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ORIGINAL PAPER

The SoundBike: musical sonification strategies to enhance cyclists' spontaneous synchronization to external music

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Abstract

The spontaneous tendency of people to synchronize their movements to music is a powerful mechanism useful for the development of strategies for tempo adaptation of simple repetitive movements. In the current article, we contribute to such strategies—applied to cycling—by introducing a new strategy based on the sonification of cyclists' motor rhythm. For that purpose, we developed the SoundBike, a stationary bike equipped with sensors that allows interactive sonification of cyclists' motor rhythm using two distinct but compatible sonification methods. One is based on the principle of step sequencers, which are frequently used for electronic music production. The other is based on the Kuramoto model, allowing automatic and continuous phase alignment of beat-annotated music pieces to cyclists' motor rhythm, i.e., pedal cadence. Apart from an in-depth presentation of the technical aspects of the SoundBike, we present an experimental study in which we investigated whether the SoundBike could enhance spontaneous synchronization of cyclists to external music. The results of this experiment suggest that sonification of cyclists' motor rhythm may increase their tendency to synchronize to external music, and helps to keep a more stable pedal cadence, compared to the condition of having external music only (without sonification). Although the results are preliminary and should be followed-up by additional experiments to become more conclusive, SoundBike seems anyhow a promising interactive sonification device to assist motor learning and adaptation in the field of sports and motor rehabilitation.

Keywords Sonification · Musical biofeedback · Sensorimotor synchronization · Movement tempo adaptation · Reinforcement learning · Reward

1 Introduction

In the domain of sports and motor rehabilitation, sonification of physical and physiological data is typically used to serve three functions, namely to motivate, to monitor, and/or to modify human performance (for an in-depth discussion, see [1]). Auditory feedback has been proven particularly useful in assisting motor learning and adaptation. The way sonification, or auditory biofeedback, is deployed for this purpose may rely on different strategies. The most typical strategy pertains to a goal-driven approach. This approach requires that the learner has an explicit representation of the target behavior, i.e., the goal. Sonification then functions as mere information carrier, allowing people to monitor their behavior, compare it to the target behavior, and adapt their behavior if required [2–4]. As indicated by Ram and Leake [5], this process is guided by reasoning and attention mechanisms and may therefore not always be the most appropriate strategy. Recently, a promising alternative strategy is being explored, drawing upon basic principles from the reinforcement learning paradigm. Reinforcement learning is rooted in the idea that people act and behave so as to maximize outcome reward. Hence, when coupling a reward to a desired behavior, people are likely to exhibit this behavior spontaneously, without needing to be told explicitly what to do. In this context, music and sound are particularly relevant as they might be rich sources of reward and pleasure (for an in-depth discussion, see [1]). One important source of pleasure in our interaction with music is entrainment or synchronization [6–8]. Thanks to this pleasure, people often exhibit a spontaneous tendency to align their movements to perceived patterns in the music, such as the beat. Spontaneous synchronization is a phenomenon ubiquitous in behavior of biological systems,

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