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Project: Exploring the neural basis of musical timing not related to a regular beat

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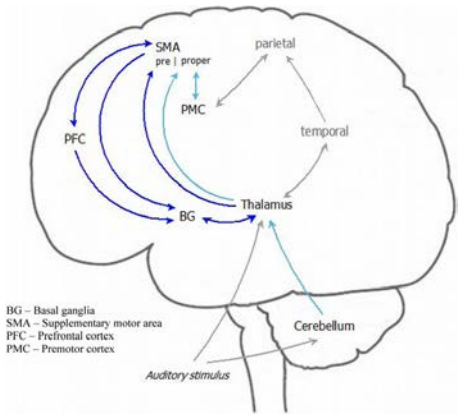
Background: Current research presents converging evidence that a basal ganglia-thalamocortical network (BGTC) mediates beat-based timing, a cerebellar-thalamocortical network (CTC) mediates timing based on durations and successive events, and the sense of time appears to be closely connected to movement and action (Kotz & Schwartze 2010; Teki et al. 2011, 2012; Schwartze & Kotz 2013; Dalla Bella et al. 2015; Coull et al. 2016). While numerous investigations have applied a variety of auditory and visual stimuli as well as motor tasks, investigations of timing based on music listening are scarce.



The figure shows

The BGTC network (blue), consisting of Basal Ganglia (BG), Thalamus, Pre-Supplementary motor area (pre-SMA) and Prefrontal cortex (PFC)

The CTC network (cyan), consisting of Cerebellum, Thalamus, Supplementary motor area (proper SMA) and Premotor cortex (PMC)

Additional circuitry (grey) involved in the processing of auditory stimuli

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Project: Based on the assumption that music evokes embodied sensations of time (Christensen 2012), I propose that fMRI studies of music listening will provide additional insight into the functions of the BGTC and CTC networks, in particular the variable differentiation and integration of these networks. It is hypothesized that listening to three different types of recorded music, pulsed music, unpulsed music, and comparatively static music, will induce characteristic differences in the involvement and interaction of the BGTC and CTC networks. Several researchers have pointed out that the mind is able to organize temporal musical patterns without reference to a beat (Bharucha et al. 2006; Huron 2006; Patel 2008; Stevens & Byron 2009).

Method: An adaptation of the sparse sampling fMRI scanning method reported by Teki et al. (2011). In a precisely timed paradigm, the test person listens to different types of musical stimuli of approximate duration four seconds, presented in quiet in order to be unaffected by scanner noise. Seconds later, the blood oxygenation level-dependent (BOLD) response to the stimulus is recorded by brain scanning. **Test subjects:** In some listeners, lack of pulse and meter in music will induce rejection or dislike, possibly resulting in a serious confounding variable. Two solutions to this problem are applicable: A) a study based on short excerpts of Indian ragas and B) a study based on music recorded for the experiment.

Stimuli: A) Indian ragas which typically juxtapose music with and without a pulse. Three types of excerpts represent 1) the unmetered part of the raga, 2) the metered part, and 3) the continuous drone alone. Relevant test persons would be participants of Indian origin, familiar with listening to ragas. If feasible, this group may be compared with a group of different participants.

B) Recordings by a jazz saxophonist: 1) coherent unpulsed melodic phrases, 2) coherent pulsed melodic phrases, and 3) continuous sustained tones. In a live performance, listeners can be expected to experience unpulsed as well as pulsed melodic phrases as pleasant and invigorating. A skilled American saxophonist, Stan Strickland from the Berklee College of Music, has expressed interest in recording music for this experiment.

Further research: Comparisons of neural resources recruited by 1) listening to unpulsed music and spoken verbal phrases, and 2) listening to pulsed music and spoken metered poetry.

A selection of references: Bharucha, J.J., Curtis, M., and Paroo, K. (2006). Varieties of musical experience. *Cognition* 100, 131-172. **Christensen, E.** (2012). *Music Listening, Music Therapy, Phenomenology and Neuroscience.* PhD thesis, Aalborg University. Available at http://www.mt-phd.aau.dk/phd-theses/ See pp. 95-96 and 105-109. **Coull, J.T., Vidal, F., and Burle, B**. (2016). When to act, or not to act: that's the SMA's question. *Current Opinion in Behavioral Sciences* 8, 14-21. **Dalla Bella, S., Benoit, C-E., Farrugia, N., Schwartze, M., and Kotz, S.A.** (2015). Effects of a musically cued gait training in Parkinson's disease: beyond a motor benefit. *Annals of the New York Academy of Sciences* 1337, 77-85. **Huron, D.** (2006). *Sweet Anticipation. Music and the Psychology of Expectation.* Cambridge, MA: The MIT Press. See pp.187-188. **Kotz, S.A. and Schwartze, M.** (2010). Cortical speech processing unplugged: a timely subcortico-cortical framework. *Trends in Cognitive Sciences* 14, 392-399; **Patel, A.D.** (2008). *Music, Language, and the Brain*. New York: Oxford University Press. See pp. 96-99. **Schwartze, M. and Kotz, S.A.** (2013). A dual-pathway neural architecture for specific temporal prediction. *Neuroscience and Biobehavioral Reviews* 37, 2587-2596. **Stevens, C.J. and Byron, T.** (2009). Universals in Music Processing. In Hallam, S., Cross, I., and Thaut, M. (eds.) *The Oxford Handbook of Music Psychology, 1st edition.* New York: Oxford University Press, 14-23. **Teki, S., Grube, M., Kumar, S., and Griffiths, T.D.** (2011). Distinct Neural Substrates of Duration-Based and Beat-Based Auditory Timing. *The Journal of Neuroscience,* 31(10), 3805-3812. **Teki, S., Grube, M., and Griffiths, T.D. (2012).** A unified model of time perception accounts for duration-based and beat-based timing mechanisms. *Frontiers in Integrative Neuroscience* Vol. 5, article 90, 1-7.