Haptic Augmented Feedback on Pirouettes

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Introduction

Wearable tactile displays may enhance motor performance by movement instruction using haptic augmented feedback (HAF) (1). Pirouettes are chosen as the task to assess this potential as the spinning motion tends to cause disorientation creating difficulty for an individual to successfully learn to control and correct errors during the maneuver (2). In this experiment concurrent HAF provided feedback on balance and tilt angle during the motion.

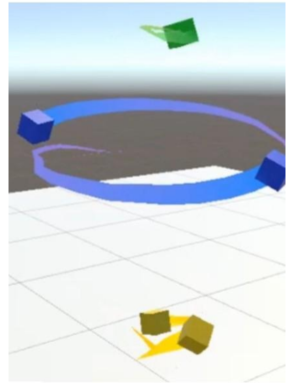
Hypothesis

HAF will increase the both the number of rotations per pirouette and the stability of the participant during the maneuver.

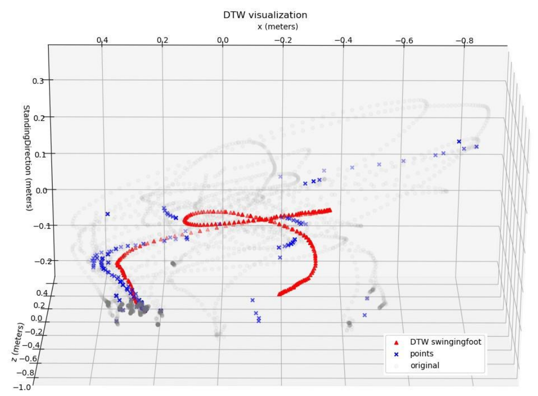
Materials and methods:

Movements were measured with HTC VIVE (New Taipei, Taiwan) virtual reality wireless motion tracking sensors via Unity (Unity Technologies, San Francisco, CA). Magnitude and direction of deviation from the optimal balanced spin axis was sent wireless to the participants as error feedback using IHMC's Adaptive Multi-agent Integration (AMI) framework and the vibrotactile transducer haptic vest.

Each participant performed 16 pirouettes (8 with HAF on & 8 with HAF off, counterbalanced for order). Participants could minimize the HAF tactile stimulus by staying on balance. Data was processed in Python with Dynamic Time Warping (DTW) based on the swing ankle to visualize and average the 8 pirouettes of each condition into a single representative movement for each participant. The magnitude of head displacement (i.e., tilt error) was estimated from the area of the ellipsoid formed by the head motion, using the shoelace formula.

