Dynamic Performance in Virtual Spaces

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Virtual, Augmented, and Mixed Reality (VAMR) applications and trainings have gained traction across business sectors, including healthcare, all around the globe. VAMR training allows the healthcare provider or student to learn and perform in a low-risk environment, while VAMR applications allow for distributed assessment and work. Ideally, the VAMR environment precisely resembles the environment where the real performance has to be executed, i.e., the physical reality (PR), to optimize transferability and enable precision control. Yet, while technology has made huge jumps towards displaying photo-realistic environments and applications, non-visual feedback (auditory, haptic, olfactory) is still evolving. In PR, humans are processing their environment multi-modally and base their actions on those multi-modal perceptions. Thus, it remains unclear if human action dynamics in information-reduced, vision-heavy VAMR of today resembles that in PR [1]–[3]. Typically, human performance and VAMR training impact is assessed *post training* as successful transfer to PR, or with respect to improved situation awareness or reduced cognitive load during control. However, if movement execution in VAMR spaces differs from behavior in PR, this may have long-term implications not only for the healthcare industry, but also for the industrial, military, and civil sectors, who currently invest into transferring ever more *executive control* to often remote digital twin applications in VAMR (or the metaverse). We therefore present a pilot study in a simple human-robot co-action paradigm investigating *dynamic* performance differences between VAMR and PR during task performance.

Fifteen students from the University of Cincinnati participated under UC IRB #2012-2827. Participants were instructed to carry a lightweight yet bulky box between two tables 30 cm high, 7m apart, as quickly as possible without running (see Fig. 1). Halfway, participants had to pass a Kuka LBR iiwa14 robot arm on a workbench (robot base at 1m height). A VR replica of this PR setup was created in Unity, including the sound of the robot moving [3]. The real and the virtual robot were operated with the exact same ROS code, ensuring trajectories are the same. Two HTC Vive tracker were strapped to the top of the box and participants waist to collect movement data. They wore an HTC Vive headset in VR trials. Each participant walked 20 times, 4 times when the robot arm did not move, and 16 times with

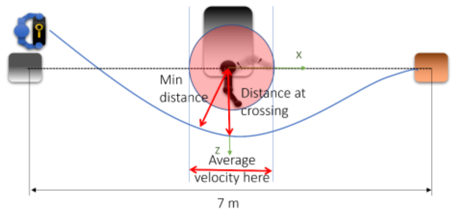

Fig. 1 Experimental Setup

the robot moving in each modality (VR/PR, 40 walks total, start modality was counterbalanced). During the trials when the robot moved, its trajectory simulated a pick and place style sorting task with random, unpredictable moves that could interfere with the participant's path.

Distance: We found no difference for the distance to robot base at crossing for the box tracker between VR (M = 1.28 m, SD = 0.30) and PR (M = 1.25 m, SD = 0.31), t(12) = -0.68, p = 0.5. The same result held for the lumbar tracker, t(9) = -0-1.64, p = 0.13. This is in line with [3], who showed that proxemic preferences typically manifest as larger preferred distance of a person to a moving robot in VR than in PR, potentially due to compressed distance perception in VR [4], yet this preference can be modulated by realistic display of spatial sound, which may be used as an additional information source for localizing the robot's current pose with respect to the participant's location.

Velocity: We did, find a difference in average passing velocity as participants walked faster in VR (M = 1.30 m/s, SD = 0.03) than in PR (M = 1.20 m/s, SD = 0.02), t(9) = -4.476, p = 0.0015, potentially because the threat of being hit by the robot in PR which also indicates an increased sense of presence [1]. Slower motion may have allowed them to remain more alert or reactive to the robot's behavior.

These results suggest that some aspects of task performance in VR may be the same as in PR, however, users may utilize different strategies in these modalities because the consequences for failure are different (e.g., collision with a virtual robot arm is quite different from a physical collision). Thus, if there are behavioral drifts in the dynamics of human-world-interaction between VR and PR, then we need to investigate and develop strategies for mitigation in order to enable optimum performance.

References

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