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Multimodal Immersive Environment for Evaluating Reaction Time and Decision-Making in Sport Situations: A Pilot Study on Time Analysis and Learning Effects

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INTRODUCTION & AIM

The assessment of motor performance in athletes is a multifaceted endeavor with methods varying across sports, each requiring assessment techniques tailored to its specific characteristics [1]. Sports science research aims to establish reliable methods, which depend on the complexity of the instruments. Athletes have been studied in controlled laboratory settings, immersive virtual reality, and real-world scenarios. However, there are inherent limitations in translating findings from controlled laboratory environments to practical sports applications [2]. To bridge this gap, this study introduces a mixed modality combining virtual immersion with physical objects. We present a quantitative assessment based on time analysis.

METHODS

This pilot study evaluated male athletes performing motor reaction tasks, moving their hands in response to visual stimuli under a go/no-go protocol. The same protocol was carried out in a quiet lab environment (QLE) and a multimodal immersive environment (MIE). The QLE lacked noise or visual distractions other than the task stimuli. The MIE included a 180°-enveloping screen with sport-specific video and audio noise and the same task stimuli as the QLE (Fig 1). Motion capture and EMG data from the upper limbs were collected. Reaction time (RT) and decision-making time (DM) were used to compare the athletes' performance (Fig 2).

