

Auditory Modeling in Sport: Theoretical Framework and Practical Applications

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Abstract

Visual models, i.e. live demonstrations or film clips, are widely used in sport as training instruments. Nevertheless, in recent years some research demonstrated that the well known property of sounds to effectively represent the temporal structure of a given task and to promote its accurate reproduction, is not valid only for simple motor gestures, but also for the complex movements that characterize sport performances. As a consequence, there is a growing interest towards the study and the implementation of auditory models as an alternative to the visual ones traditionally used. The present work begins by theoretically frameworking the use of auditory modeling in sport according to the Theory of Event Coding. Then, some of the practical applications of the two auditory modeling techniques, i.e. Movement Sonification and Second Order Biofeedback, are synthetically reviewed.

Keywords: sound; sport; auditory modeling; Theory of Event Coding; Movement Sonification; Second Order Biofeedback.

Auditory modeling: The theoretical framework

Performance models are commonly used in sport as training instruments. In the common practice, these models are mainly based on vision: the correct execution of a given gesture/movement is shown either by the trainer himself or through a film clip. This “pragmatic” tradition lays its scientific foundation in Bandura’s (1977) research on learning through imitation, as well as in many other studies that investigated the learning of simple motor sequences through the exposition to visual models (e.g. Blandin, Proteau, & Alain, 1994; Scully & Newell, 1985; Shea, Wright, Wulf, & Whitacre, 2000). The rationale underlying this method is that an accurate observation of a correct movement can promote the emulation of that motor pattern, thus generating learning. From a physiological perspective, this would happen thanks to mirror neurons clusters, which would fire in motor areas also when the movement is only observed (Rizzolatti, Fadiga, Gallese, & Fogassi, 1996).

However, while visual models are useful in the acquisition of new motor gestures (Ste-Marie et al., 2012), there is no clear evidence of their effectiveness in optimizing the execution of movements whose motor schemata are already developed, which is the case of athletes. Beside this fact, some researchers demonstrated that auditory models, i.e. sequences of sounds reproducing the timing of a given movement, are more effective than visual ones in promoting the identification, the discrimination, the memorization and the reproduction of precisely timed movements (e.g. Doody, Bird, & Ross, 1985; Glenberg & Jona, 1991; Grondin & McAuley, 2009;

Lai, Shea, & Little, 2000), which is the case of athletic and technical gestures in sport.

A first explanation to this superiority of the sound was provided by Keele, Pokorny, Corcos and Ivry (1985), who demonstrated that there is a significant correlation between the auditory perceptual timing and the motor production one, thus claiming that their respective mechanisms are tightly interconnected. To address the same issue, in more recent years the Theory of Event Coding (TEC; Hommel, Müsseler, Aschersleben, & Prinz, 2001; Zmigrod & Hommel 2009) was proposed. The TEC claims that auditory perception and motor action share a common representational system, in which perceptual processes would activate some codes associated with the features of the perceived events. These codes would be pre-activated when people have to make a movement and, because of this activation, these codes would have a higher probability to be used in the motor planning. Auditory models would promote the activation of the codes associated to the temporal features of the sound. Thus, these codes would be pre-activated during motor planning, promoting the production of movements with the same temporal features of the perceived sound.

From a neurophysiological perspective, the TEC received support from fMRI studies. Indeed, Chen, Penhune and Zatorre (2008) registered activation in participants motor regions (supplementary motor area, mid-premotor cortex, and cerebellum) while they were listening to rhythms to be later reproduced by tapping. Moreover, Woods, Hernandez, Wagner and Beilock (2014) obtained similar results with athletes, registering activation in areas involved in action planning (supplementary motor area, pre- and postcentral gyri, inferior frontal gyrus, and parietal operculum) when they were passively listening to familiar sport sounds.

In sport, movements have to be precisely timed to be successful. According to the TEC, listening to an auditory model deriving from a correct and high-level performance should promote its accurate reproduction: this is the rationale underlying the use of auditory modeling in sport.

Practical applications in sport

There are two auditory modeling techniques, which share the described rationale but practically implement it in different ways. Movement Sonification (MS; Effenberg, 1996) consists of the conversion of some physical parameters (e.g. velocity, force) of the movement under investigation into an artificial/synthetic sound. Second Order Biofeedback (SOBF; Agostini, Righi, Galmonte, & Bruno, 2004), instead, is based on the natural sounds produced by athletes during their action (e.g. the physical

impact of limbs/equipment with air/ground/water/ball). In the next two sections, some of the practical applications of the two techniques are reviewed.

