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Improving Haptic Acuity: Using Robotic Haptic Device and Virtual Reality

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INTRODUCTION

Haptic perception plays a fundamental role in daily life, influencing how we interact with our surroundings and perform various tasks with precision. Studies have shown that haptic feedback is just as important as visual and auditory feedback, serving as a crucial sensory pathway for gathering and interpreting information. Touch allows us to perceive textures, shapes, and forces, complementing other senses to create a comprehensive understanding of our environment. Moreover, haptics becomes even more critical in professions that rely heavily on tactile sensitivity, such as surgeons performing delicate procedures inside a patient's body or pilots maneuvering an aircraft.

MATERIALS AND METHODS

We constructed VR-based scenes using the Unity Game Engine and connected the Touch Haptic Device to simulate various physical characteristics of objects in Test and Training sessions. 22 participants completed the daily 30-minute practice over 10 consecutive days. The tasks of each day consisted of a Pre-training test session, a Training session, and a Post-training test session (Fig. 1). In each Training session, participants interacted with virtual objects that varied in properties such as friction, viscosity, stiffness, and pop-through force. In each Test session, participants were tasked with exploring the shape, position, and physical characteristics of hidden objects within a virtual black box. Performance and workload were assessed based on their touch acuity and NASA-TLX score after each Test session, respectively.

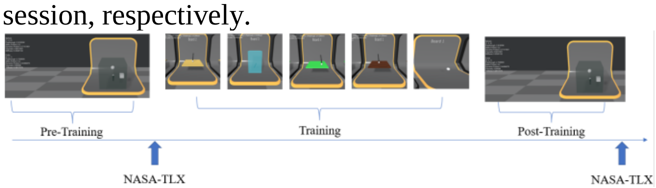

Fig 1: Experiment timeline and scenes of Training and Test sessions.

RESULTS AND DISCUSSION

As indicated in Fig. 2, the haptic acuity performance showed a general ascending relationship across the trainings. The performance initially improved and reached local peaks between Day 5 to 8. It suggested that consistent training can lead to improvements in haptic perception. Next, the subsequent plateau from training Day 8 to 10 coincided with traditional learning and skill acquisition models, which exhibit a plateau or continuous upward trend.

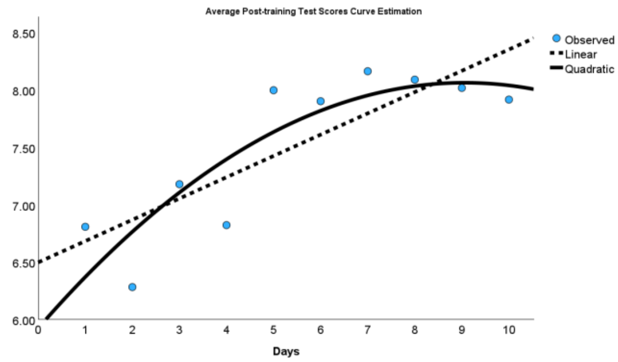

Fig 2: Linear model (dotted) and quadratic model (solid) of average Post-training Test Performance Scores over the ten training days.

As indicated in Fig. 3, the NASA-TLX scores showed a general descending trend, indicating that participants perceived the haptic acuity tests as less demanding with the trainings. Moving to Day 8 and 9, the NASA-TLX scores elevated again, coincided with the plateau in haptic acuity performance on the same period. Because participants strived for maximum haptic acuity during peak performance days, leading to elevated workload.

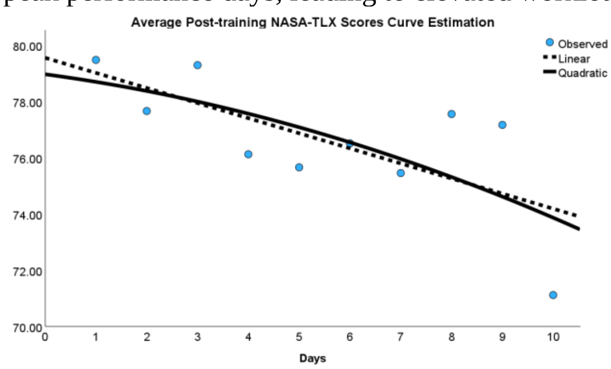

Fig 3: Linear model (dotted) and quadratic model (solid) of average Post-training Test Performance Scores over the ten training days.

CONCLUSIONS

This study provided novel insights into the effects of haptic acuity trainings on performance and workload. Participants' haptic acuity showed a general ascending trend over the trainings. Also, participants' workload displayed a general descending trend over the trainings. The workload significantly reduced as measured by the reduction of Post-training NASA-TLX scores. The findings could facilitate the development of a repetitive and multimodal training model to enhance haptic acuity. Ultimately, we hope to develop effective protocols that enhance haptic skills in the related fields.