Interval Timing in Virtual Reality: Merits, Goals, and Premises

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ABSTRACT

Recent evidence suggests that the subjective experience of time can be altered by immersive virtual reality (VR). A thorough understanding of this phenomenon opens interesting prospects, both for the design of user-friendly VR-based interfaces to support human-computer interaction, and for the scientific investigation of human time perception under more realistic and yet controllable conditions. Here I will delineate some of the future challenges and research questions with respect to the effects of VR on interval timing in the range of several seconds. One of these questions is whether VR induces changes in the perception of time itself or whether it "just" alters our expectations regarding the duration of physical events.

KEYWORDS

Virtual Reality, Interval Timing, Time Perception, Temporal Expectations

1 TIMING IN VIRTUAL AND REAL ENVIRONMENTS

Since virtual reality (VR) techniques became increasingly sophisticated and affordable even for many private households, there has also been an increased interest in defining its possibilities and its limitations. Various research studies have focused on the question whether basic perceptual qualities like color, spatial size, or visual depth are comparable between VR and real environments [11, 12, 17], and, in case they are not, whether and how the fidelity of the virtual environment can be improved [9]. One of these basic qualities is the sense of time, and in recent years, many experimental studies have provided evidence that the immersive experience of VR and the often coincidental feeling of detachedness from the real environment and the own body can induce changes in the perception of time [1, 3, 24].

Altered temporal experience in VR can exert its influence on many scales, from the detection of temporal asynchronies in the range of milliseconds [8] to the estimation of long intervals in the range of several minutes or even hours [5,9]. Most studies on the effects of VR on time perception fall within the last category. For example, breast cancer patients undergoing chemotherapy rated the duration of the therapeutic sessions as shorter when they were mediated by VR [19].

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In contrast to the investigation of rather long durations, there is a lack of studies investigating how interval timing in the range of seconds is affected by the experience of immersive VR, and how this process can be biased by a systematic manipulation of the virtual environment. This is surprising, as it has been demonstrated that the perceived duration of environmental stimuli differs depending on their spatial location relative to the observer. Left or right shifts of visuospatial attention provoke an under- or an overestimation of time, respectively [4], and stimuli presented in far distance from the observer are perceived as shorter than stimuli presented in near space [7]. Moreover, the perception of temporal durations can be influenced by environmental aspects such as room size [15] and spatial atmosphere [2], factors that can be manipulated in VR without difficulty. These findings suggest that the perceived duration of short intervals presented in VR can be manipulated by introducing systematic changes in the virtual environment. There are two main reasons for investigating these effects, the first related to VR as a purpose in itself, and the second related to VR as a means to an end.

2 OPTIMISATION OF VIRTUAL REALITY SYSTEMS

Manipulations of temporal experience in VR could provide valuable information for the design of VR-based human-computer interactions (HCI), for example to minimise the apparent duration of interaction processes [22, 23]. An important future goal in the field of HCI consists in the specification of design principles for VR environments, in order to optimise the temporal experience of single processes (in contrast to the perceived duration of the VR-based interaction itself). Are there specific spatial factors that can influence the perceived duration of events presented in VR, similar to the near/far and left/right distinction reported in the real world and for 2D screens [4, 7]? Due to the increased immersiveness of VR applications, the effects of spatial location and spatial size on interval timing might even be more pronounced relative to 2D screens. Another possibility to manipulate temporal experience in VR is provided by the use of avatars, the appearance of which could be personalised to the specific user [24], as well as by the introduction of a deviant translation between own body movements and the visual feedback regarding the avatar's movements [5]. In one study, it was reported that ten minutes adaptation to an unusual coupling between own movements and the speed of environmental events in a VR-based computer game can lead to temporal recalibration and ultimately change time judgments [5]. Also basic visual features of the virtual environment like the composition of colour might be of interest to alter the perceived duration of stimuli [21].

The most substantial asset of VR consists in the fact that such environmental factors can be easily controlled and changed, and to exploit this potential for the optimisation of VR-based HCI is a promising and use-oriented research area.

3 VIRTUAL REALITY AS RESEARCH METHOD

A better understanding of interval timing in VR is not only relevant to specify design principles for virtual environments. VR also constitutes a great potential as a scientific tool to investigate the process of time perception, because it enables us to introduce aversive or even physically impossible situations in controlled experiments and allows us to assess their effects on the sense of time. By this means, it was demonstrated that the estimation of time intervals can be influenced by the manipulation of external *Zeitgeber* [18] and it has been suggested that the performance in a VR-based interval timing task might be predictive of age-related cognitive decline [14]. Moreover, there is evidence that the embedding of stimuli within a naturalistic context can influence timing performance [10, 16, 20]. However, an important premise for interpreting altered time judgments as resulting from VR-based manipulations is, that the method does not interfere with the perception of time itself [25].

