Real-Time Sonification of Motor Coordination to Support Motor Skill Learning in Sports

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1 OBJECTIVES

It is essential that we recognize our own posture and body movement if we are to acquire and improve goal-directed actions such as sports. However, it is not easy to adequately realize one's own state where multiple body segments are temporally coordinated. Although visual feedback (e.g., snapshots and video streaming) has been the most widely used way of displaying motor information (reviewed by Sigrist et al. 2013), they are expected to be limited in terms of showing the temporal structure of segmental activity because of the insufficient temporal resolution of human visual perception compared with that of auditory perception. In fact people often utilize auditory feedback to realize temporal features of motor behavior in daily life such as speech articulation (Sasisekaran 2012). The sonification of motor information is designed to extend the human auditory system so that it can utilize motor control in limbs in addition to speech. It is expected that the artificially provided auditory feedback integrates somatosensory information in action and such integration enhance motor learning.

The results of previous studies have already been applied to sports training, but most of them have sonified the behavioral outcomes (e.g., ski displacement, Kirby 2009) or individual segmental activity (e.g., the timing of wrist and ankle movement in karate, Yamamoto et al. 2004). Instead our idea is to sonify the temporal coordination of multiple body segments, that is, how the body is controlled. In this study we propose the sonification of segmental coordination in sports action using muscle activity and acceleration signals in multiple target segments.

2 METHODS

To realize auditory feedback motor coordination in sports action we used surface electromyography (EMG) and acceleration signals, which we recorded at sampling rates of 2000 Hz and 150 Hz, respectively, by using a wireless sensor (Trigno Wireless EMG, DELSYS, USA) attached to the surface of the target muscles. The recorded EMG and acceleration signals were delivered to a PC at 10 kHz and were processed for conversion into sound using the custom-made software developed in Processing 2.

3 RESULTS

For most sports it is critical to coordinate the activity of multiple muscles sequentially. For instance, in baseball pitching, a pitcher needs to operate his/her muscles in sequence from the leg to the arm, which is well known as a segmental kinetic chain (Feltner 1989). Thus we attempted to sonify the precision of such sequential muscle activity patterns, based on multiple EMG signals from the lower and upper limb muscles.

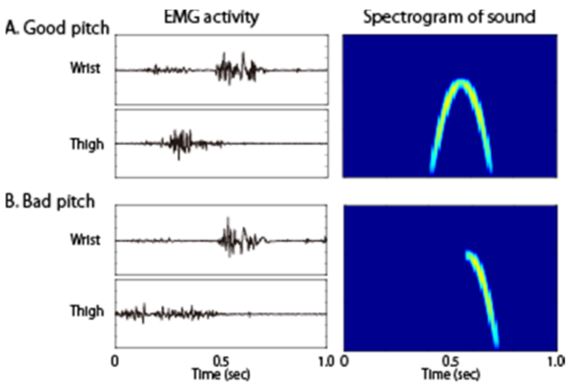

Figure 1: Sonification of the "precision" of pitching coordination.

Figure 1 demonstrates an example of the sonification of the "precision" of pitching coordination. Good pitching almost always includes clear leg and arm muscle activity (left panel in Fig.

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1A), while bad pitching frequently does not (left panel in Fig. 1B) indicating the poor precision of muscle coordination. We aimed to convert this precision of coordination into sound. For good pitching, the sound signal consisted of a chirp waveform. Its fundamental frequency was initially low. It gradually increased after the onset of EMG activity was detected in the thigh muscle, and then gradually decreased after the onset of EMG activity in the wrist muscle (right panel in Fig. 1A). In contrast, for bad pitching where the thigh EMG activity was insufficient, the first increase in the chirp waveform was not present (right panel in Fig. 1B). The pitcher could hear a wind-like sound with good pitching, but not with bad pitching.

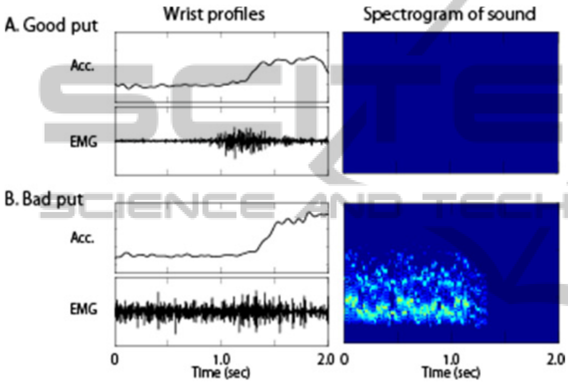

Figure 2: Sonification of excessive muscle activation during preparation for putting in golf.

A sports player often could not perform well because he/she was trying too hard. This corresponds to unintentional excessive activation of the muscles caused by mental pressure, and it is very common and serious in sports. Thus it would be useful to make an athlete aware of this potential for excessive muscle activation.

Figure 2 shows an example of the sonification of excessive muscle activation in the initial stages (address and take back) of putting in golf, based on a wrist extensor EMG and acceleration signals. The sound signal consisted of a periodic waveform whose amplitude and fundamental frequency were varied in proportion to the short-term power of the EMG activity only when the acceleration was below a certain threshold, while these values were kept at almost zero when the acceleration was above the threshold. Therefore, the golfer could hear sounds during the preparation (address) period when the muscle was activated more than necessary while the wrist moved slightly (Fig. 2B). Conversely, he/she could not hear these sounds when the muscle was relaxed (Fig. 2A). No sound was produced when the wrist was moving (taking back).

4 DISCUSSION

Although this study showed two examples of the sonification of the temporal coordination of multiple segmental activities in sports action, the combination of segmental information and auditory ways of presenting them should vary according to the objective of the players. For example, the sonification of the precision of segmental activities (Fig. 1) may be more useful to a novice or an intermediate player for improving his/her basic temporal pattern of a target form, while the sonification of excessive muscle activation (Fig. 2) is beneficial as regards recognizing one's own mental state during a given action.

We should consider other elements of sonification. For instance, it is very important to detect the key features of motor coordination in a target action. It is also critical to assess the effectiveness of auditory feedback. Further empirical studies are needed to help a player learn a desired sports-related motor skill effectively.

REFERENCES

Feltner, ME., 1989. Three-dimensional interactions in a two-segment kinetic chain. II. Application to the throwing arm in baseball pitching. International Journal of Sport Biomechanics 5: 420–450.

Kirby, R., 2009. Development of a real-time performance measurement and feedback system for alpine skiers. *Sports Technology*. 2: 43-52.

Sasisekaran, J., 2012. Effects of delayed auditory feedback on speech kinematics in fluent speakers. *Perceptual and Motor Skills*. 115: 845–864.

Sigrist, R., Rauter, G., Riener, R., Wolf, P., 2013. Augmented visual, auditory, haptic, and multimodal feedback in motor learning: a review. *Psychonomic Bulletin & Review*. 20: 21-53.

Yamamoto, G., Shiraki, K., Takahata, M., Sakane, Y., Takebayashi, Y., 2004. Multimodal knowledge for designing new sound environments. In *The International Conference on Human Computer Interaction with Mobile Devices and Services*. Citeseer.