Evoked Response: White Paper

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Evoked Response is dedicated to an evidence-based approach to discovering novel forms of music therapy.

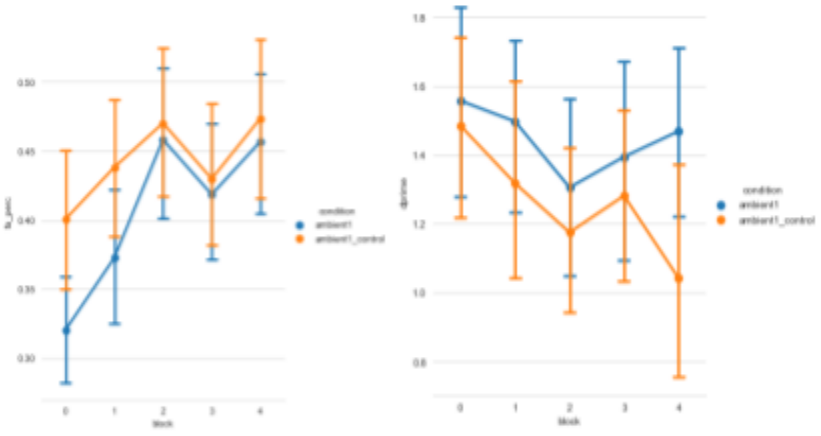
Background

Music is a powerful medium for affecting the mind. It can be as energizing as it can be hypnotic. Music engages regions all throughout the brain, from the auditory cortices (e.g., Bermudez et al., 2009; Schneider et al., 2002), to the prefrontal cortex (e.g., Lehne et al., 2014), and even the evolutionarily oldest parts of the brain like the brainstem (e.g., Wong et al., 2007).

Like music, the brain has its own rhythms in the form of electrical activity called neuronal oscillations, which regulate the communication between neurons (Siegel, M., Donner, T. H. & Engel, A. K., 2012). Neuronal oscillations facilitate internal communication between the brain's widely distributed neuronal networks (the dorsal attention, saliency, and default mode networks, to name a few), which tend to respond in tandem (Lee, M. H., et al., 2013). Neuronal oscillations may serve as the much-needed link between neuron activity and cognition and subsequent behavior (Schön, D. & Tillmann, B., 2015).

Music as stimulation

In many scenarios, music could be seen as an ideal form of noninvasive brain stimulation. Rhythmic auditory stimuli (musical rhythms) are capable of synchronizing neuronal activity *(*Schön, D. & Tillmann, B., 2015*)* and have been shown to influence neuronal oscillations in such a way that they synchronize to the temporal regularities inherent in the stimulus (Luo & Poeppel, 2007; Doelling & Poeppel, 2015). In other words, rhythms and beats in music can cause corresponding "electrical beats" in the brain.



Listening to our music for 20 minutes, subjects (n=375) show faster reaction times at the start, and higher accuracy as the track goes on.

This results in what is called *entrainment* or *phase locking* where neuronal networks become more organized, or "beat to the same drum" (der Nederlanden, C. M. V. et a.l, 2020; Tal, I. et al., 2017). To be more specific, we call it *Neuro-musical Binding*, where neural phase locking is the result of musical structure. It is believed that neuronal oscillations entrain to the beat of rhythmic external stimuli in order to better focus on and process incoming sensory information (Lakatos et al. 2019). Synchronized neural networks may therefore result in potentially more efficient cognitive processing (Buzsaki, G., 2004) and dysfunctional entrainment may underlie a wide range of processing difficulties across psychiatric conditions (Calderone et al. 2014).

Studies have already shown that altering neuronal oscillatory patterns can have benefits for a number of cognitive processes, such as attention (Helfrich et al. 2018), speech processing (Meyer 2018), and memory consolidation (Papalambros et al., 2017, Ngo et al., 2013). When synchronized to existing electrical activity in the brain, for example, audio has even been shown capable of increasing memory consolidation during sleep (Papalambros et al., 2017, Ngo et al., 2013). It is therefore positive that we can alter our mental state by aligning neuronal oscillations to a different rhythmic stream.

Results of slow-wave stimulation over a 7 day period

The hypothesis that musical structure can cause "phase locking" in the brain has wide empirical support (Jones, M. R. et al., 2002, der Nederlanden, C. M. V. et a.l, 2020). There is growing evidence that music can entrain neuronal oscillations (Bolger, D. et al., 2013) and functional changes in brain networks has been linked to our affective responses to music (Sachs et al., 2020). It is therefore an exciting time in the area of music cognition and music therapy, with many avenues to increase our understanding and make a positive impact on the world.

Our Process

1. Composition: Music is created by composers and musicians who are versed in music cognition, and with the guidance of neuroscientists. The overall instrumentation is designed to create rhythmic stimuli naturally, using quantized notes and beats. Scientific literature gives hints as to how the music should be specially designed for specific

purposes, such as to help people with ADHD or insomnia.

2. Testing: Musical compositions and hypotheses are scientifically tested with both neuro-imaging equipment and in large-scale behavioral studies.

3. Feedback: Results from scientific testing - as well as analytics from clients - are fed back into the music composition process to improve methodologies and draw novel hypotheses.

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