THE EFFECTS OF VARIOUS PARAMETER COMBINATIONS IN PARAMETER-MAPPING SONIFICATIONS

S. Camille Peres[1], Daniel Verona[2], Paul Ritchey[1]

Texas A&M University
[1]Department of Environmental and Occupational Health
[2]Department of Biomedical Engineering

ABSTRACT

This study will be investigating the design of parameter-mapping sonifications and investigating how different combinations of sound parameter mappings affect the user's ability to understand and interpret sEMG data. The parameter mappings being used are all redundantly mapped and the specific parameter combinations are 1) pitch and loudness, 2) pitch, loudness, and attack time, and 3) loudness and attack time. There will be both spatialized (right and left) and non-spatialized versions of each of these mappings. These mappings will be used to present sonifications of two channels of sEMG data to participants to explore if they can identify muscle activation order (which muscle activates first) and relative muscle exertion levels (which muscle has a higher exertion). It is expected that participants will perform better with the spatialized mappings. It is also expected that the participants will perform better with the mappings that include attack time because this results in greater timbral variety.

1. INTRODUCTION

The simplest accepted definition of sonification is "the use of non-speech audio to convey information" [1]. However, as new techniques for sonification have been implemented, a further definition of sonification was offered by Hermann [2]. This definition states that a technique which takes data as input and generates sounds can only be called a sonification if the sound reflects objective properties of the data, the conversion of data to audio is systematic (explicitly defined), the generated sounds are reproducible, and the system can be used with different data sets. Also in [2], Hermann discusses the necessity of defining what type of sonification is being employed: audification, parameter-mapping sonification, or model-based sonification.

This study is using parameter-mapping sonification (PMSon) to sonify surface electromyography (sEMG) data. sEMG measures muscle activation and exertion and is used as an index of fatigue processes occurring within a muscle [3], and as a biofeedback tool [4]. PMSon is a common form of sonification [5,6,7] defined as the mapping of data features to acoustic features of sound events or streams [2]. Many parameters of sound have been examined for use in PMSon, including pitch, loudness, harmonics, speed, tremolo, attack time, and spatial location [8,9,10]. However, there is still a lack of objective evaluation of sonification parameters [10].

For some auditory displays, it has been shown that mapping more than one parameter redundantly (such as pitch and loudness) results in better performance than mapping only one parameter at a time [11]. However, the benefit in performance was only found when certain dimensions of sound were used, specifically pitch and loudness. When scatterplots of temperature data were sonified and spatialization (panning) was used to redundantly represent time (x-axis), performance improved compared to a temporal mapping only [12]. The number of octave ranges used was also varied and it was found that participants performed better with wider octave ranges as compared to a one octave range. These findings indicate that for different types of auditory displays, the best parameters used for mapping will likely be different, and thus empirical research needs to be conducted to identify the most appropriate mappings.

This study is currently in progress and data collection is expected to begin soon. The study seeks to evaluate four parameters of sound as they relate specifically to sonifying sEMG data: pitch, loudness, attack time, and spatial location. Sonification of EMG data has been shown to have potential clinical application in regards to diagnosing musculoskeletal problems [13] and in rehabilitation for stroke patients [14]; however the pleasantness of EMG sonification needs improvement [13, 15]. The purpose of this study is to identify parameters of sound that are useful for interpreting sEMG data, and to determine which mappings users find to be the most intuitive and the most pleasant.

2. PARAMETER MAPPING

Mapping pitch and loudness redundantly has been shown to improve user performance [11]. However, it may be the case that certain redundant mappings do not result in redundancy gains and certain redundant mappings do [11]. With this in mind, we have taken the four parameters of sound mentioned above and combined them to create six different redundant sonification designs:

1. Pitch, Loudness, Non-spatialized
2. Pitch, Loudness, Attack time, Non-spatialized
3. Loudness, Attack time, Non-spatialized
4. Pitch, Loudness, Spatialized
5. Pitch, Loudness, Attack time, Spatialized
6. Loudness, Attack time, Spatialized

SuperCollider is being used to create the sonifications for this study. The Pbind function in SuperCollider is used to play 10 tones per second, and the parameters of each tone (pitch, loudness, and attack time) are controlled by the sEMG data. Triangle waves are being used for these sonifications, since they are slightly brighter in tone than sine waves. Pitch and loudness increase as the sEMG amplitude increases and attack time decreases as the sEMG amplitude increases. Each sonification presents two channels of sEMG data simultaneously, and the channels are referred to as Muscle A and Muscle B. To spatialize the sonifications, data from

Muscle A are panned hard left and data from Muscle B are panned hard right. The non-spatialized mappings play data from both muscles equally in the left and right audio channels.