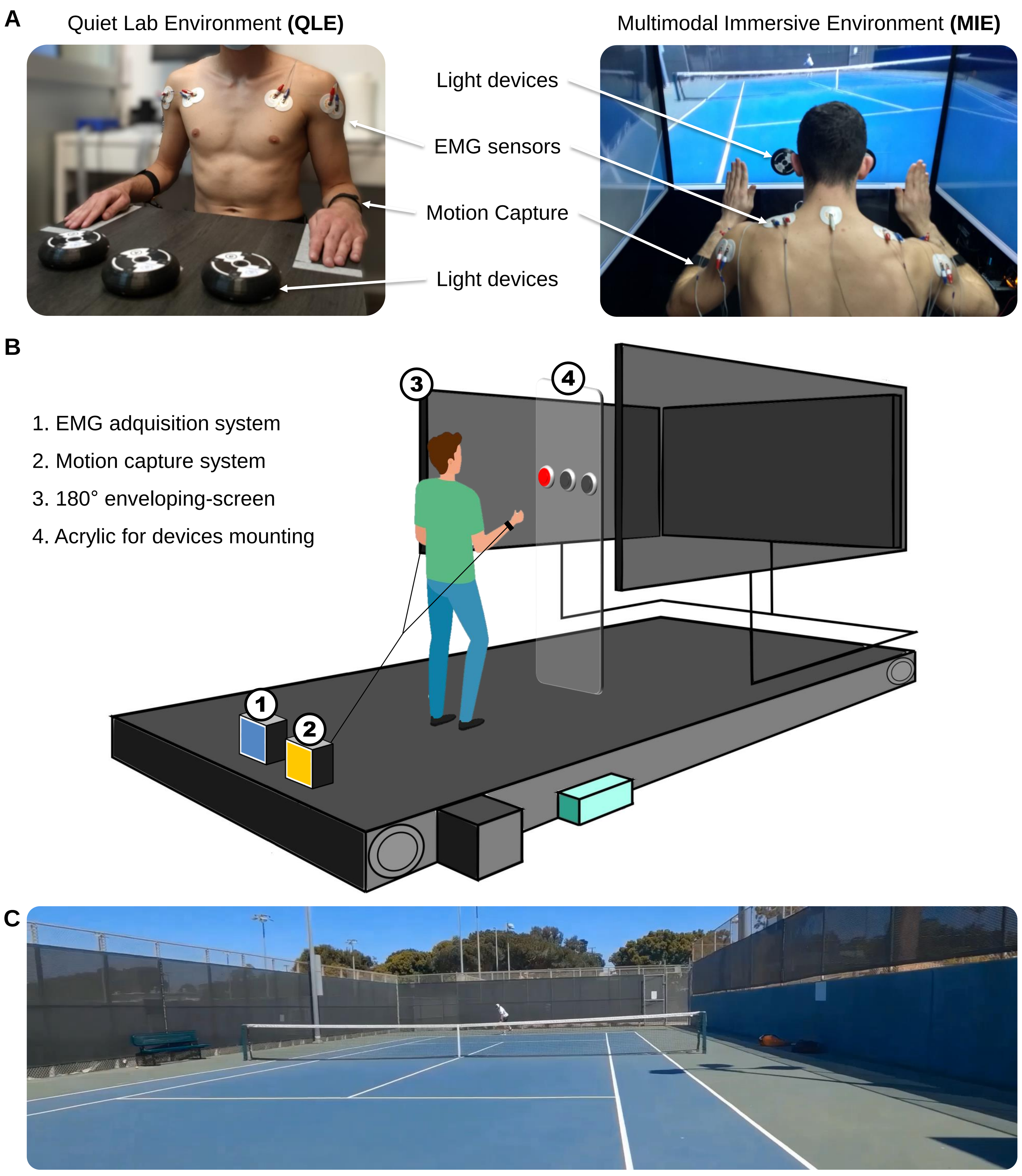

Figure 1. Experimental Setup. (A) The left photograph depicts the Quiet Lab Environment (QLE) with the subject in the initial position and three stimulus devices in front on the table. The right photograph depicts the Multimodal Immersive Environment (MIE) with the subject in the initial position in front of the stimulus devices. Behind the devices, and around the subject, the 180°-enveloping screen projecting sport-related situations. (B) Schematic arrange of the instruments for the MIE setup. Screens projections and light devices are synchronized to deliver stimuli. EMG and motion capture systems are synchronized to collect data, also synchronized with light devices. (C) Representation of one sport scenario presented on the 180°-enveloping screen. In this case, tennis service.

