reliably without large errors, and that their judgments only slightly differed from the real world in the IVE. One explanation may be the cumbersome instrumentation of the subjects as well as the weight of the HMD, which induces discomfort and increases the task complexity, which might have resulted in a longer perceived elapsed time. For instance, James [6] observed that for time judgments the task complexity can cause misperception due to subjects losing track of elapsed time.

However, while we used a measurement protocol to assess time judgments in this experiment that is similar to measures used to assess distance and speed judgments [14], there are no established measures or previous works on how to best assess time judgments in VR. Those are challenging questions whether time misperception occurs in IVEs and how perceptual differences could be assessed with measures that are not based on counting seconds.

3 Conclusion

In this work we have analyzed time perception in VR. While time misperception in VR has not been considered so far, our initial results suggest that future research should also analyze on the factor during self-motion perception, which may explain some differences in space and speed judgments between the real world and IVEs. In order to manipulate time in IVEs, one could scale the virtual time relative to a reference time. For instance, one could manipulate different virtual time cues in IVEs in a subtle or overt way. One could accelerate or decelerate virtual clocks in the view of the users, or one could increase or decrease the time span of a virtual day, e. g., by making the sun move slower or faster. Both approaches may have an impact on the user's time estimation. However, the question remains how to evaluate the estimation of time in an IVE without only testing the subject's ability of counting seconds. In the future we will pursue these questions in more detail.

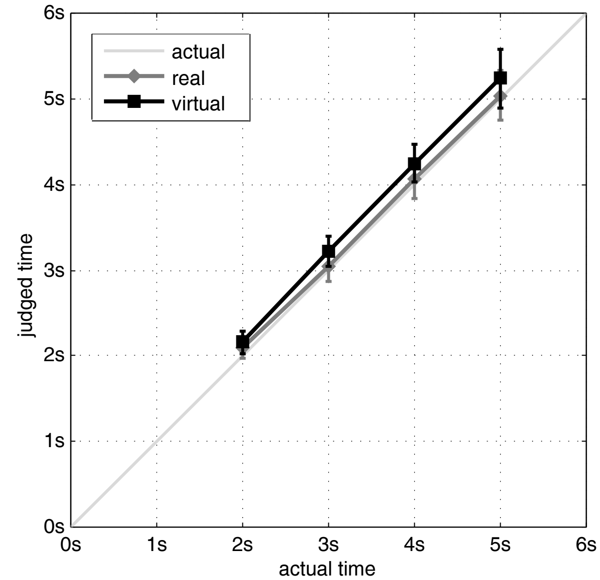

Figure 1: Results of the time estimation experiment in the real world (gray) and virtual world (black). The horizontal axis shows the actual times and the vertical axis shows the time judgments. The vertical bars show the standard error of the mean.

References

[1] R. S. Allison, L. R. Harris, M. Jenkin, U. Jasiobedzka, and J. E. Zacher. Tolerance of temporal delay in virtual environments. In *Proceedings of Virtual Reality (VR)*, pages 247–253. IEEE, 2001.

[2] J. Cohen, C. E. M. Hansel, and J. D. Sylvester. A new phenomenon in time judgment. *Nature*, 172:901, 1953.

[3] R. Efron. Effect of stimulus duration on perceptual onset and offset latencies. *Perception & Psychophysics*, 8:231–234, 1970.

[4] S. Grondin. *Psychology of Time*. Emerald Group Publishing, 2008.

[5] H. Helson and S. M. King. The tau effect: An example of psychological relativity. *Journal of Experimental Psychology*, 14:202–217, 1931.

[6] W. James. *The principles of psychology*. Dover, 1957.

[7] B. Jones and Y. L. Huang. Spacetime dependencies in psychophysical judgment of extent and duration: Algebraic models of the tau and kappa effects. *Psychological Bulletin*, 91:128–142, 1982.

[8] A. Kramer and M. Merrow. *Handbook of Experimental Pharmacology 217: Circadian Clocks*. Springer, 2013.

[9] J. M. Loomis and J. M. Knapp. Visual perception of egocentric distance in real and virtual environments. In L. Hettinger and M. Haas, editors, *Virtual and Adaptive Environments*, pages 21–46. Erlbaum, 2003.

[10] N. A. Macmillan and C. D. Creelman. *Detection Theory: A User's Guide*. Psychology Press, 2004.

[11] M.-E. Roussel, S. Grondin, and P. Killeen. Spatial effects on temporal categorization. *Perception*, 38:748–762, 2009.

[12] J.-C. Sarrazin, M.-D. Giraudo, J. Pailhous, and R. J. Bootsma. Dynamics of balancing space and time in memory: Tau and kappa effects revisited. *Journal of Experimental Psychology: Human Perception & Performance*, 30:411–430, 2004.

[13] Z. Shi, H. Zou, and H. J. Müller. *Advances in Haptics*, chapter Temporal Perception of Visual-Haptic Events in Multimodal Telepresence System, pages 437–449. InTech, 2010.

[14] F. Steinicke, G. Bruder, J. Jerald, H. Fenz, and M. Lappe. Estimation of detection thresholds for redirected walking techniques. *IEEE Transactions on Visualization and Computer Graphics (TVCG)*, 16(1):17–27, 2010.

[15] P. Willemsen and A. A. Gooch. Perceived egocentric distances in real, image-based, and traditional virtual environments. In *Proceedings of Virtual Reality (VR)*, pages 275–276. IEEE, 2002.