Developing a Real-Time Movement Sonification System for Upper-Limb Rehabilitation for Stroke Survivors

Thomas H. Nown, *Graduate Student Member, IEEE,* Andrew Kerr, Ivan Andonovic, *Senior Member, IEEE,* Madeleine A. Grealy, Christos Tachtatzis, *Senior Member, IEEE*

Abstract— **Real-time movement sonification is currently being researched as an intervention for upper-limb rehabilitation for stroke survivors. A system using the Azure Kinect SDK has been developed to empower researchers to investigate this intervention. The presented study shows that users without neurological impairment can identify their own movements through the real-time audio feedback generated through the prototype system.**

Clinical Relevance— **This study provides justification for a future feasibility study with stroke survivors using the developed system, by establishing existing functionality in users without movement impairment.**

I. Introduction

Upper-limb hemiparesis is a common persisting problem for stroke survivors. New rehabilitation interventions are needed to improve independence and reduce the costs of care. One such intervention, referred to as 'movement sonification', shows promising signs of improved motor re-learning. Movement sonification requires a system to monitor human movement and convert associated data to relatable auditory feedback. Since these systems are not currently available off-the-shelf, a new real-time movement sonification system utilizing the Azure Kinect Software Development Kit (SDK) has been developed at the University of Strathclyde. This study investigates the extent to which users of this system perceive a correspondence between their movements and the sounds produced during real-time movement sonification.

II. Methods

10 volunteers from the University of Strathclyde with normal hearing and upper-limb movement performed reaching movements with their right hand. During each forward reach the hand position was mapped to audio pitch, and no sound was generated when the right hand was still. On some trials a triangle-wave component was added to modulate the pitch of the synthesized sound for 11 notes. This was triggered halfway through the reaching forward phase of the movement. The amplitude of this component depended on the trial assignment to one of four conditions: Severe Modulation (amplitude = six), Moderate Modulation (amplitude = three), Subtle Modulation (amplitude = two) and, No Modulation (amplitude = zero). There were 40 trials in total, 10 in each modulation condition, and they were presented randomly. Following each sonified movement the participant rated the extent to which they perceived the sound to correspond to their movement on a seven-point Likert scale ranging from 'Strongly Disagree' to 'Strongly Agree'.

Thomas H. Nown is with the University of Strathclyde, Glasgow, G1 1RD; e-mail: thomas.nown@strath.ac.uk

III. Results

Data from the four conditions were analysed using a one-way repeated measures ANOVA. This showed a statistically significant difference ($F(3,27) = 52.992$, $p < 0.001$, $\eta_p^2 = 0.855$). Pairwise comparisons revealed the trials with Severe Modulation were rated as having a lower correspondence between movement and sound than the trials with Moderate Modulation (p=0.034, 95% C.I. = -1.198, -0.042). The Moderate Modulation trials were rated significantly lower than the Subtle Modulation trials (p=0.001, 95% C.I. = -1.904, -0.636) and the Subtle Modulation trials were rated lower than the No Modulation trials (p=0.005, 95% C.I. = -2.987, -0.543).

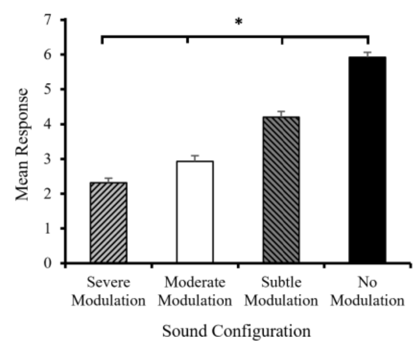

Figure 1. Means and standard deviations for participant's ratings in the four sound modulation conditions (*p<0.05).

IV. Discussion & Conclusion

Results from this study indicate that users with normal upper-limb movement can identify their movements from false movement sonification configurations through the quality of audio feedback, whilst using the developed system. Future work in this area is multifaceted, with one aspect to investigate the feasibility of this system with stroke survivors and the second aspect to transfer the capabilities of this system into an accessible technology, such as a smart phone.

Acknowledgment

Funding for this project was obtained through ESPRC grant number EP/LO15595/1 Centre for Doctoral Training in Medical Devices and Health Technologies.