Movement Sonification

The first application of MS to sport did not concern a specific technical gesture, but a basic movement for different sports, i.e. the countermovement jump. Effenberg (2005) sonified such jumps by mapping the vertical component of the ground reaction force, measured by a force plate, to the amplitude and frequency of sound as an electronically sampled vocal *a*. Then, sports students were asked to reproduce as accurately as possible the height of jumps in two conditions: after watching a mute film clip or after watching a sonified film clip. Participants were significantly more accurate in the latter condition. This outcome demonstrates that MS has a positive impact on the performance, but the absence of a MS-only condition does not allow disentangling its relative “weight” in comparison with the visual model.

Schaffert, Mattes and Effenberg (2011) conducted a study that demonstrates the effectiveness of MS in optimizing a sport movement. These authors developed a system that sonify on-line the acceleration (and the deceleration) of rowing boats, giving rowers the possibility to monitor the effectiveness of their rowing cycle. Results revealed that, at the same stroke rate, boat velocity was significantly higher when the sonifier system was switched on than when it was switched off. Moreover, the distance travelled, a factor dependent on the boat velocity, was obviously also greater when the sonifier system was switched on than when it was switched off. These outcomes highlight two important aspects: the first one is that also MS alone can improve performances; the second one is that also complex sport movements, like rowing cycle is, can benefit from this technique.

Murgia and colleagues (2012) conducted another study that demonstrates the effectiveness of MS in sport. These authors created auditory stimuli to guide lifters during the one-repetition bench press exercise; the stimuli consisted of an initial countdown, followed by a low-intensity sound (60 db), which corresponds to the down phase of the exercise, and by a high-intensity sound (95 db), which corresponds to the pressing phase. Results revealed that the average power exerted in the auditory stimulation condition was significantly greater than that exerted in the control condition.

Second Order Biofeedback

The first application of SOBF to sport was implemented by Agostini, Righi, Galmonte and Bruno (2004), and concerns hammer throw. The natural sound these authors used was that produced by the hammer’s friction with the air while rotating, recorded by placing a microphone near the head of the hammer itself. By proposing to athletes the auditory model associated with their longest baseline throw, two kinds of performance improvement were obtained:

compared to the baseline, the experimental throws showed both a significant increase in the average length and a significant decrease in length variability. These outcomes highlight that SOBF promoted an upward standardization of the throwing performance.

Another study that demonstrates the effectiveness of SOBF in optimizing a sport performance is a “case-study” on swimming conducted by Galmonte, Righi and Agostini (2004). These authors recorded the sound produced by a young agonist swimming at a standard stroke rate; then, together with the athlete, they chose the best stroke and looped it, thus creating an ideal auditory model. This model was provided to the athlete before a new swimming session, in which he obtained performance improvements similar to those described for the previous study, i.e. slower and less variable times to complete the standard distances compared to the baseline.

Another important study concerning SOBF is that conducted by Galmonte, Agostini and Righi (2009). It is really important because it compared the effectiveness of an auditory model to that of a visual one and that of an audio-visual one. The sport under investigation was the tennis, and in particular the serve. On a first day, young tennis players were asked to perform 100 serves; for each participant, together with the trainer, the best serve was chosen in order to create one of the three above mentioned models, according to the experimental group. Then, on a second day, athletes were provided with this model before performing other 100 serves. Results revealed a non-significant decrease of serve efficacy (i.e. the number of valid serves out of the total trials) for the visual model group, and a significant increase of serve efficacy for both the audio-visual and the auditory model groups, with the latter one showing a greater performance improvement. Moreover, the auditory model group showed less variability compared to both the audio-visual and the visual model groups.

Conclusions

According to the TEC, listening to an auditory model deriving from a correct performance should promote its accurate reproduction. This would be due to the fact that auditory perception and motor action would share a common representational system, so that the pre-activation of the codes associated to the temporal features of the perceived sound would promote the reproduction of a movement with the same temporal features.

Beyond the research synthetically described here, there are other studies that demonstrate the effectiveness of auditory modeling in optimizing sport performances, both in the form of MS (for a review, see Sigrist, Rauter, Riener, & Wolf, 2013) and SOBF (e.g. Murgia et al., 2011; Prpic et al. 2010). Besides continuing to test the effectiveness of the two techniques in new sports, an interesting future direction in this field could be that of comparing them on the same sports, in order to discover which disciplines can benefit more from MS and which ones can benefit more from SOBF.

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