

Motor performance as a reliable way for tracking face validity of Virtual Environments

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The intrinsic presence of temporal delay in Virtual Environments (VE) (we refer to the concept of “*end-to-end latency*” (ETEL) (Adelstein et al., 1996)), as well as communication time delay in tele-operation (Ferrel W.R., 1963) predictably leads to a degradation of user’s performances. For engineers working on VE, ETEL is commonly associated to the concept of spatio-temporal realism and requires technical solutions to overcome its undesirable consequences. We believe that scientific people can partly respond to the engineers’ attempts, albeit being concerned with more theoretical problems. For instance, the study of perception-action coupling via the “moving room” paradigm suggested that an unusual matching between two sensory modalities induced postural instabilities. This behavioral feature can be used to detect simulator sickness (Stoffregen and Smart, Jr., 1998). In a similar way, the exposure to ETEL in VE leads to a “*sensory re-arrangement*” (Welch, 1978) between several sensory modalities. Its motor and perceptive consequences have to be studied.

An experimental ball-bouncing apparatus (cf. Figure 1A and B) was set up by using VE technology. This VE allows the monitoring of human periodic behaviors when participants are asked to manipulate a physical racket which control the displacement of a virtual racket, and this in order to achieve regular virtual ball-bouncing. ETEL refers in this case to the temporal mismatch between the movement of a physical racket and its visual consequences (the displacement of virtual racket). We design a psychophysics experiment to estimate the perception threshold of ETEL and its damaging consequences on motor performance during a ball-bouncing task. The ETEL of our set-up was manipulated to provide nine different values ranging from 30 to 190 ms (ETEL conditions). Subjects performed rhythmical movements either to regularly bounce a virtual ball (With Ball condition) or just for observing the visual consequences of their movements (No Ball condition) in the nine ETEL conditions. After each trial, subjects had to verbally report whether both rackets appeared synchronous or not. From logistic curves fitted to the participants’ answers (cf. Figure 1C and D), the computation of the individual Point of Subjective Equality for 50% discrimination likelihood (PSE) revealed that bouncers become aware of ETEL from only 99 ms on average in the NB condition. This discrimination threshold was lowered to 88 ms when regular collision with the virtual ball was expected (WB condition). A paired test-*t* ($N = 14$, Diff. = 18.70, Ecart-type = 31.54, $t = 2.22$, $df = 13$, $p = .04$) revealed a significant difference in the PSE values between these two sessions. When considering motor performances in WB condition, it appears that while mean values of performances are significantly damaged above 110 ms, standard deviation values increases as soon as ETEL increased.

Conclusions and recommendations to engineers can be drawn from this study. (1) The two measured perception thresholds of ETEL are largely superior to the baseline ETEL value (30ms) of our virtual environment. Consequently, realistically-perceived enactive interfaces can be designed despite significant ETEL. (2) The difference found between the two psychophysics thresholds in WB and NB conditions, evidences that participant judgments partially rely on ball-racket interactions to discriminate ETEL. The earlier occurrence of ETEL perception in WB condition, regarding to NB condition enhances the human ability to perceive spatio-temporal anomalies (O’Sullivan et al., 2003), particularly when observing collisions. Reliable computation and rendering of collision in VE seem then to require more effort than expand on ETEL shortening in the development of

realistically-perceived interface. (3) At last, perception of ETEL and performance damage do not appear to overlap. The variability in motor performances stands out to be more accurate than psychophysics threshold to evaluate the sensitivity of VE users to ETEL. This general result suggests that a subjective “good” performance of a VE, when users have the feeling that the the real movement is depicted in “real time”, does not guaranty the functional validity of the VE.

