It's all about Rhythm! Empirical evidence for the benefits of acoustic stimuli/information in sports and rehabilitation

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***Summary*— Research over the past two decades revealed a rich physiological connection between the auditory and motor system across a variety of cortical, subcortical, and spinal levels. Entrainment accrues due to the fast and precise processing of temporal information in the auditory system. Results in high performance sports and neurologic rehabilitation showed significantly improved movement-execution and stabilized temporal motor control with provided external acoustic information due to rhythm-based auditory-motor-synchronization.**

INTRODUCTION

Acoustic stimuli have a profound and direct effect on the motor system. Particularly, rhythmic information enforces motor responses. Provided audibly as external acoustic feedback (AF), it supports the timing of movement-execution subliminally [1] as rhythm provides a continuous and anticipatory time reference for mapping movements within a temporal template [2]. Cyclical movements are particularly suited due to their regularly repetition in time. The fast-acting physiological entrainment mechanisms between rhythm and motor responses serve as coupling mechanisms to stabilize and regulate movement patterns. Based on these findings, an AF-concept for on-water training in high performance rowing was developed and implemented into the German Rowing Association. Sonifying a kinematic parameter of the boat motion, it was aimed at increasing mean boat velocity (v_B), assuming that AF has an effect on the time structure of the rowing cycle [3]. In rehabilitation, 3 techniques in motor therapy for neurologic patients were developed and have become standard in neurologic music therapy [2]: rhythmic auditory stimulation (RAS) for gait, patterned sensory enhancement (PSE) for upper extremity and full body coordination, and therapeutic instrumental music playing (TIMP). RAS, PSE, and TIMP involve the use of rhythmic sensory cuing on the motor system and are based on entrainment models in which rhythmic auditory cues synchronize motor responses into stable time relationships. Multiple studies have demonstrated the therapeutic benefits of rhythmic entrainment via RAS, PSE, and TIMP in motor therapy, most extensively with patients post Cerebrovascular accident (CVA) and Parkinson's disease (PD).

METHODS

The German National Rowing Team (juniors, seniors *N*=47, 12 boats; adaptives *N*=6) was examined with *Sofirow*. Boat acceleration (a_B) was measured (MEMS-sensor ≥125Hz), parameter-mapping-based sonified and provided online during rowing for 3 training sessions per boat. AF was presented in blocks (with and without alternately). Investigations in gait rehabilitation were realized with patients (1) post CVA (experimental-control-group) over a 6-week (*N*=20) and 3-week daily training program (*N*=78) and, (2) with Parkinson's disease (*N*=37) over a 3-week at-home based exercise program (30min. daily).

RESULTS

ANOVA showed significantly increased mean v_B with AF compared to sections without AF for all boats ($p<.01$). Intra-cyclical analysis revealed qualitative changes in the a_B-time structure for its critical phases (recovery and front reversal), and a reduction of a_B-variations during the recovery. Results in PSE and TIMP studies have shown significant reductions in variability of arm trajectories and significant increases in functional arm motor tests. Gait studies showed significantly improved velocities with increases in stride length and cadence for the RAS groups vs. control groups. In-depth physiological analysis of EMG patterns showed significantly decreased muscle shape variability and asymmetries for RAS and thus, more stable gait patterns [2].

DISCUSSION & CONCLUSIONS

Results showed how the temporal structure of acoustic stimuli can be used as a physiological template to cue the control and temporal regulation of movements. Sonified boat motion reflected the rhythm of the rowing cycle by providing detailed information of its characteristic phases, yielding to improved crew synchronization. RAS demonstrated a strong facilitating effect on motor performance in several patient groups with gait deficits (CVA and PD) and also improves positional and muscular control. Facilitation and immediacy of effects occurred due to the close neural connection between auditory and motor areas [1]. Acoustic stimuli uses multiple auditory-motor pathways to access and entrain central motor processors that are coupled to rhythmic time information, suggesting, that the interaction stabilized the internal rhythm generating system and reintegrated timing networks [4] independent of specific participant groups.

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