3. METHODS

3.1. Participants

Participants for this study will be recruited from Texas A&M University, and will only be allowed to participate if they do not have a self-reported hearing impairment. Any musical experience will also be noted.

3.2. Procedure

Participants in this study will use headphones to listen to the sonifications of sEMG data. Each participant will listen to ten sonifications of each design for a total of 60 sonifications. Each sonification is 10 seconds in duration and presents data from two different muscles (Muscle A and Muscle B) simultaneously. In each sonification, both muscles begin at rest, contract briefly, and then return to rest. After listening to each sonification, participants will be asked to identify which muscle activated first (A or B), and which muscle had a higher exertion (A or B). Their responses will be recorded into a database for analysis.

3.3. Design

The study will be a fully within factorial design with 4 independent variables regarding auditory dimension: pitch loudness, attack time, and spatial location. There are two performance dependent variables: judgment of start time and judgment of intensity. There will also be several subjective dependent variables.

3.4. Measures

The ability of the participants to identify the features of activation time and exertion level in the sEMG data will be used to determine the overall value of each sonification design. Participants will also be asked to rank the designs in terms of pleasantness, so that any correlations found between the pleasantness of a design and its ability to accurately convey information to the participant can be investigated further.

4. EXPECTED RESULTS

It is expected that the mappings which spatialize the sonification will result in better performance due to the fact that spatialization allows for easier localization of the separate sEMG channels within the stereo field. Additionally, it is expected that the mappings which include attack time will result in better performance due to the fact that they contain greater timbral variety. For this reason, it is also expected that the mappings which include attack time will be deemed more pleasant to listen to.

5. REFERENCES

[1] Hussain, Tilevich, Bucvik, & Kim. “Sonification Design Guidelines to Enhance Program Comprehension.” *Proceedings from the 17th International Conference on Program Comprehension* (2009): 120-129.

[2] Hermann. “Taxonomy and Definitions for Sonification and Auditory Display.” *Proceedings of the 14th International Conference on Auditory Display* (2008): 1-8.

[3] De Luca. "The Use of Surface Electromyography in Biomechanics." *Journal of Applied Biomechanics* 13 (1997) 135-163.

[4] Steele et al. "Electromyography as a Biofeedback Tool for Rehabilitating Swallowing Muscle Function." *Applications of EMG in Clinical and Sports Medicine* (2012): 311-328.

[5] Barrass, Whitelaw, & Bailes. “Listening to the Mind Listening.” *Leonardo Music Journal* 16 (2006): 13-19.

[6] Daye & de Campo. “Sounds Sequential: Sonification in the Social Sciences.” *Interdisciplinary Science Reviews* 31.4 (2006): 349-364.

[7] Kramer et al. “Sonification Report: Status of the Field and Research Agenda.” *Tech. Rep., International Community for Auditory Display* (1999)

[8] Anderson & Sanderson. “Sonification Design for Complex Work Domains: Dimensions and Distractors.” *Journal of Experimental Psychology: Applied* 15.3 (2009): 183-198.

[9] Baier, Hermann, & Stephani. “Event-Based Sonification of EEG Rhythms in Real Time.” *Clinical Neurophysiology* 118 (2007): 1377-1386.

[10] Dubus & Bresin. “A Systematic Review of Mapping Strategies for the Sonification of Physical Quantities.” *PLOS ONE* 8.12 (2013): 1-28.

[11] Peres & Lane. “Auditory Graphs: The Effects of Redundant Dimensions and Divided Attention.” *Proceedings of ICAD 05-Eleventh Meeting of the International Conference on Auditory Display* (2005): 1-6.

[12] Ritchey et al. “Effective Design of Auditory Displays: Comparing Various Octave Ranges of Pitch and Panning.” *Proceedings from the 16th International Conference on Auditory Display* (2010): 121-125.

[13] Pauletto & Hunt. “The Sonification of EMG Data.” *Proceedings of the 12th International Conference on Auditory Display* (2006): 152-157.

[14] Sholz et al. “Sonification as a Possible Stroke Rehabilitation Strategy.” *Frontiers in Neuroscience* 9 (2014): 1-7.

[15] Yang & Hunt. “Real-Time Auditory Feedback of Arm Movement and EMG in Biceps Curl Training to Enhance the Quality.” *Proceedings from SoniHED – Conference on Sonification of Health and Environmental Data*.