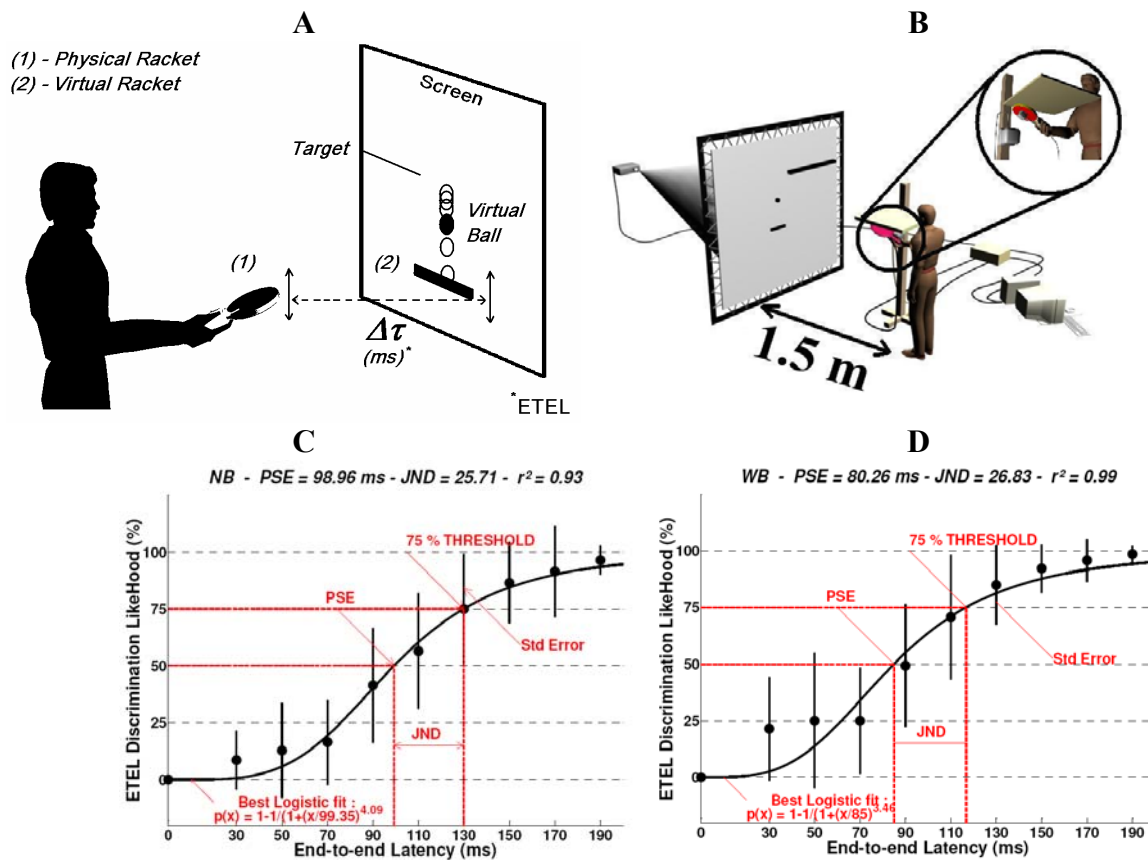


Figure 1. (A and B) Virtual Ball-Bouncing set-up. During WB session, subjects are asked to periodically hit the ball to one given height (a target). With delayed visual feedbacks, the manual control of the physical racket makes it possible to control the delayed displacement of a virtual racket in order to interact periodically with a virtual ball. (C and D) Psychometric function of all subjects for NB and WB sessions. Mean values of PSE (i.e. 50% ETEL discrimination threshold) and r^2 are noticed in title.

References

- Adelstein, B. D., Johnston, E. R., & Ellis, S. R. (1996). Dynamic response of electromagnetic spatial displacement trackers. *Presence-Teleoperators and Virtual Environments*, 5, 302-318.
- Ferrel, W. R. (1963). Remote manipulative control with transmission delay. *Perceptual and Motor Skills*, 20, 1070-1072.
- O'Sullivan, C., Dingliana, J., Giang, T., & Kaiser, M. K. (2003). Evaluating the Visual Fidelity of Physically Based Animations. Proceedings of Special Interest Group on Graphics and Interactive Techniques, (SIGGRAPH'03) (22)(3). ACM Transactions on Graphics.
- Stoffregen, T. A., & Smart L. J., Jr. (1998). Postural instability precedes motion sickness. *Brain Research Bulletin*, 47, 437-448.
- Welch, R. B. (1978). *Perceptual modification : Adapting to Virtual environment*. Academic Press, New York.