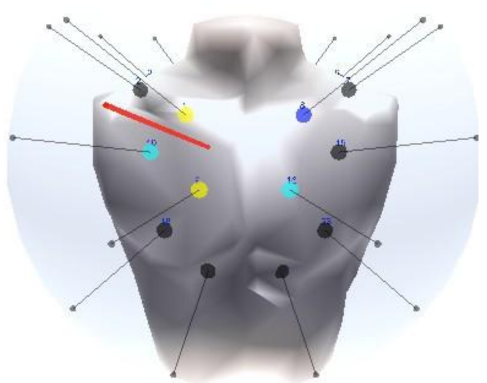


Pirouette in Unity



Example visualization of Dynamic Time Warping

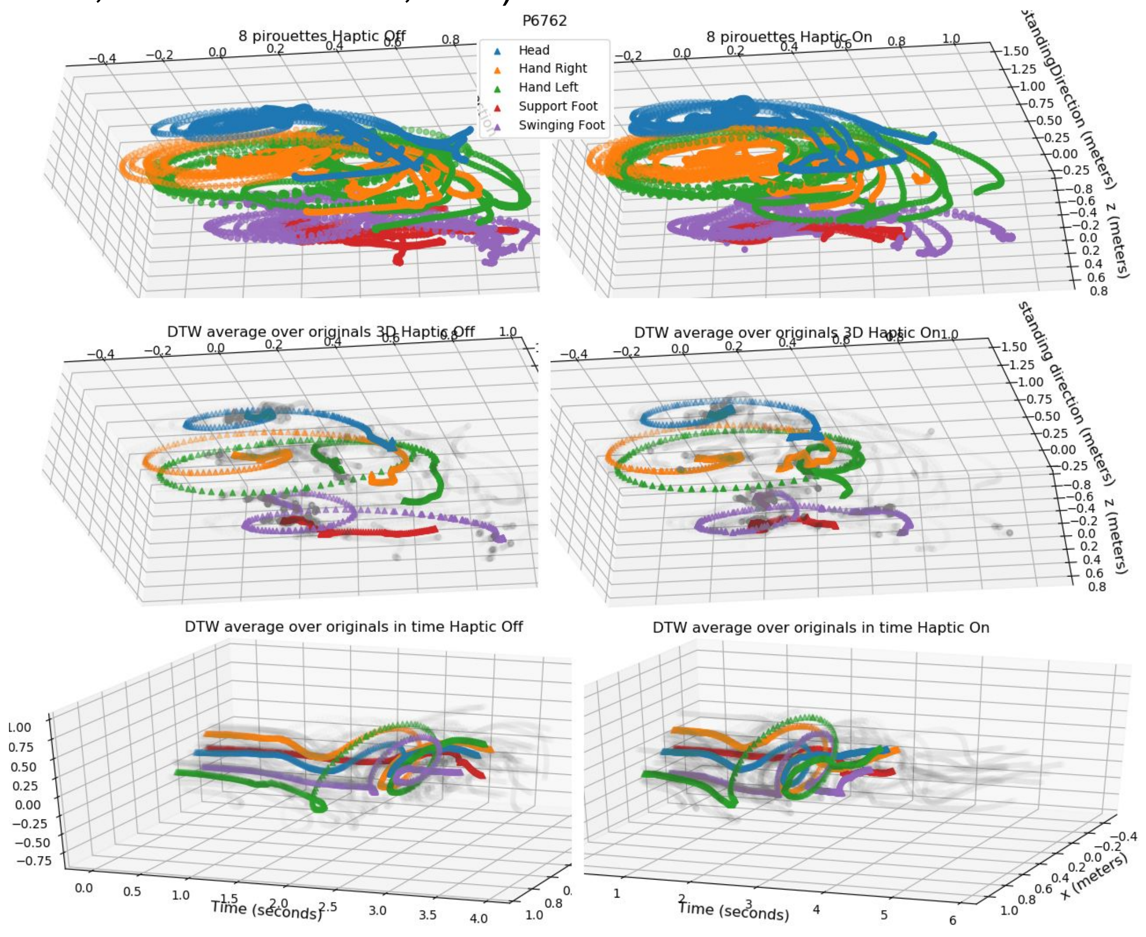
Participant performing a pirouette



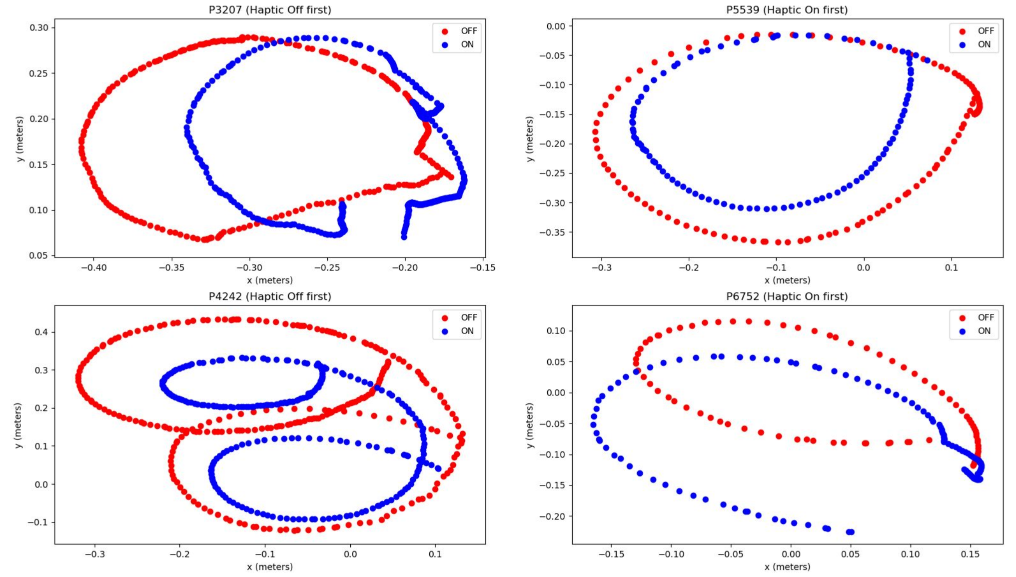
GUI of AMI showing example of active vibrotactile display

Results

Analysis with t-test (SPSS, IBM Corp., Armonk, NY) revealed no significant difference in the number of rotations between the HAF on and and HAF off conditions. The area encompassed by the head trajectory, however, differed significantly between conditions (p=0.024, HAF On 6 cm^2, +/-2, HAF Off 9 cm^2, +/-6).



Dynamic Time Warped averaged example of one participant plotted in 3d and in 2d against time. Originals shown in gray and representative tracked objects are colored.



God's eye view of DTW head trajectories (HAF on vs. HAF OFF).

Conclusions

HAF did not impact the number of rotations generated per pirouette, however, it did affect the trajectory of the head, indicating a more stable posture. Due to the latency of the HAF with this system and reaction time participants were likely not able to make specific adjustments to HAF stimuli during the pirouette. Participants likely investing more attention to balance because of the HAF.

Due to COVID-19 delays, a follow-on study could not be completed and no conclusions can be made on motor learning (3).

Literature cited

1. 1. Sigrist, R., Rauter, G., Riener, R., & Wolf, P.(2013). Augmented visual,auditory, haptic and multimodal feedback in motor learning: A review
2. 2. Lott, M. B., & Laws, K. L. (2012). The Physics of Toppling and Regaining Balance during a Pirouette
3. Schmidt RA, Lee TD. Motor Control and Learning: A Behavioral Emphasis (2005)

Acknowledgments

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Further information

www.ihmc.us/research/multi-sensory-multi-modal-neural-interfaces/