Imagine yourself standing in your apartment (Figure 1A). In your hand you are holding a stone, exactly one meter above the ground. Then you drop the stone and you measure the time until it hits the ground. You measure 450 ms. The event stone falls one meter takes 450 ms. Then you go standing in a lake, water up to your chest (Figure 1B). The stone is in your hand as before, and again you drop it and measure the time until it hits the ground. 1400 ms. The same event takes longer. Obviously it would be incorrect to conclude that time moves slower in the lake. The apparent time dilation is based on the different circumstances.

Now you change the situation. Instead of dropping the stone under those two conditions (apartment versus lake), you just imagine the event and the two conditions, and you produce the respective durations (Figure 1C). You say "start" when you imagine the stone leaving your hand, and you say "stop" when you imagine it hitting the ground. Knowing about the different circumstances and having specific expectations about how they would affect the fall of the stone, you most likely will produce a longer time interval for the lake condition. Now what's the most plausible explanation in this case? That the imagination of standing in water has altered your sense of time? Or that the different conditions triggered different expectations regarding the duration of the event stone falls one meter?

Should we not apply the same reasoning in the case of VR? Does VR not represent a specific situation that might as well trigger deviating temporal expectations? When comparing the performance in time perception tasks between VR and real environments, it is easy to preassume that this is not the case. That our expectations with respect to the duration of physical events are unaltered. However, when interacting with computer programs, most people are frequently confronted with system-generated temporal delays, time lags caused by processor overload. Based on such experiences, one might indeed expect (on a conscious or sub-conscious level) that a virtual stone in a virtual environment might take slightly longer to fall to the virtual ground than it would be the case for a real stone in the physical world. On the other hand, there is evidence that VR coincides with dissociative experiences and a reduced sense of presence in objective reality [1], suggesting that there is reason to consider it as a situation in which timing processes per se might be different [13, 24].

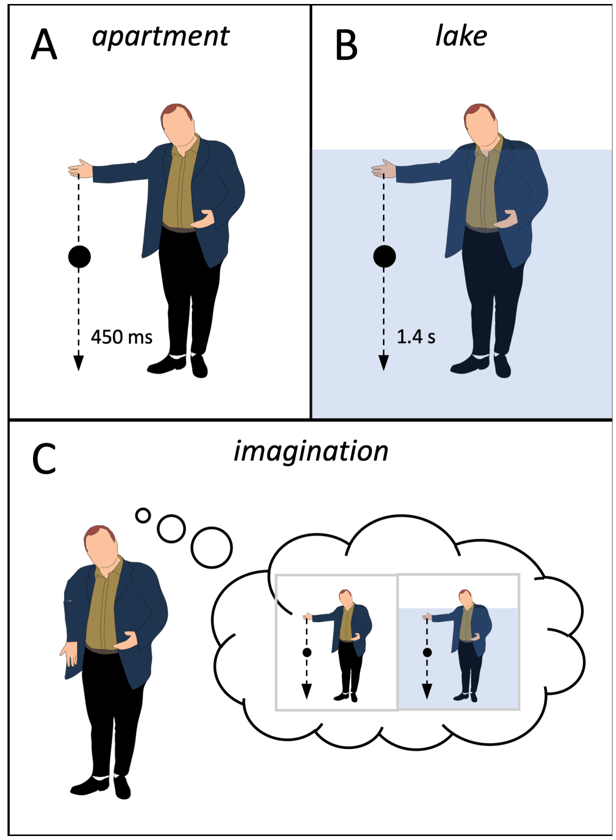

Figure 1: The event *stone falls one meter* takes less time in the apartment (A) than in the lake (B). When producing the duration of the imagined event (C), the produced duration would most likely be longer in the imagined lake condition.

Therefore, an important first step for the study of interval timing in VR consists in the verification that the method of VR itself does not affect the perception of durations in the range of seconds. For example by comparing estimates for the duration of concrete physical processes (like the event *stone falls one meter* in our example) and abstract time units (e.g., "one second") [6]. Only if this premise is confirmed, we can interpret changes in temporal judgments as resulting from the way the virtual environment was manipulated. Only when we know that the experience or the imagination of standing in water does not itself interact with our sense of time, we can interpret a difference in timing performance as an effect of the water's temperature [26].

There are studies intending direct comparisons between the timing performance in two virtual environments with only one specific difference, and it seems reasonable that a general effect of VR could be neglected in those cases. There remains, however, the possibility of interaction effects. For example, if VR generally coincides with an acceleration of the subjective time flow, it might affect the perceived contrast between two time intervals and hence differently influence timing performance. As a consequence, the effects of different VR conditions might not be generalisable to analogous conditions in the real world, unless the general effect of the VR method itself is known.

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