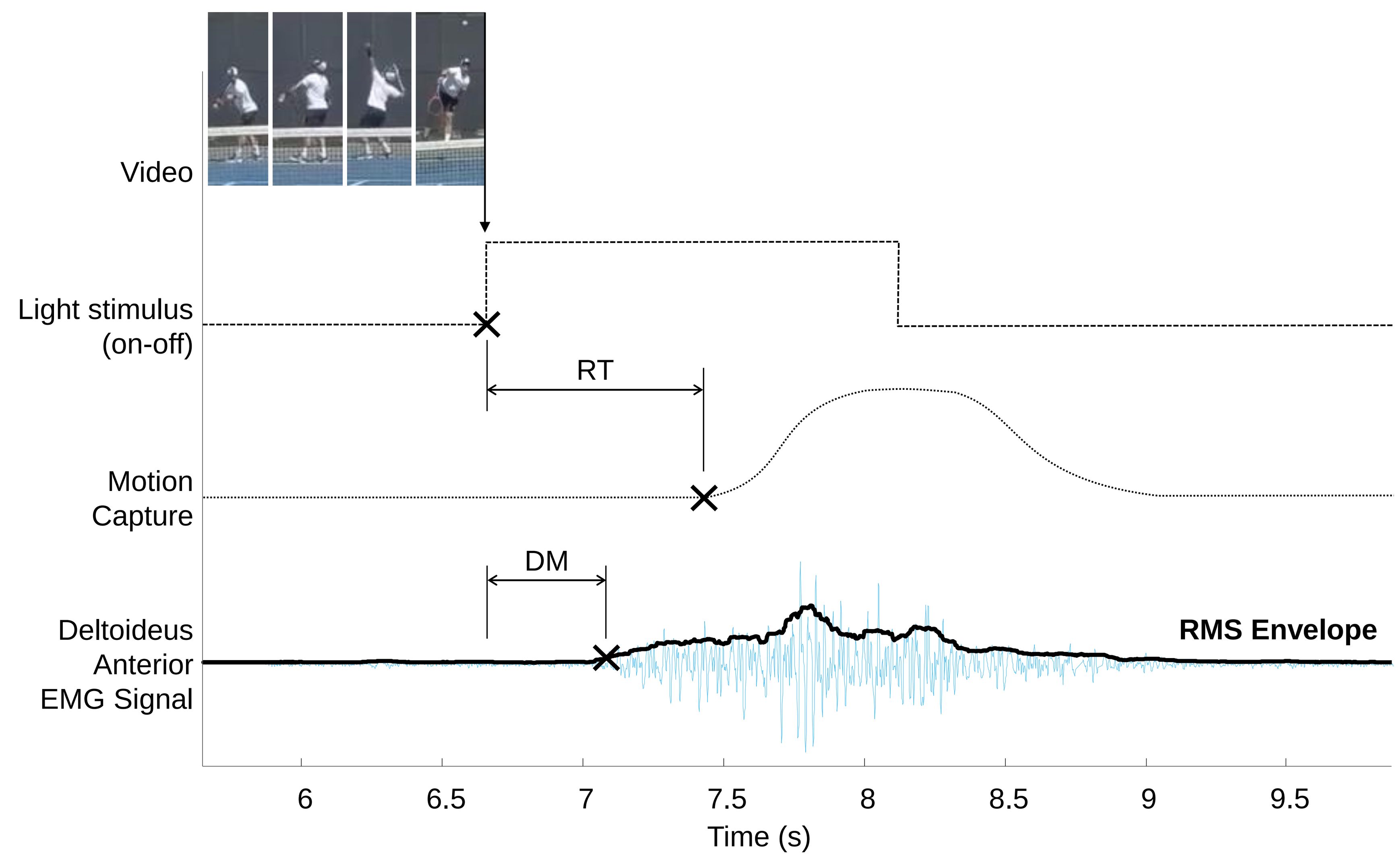

Figure 2. Schematic representation of synchronized data over time. The upper line presents some video captures to illustrate the scenario showed to participants. The strike moment is synchronized with lighting-on stimulus. The second line shows the reactimeter signal as binary on–off data. The third line shows motion capture when either hand was moved. These data are an analog time-series scaled in millimeters derived from digital signals collected with a linear position transducer. The movement of either hand is detected when there is a change in the steady state, transitioning from a flat line to an increasing amplitude following the presentation of a visual stimulus. The fourth line depicts the normalized EMG data from prime motor muscle. The bold black line over the EMG signals is the envelope detected using the root mean square method (RMS). The crosses (x) indicate the onset of light, movement, and muscle contraction. Reaction time (RT) is the interval between light turn-on and movement onset. Decision-making time (DM) is the interval delimited between light turn-on and effective muscle contraction detected.

RESULTS & DISCUSSION

Table 1. Reaction time (RT) and Decision-making (DM) performances in milliseconds.

	Dominant hand		Non-dominant hand	
	RT (ms)	DM (ms)	RT (ms)	DM (ms)
QLE	409 ± 89	297 ± 77	444 ± 67	284 ± 89
MIE	387 ± 80	298 ± 79	389 ± 93	279 ± 80

Table 1 shows the athletes' performance for RT and DM times across environments as mean ± standard deviations, for the both hands. The two-way ANOVA showed no significant differences for RT and DM between left and right-hand performance across environments, consistent with previous findings. RT in the MIE was significantly shorter ~10% ($p<0.001$, ES=0.52) than in the QLE. DM showed no differences between environments. While the absence of changes in DM suggests consistent processing speed in both environments, this indicate a potential advantage for using combined scenarios in future assessments. Moreover, DM may serve as a more reliable indicator of motor-cognitive performance than RT, as it seems to be unaffected by peripheral processes [3].

CONCLUSION

A multimodal immersive environment could allow the introduction of specific stimuli for physical training and assessment, thereby improving the transferability of findings to real-world sports situations.

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