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ScienceDirect

Procedia - Social and Behavioral Sciences 126 (2014) 24 – 26

Procedia
Social and Behavioral Sciences

ICTTP 2014

Entrainment: A domain general cognitive timing mechanism?

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Abstract

From an early age onwards we tend to synchronize to temporally regular and rhythmic stimuli, such as the beat in music, which inevitably leads to movement. Recently, such basic mapping of temporally regular sound and motor behavior has been critically discussed and the four speakers of this symposium will address extensions of a basic sensorimotor conceptualization of entrainment in their talks. M. Henry and colleagues discuss oscillatory entrainment in perception only, while E. Large puts to test whether oscillatory entrainment simply mirrors stimulus frequency when movement is coupled with syncopated rhythm. J. Grahn explores whether non-beat related factors impact synchronization in movement, while S. Dalla-Bella confers how stimulus complexity affects people's capacity to synchronize finger tapping but also perception. The symposium will be discussed by V. Penhune.

Selection and peer-review under responsibility of the Organizing Committee of the International Conference on Timing and Time Perception.

Keywords: Rhythm; Timing; Synchronization; Movement; Audition

1. Neural entrainment as a mechanism for auditory timing by Molly Henry, Björn Herrmann, and Jonas Obleser

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Selection and peer-review under responsibility of the Organizing Committee of the International Conference on Timing and Time Perception.
doi:10.1016/j.sbspro.2014.02.304

Behaviourally relevant environmental stimuli are often characterized by some degree of temporal regularity. Dynamic attending theory provides a framework for explaining how perception of stimulus events and their temporal properties is affected by the temporal context within which they occur. We have recently begun to investigate how entrainment of low-frequency neural oscillations might support auditory perception of temporal and non-temporal stimulus properties as a neural implementation of dynamic attending. I will present recent magneto- and electroencephalography (M/EEG) data from our group that demonstrates the critical role of entrained low-frequency oscillations in time perception, specifically, and auditory perception more generally.

2. Synchronization to missing pulse rhythms *by Edward Large*

Pulse and meter have been hypothesized to arise as endogenous cortical rhythms that entrain to acoustic rhythms. Synchronized cortical activity has been observed in auditory and motor cortices using non-invasive measures, and has been linked with movement synchronization. In most experiments, however, a difficulty arises in interpreting synchronized movements or synchronized neural fluctuations as entrained neural oscillation, because the entrained frequency is also present in the acoustic stimulus. Here, we investigate synchronization of periodic movements to highly syncopated rhythms whose amplitude envelopes contain no spectral energy at the frequency of the intended pulse. We show that listeners entrain predominantly at the intended pulse frequency even for such “missing pulse” rhythms. This rules out synchronization due merely to the input frequency and provides a potential link between synchronized movement and endogenous neural oscillation. Missing pulse rhythms may prove a useful class of stimuli in future experiments that directly measure neural activity or investigate movement synchronization in special populations.

3. How non-temporal factors influence entrained movement *by Jessica Grahn*

Music can elicit spontaneous movement, even in young infants, and simply listening to music activates movement areas in the brain. Music has also been used to improve the motor symptoms of movement disorders. For example, listening to music that is set to a walking pace can improve gait (walking ability) in Parkinson’s disease patients. Currently, however, we do not know the mechanism by which music alters movement, either in healthy volunteers or in patients. The assumption is that music drives movement through beat perception, because movements are usually synchronized to the beat. However, beat perception ability varies amongst individuals, and is specifically compromised in some neurological disorders. Therefore, other musical factors may be important for music to drive movement. I will discuss studies of how beat perception ability modulates the effects of music on movement. In addition, the talk will present data on how non-beat-related factors (e.g., enjoyment) may alter specific gait kinematics, such as movement speed or balance. The data suggest that beat perception ability does modulate the effects of music on gait, and that non-beat-related factors affect movement. The implications of this research for music-focused gait protocols in neurological patient populations will be discussed.

4. Synchronizing to auditory rhythms: Effects of stimulus complexity *by Simone Dalla Bella*

The majority can move to the beat of an auditory rhythm. This is visible in dance, synchronized sports, and in the pervasive tendency to tap or bounce to the beat of the last musical hit. Music is particularly well suited for capturing movement as compared to other complex sounds (e.g., speech), due to its temporal regularity and metrical structure. Temporal complexity of the pacing stimulus is critical for synchronization to the beat and is likely to differently recruit brain circuitries underlying perceptual and motor timing. Here we investigated how stimulus complexity affects synchronization and perceptual timing in healthy individuals and patients with motor disorders (i.e., Parkinson's disease). Healthy young and older adults and patients with Parkinson's disease (PD) were asked to synchronize via finger tapping to the beat of auditory stimuli showing different complexity (i.e., an isochronous sequence, a musical excerpt, and amplitude-modulated noise based on the excerpt). In addition, in a perceptual timing task, they were asked to detect anisochrony (i.e., local time-shift affecting the interval between two beats) in isochronous sequences and in a musical excerpt. Stimuli were presented at three different rates (450, 600, and 750

ms). Healthy adults were typically less consistent when synchronizing with complex stimuli than with an isochronous sequence. This difference was not found in PD patients at the group level (i.e., their synchronization was inconsistent with all stimuli). Moreover, patients manifested impaired perceptual timing, mostly with musical stimuli. Yet, a close look at individual performances revealed intriguing patterns of dissociations between simple and complex stimuli. Some of the patients revealed poor synchronization with a complex stimulus (music or noise) while they could tap to a metronome. Others exhibited the opposite pattern. In addition, poor synchronization was not systematically accompanied by poor perceptual timing. These effects of stimulus complexity are discussed in light of current models of perceptual and motor timing in the healthy brain and in patients with motor dysfunctions.