Achieving Millisecond Temporal Accuracy in XR: A Validated OpenXR Framework for Stimulus, Input, and Clock Synchronisation.

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When multiple individuals are embodied in virtual bodies during social XR interactions, a key challenge is quantifying co-presence, the subjective and physiological sense of being in a shared space with others. We are currently using EEG hyperscanning and ERPs to study co-presence and social interaction in multi-user VR through a cooperative game. However, exploring these social dynamics requires a more fundamental technical capability: the ability to relate neural signals to precisely timed events, such as stimulus onsets or a partner's actions, across multiple participants.

To address this, we present a validated, cross-platform timing framework for Unity based on OpenXR. The framework leverages runtime-provided display predictions to estimate stimulus onset, captures responses via a dedicated high-frequency background process, and aligns device clocks into a unified timeline.

We validated this framework against optical ground truth (Black Box ToolKit) across Meta Quest 3, Quest Pro, Pico Neo 3 and PICO 4 Ultra Enterprise in both PC-VR and standalone modes. Results demonstrate near-millisecond stability, with wired configurations showing a near-constant offset of ~1 ms (SD < 0.4 ms), enabling robust event marking for time-sensitive research such as EEG/ERP studies. This framework provides a comprehensive solution for researchers requiring reliable temporal control in XR, from basic reaction-time studies to complex neurophysiological experiments in embodiment and multisensory perception.

This research was funded under Presence XR, a Horizon Europe Innovation Project co-financed by the EC under Grant Agreement ID: 101135025.