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Music Influence on Visual and Motor Cortex: A Synesthetic Activity Explored with Evoked Potentials

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ABSTRACT

Evoked potentials provide a direct assessment to explore the functioning of nervous system that complement the anatomical information provided by neuroimaging (Normann, 2007). Recent studies reported interesting neurophysiologic changes in musicians, particularly with reference to hearing function, showing enhanced auditory evoked potentials in musicians along with enhanced attentive and pre-attentive skills compared to non-musicians. This line of research opens up the perspective about measuring the effects of music and its role in integrating multiple brain structures and to develop rapid neurophysiologic changes.

In the present study, we aimed to explore the influence of music on visual and motor areas by recording Visual Evoked Potentials (VEPs) and Motor Evoked Potentials (MEPs) to Transcranial Magnetic Stimulation (TMS), in a shifted paradigm of research that investigated the effects of music listening, moving the exploration *from* auditory *to* visual and motor pathways.

Eighteen subjects without ocular pathology were enrolled in the study. They were divided in two groups depending on the type of music indicated as mostly preferred: Narrative (melodic) and Music Releasing Movement (MRM, energetic and rhythmic). The examined subjects were asked to listen to a piece of their favourite music for about 45', while seated comfortably; both evoked potentials were recorded immediately before and after the listening session according to the following sequence: pre-listening VEPs, pre-listening MEPs, Music listening, post-listening MEPs, post-listening VEPs. VEP recordings to checkerboard pattern reversal performed at 15' and 60' were analysed for changes in the P100 amplitudes. MEPs to paired TMS were analysed for changes in threshold and amplitudes in order to evaluate differences in the intracortical inhibitory profile from 1msec to 10 msec intestimulus intervals (ISIs).

Post-music listening VEPs to checkerboard pattern reversal at 60', resulted in a significant increase of P100 amplitude, with respect to the pre-listening values, in the Narrative music subjects, but no significant P100 differences were recorded in the MRM group that instead demonstrated remarkable changes in motor excitability, with totally disinhibited MEPs at 2 msec, 3 msec and 4 msec ISIs, indicating a loss of the physiologic intracortical inhibition. On the contrary, no significant MEP changes were measured in the Narrative group after music exposure. Subjects belonging to the MRM group showed to accompany music listening with typical rhythmic gestures that goes along with the sound, whilst the Narrative group remained mainly in a motion less state, suggesting a relationship between music preference, personality and cortical activation.

The present study provides neurophysiologic evidence of music induced short-term synaptic plasticity in *non-hearing* areas, mediated by a change in cortical excitability of visual and motor areas.

The reshaping impact of music further supports the perspective that music-induced neuroplasticity can be used for education, treatment and rehabilitation of important clinical disorders (Särkämö, 2016).

I. INTRODUCTION

"Let your eye catch the sound.
Then you will finally understand."
Zen Master Tozan

Music has become an important model in neuroscience for better understanding the brain and in the last decade an increasing number of studies have shown differences in neuroplasticity and connectivity of musicians compared to non-musicians. From a series of emerging studies in music neuroscience, it is clear that music has a vast impact and is processed by numerous brain areas containing dedicated neural networks that have the role of converging its effects on the majority of neurologic and cognitive functions (Warren, 2008).

Music deals primarily with perception and action, but also with general cognitive processes, memory, emotions and prompts imagination. In the light of we are learning from the ongoing research, it represents much more than an aesthetic experience, an acoustic stimulus, or a sensory modality adopted to accomplish a controlled experimental design, but is the expression of a suppletive cognitive code that generates a phenomen of highly subjective human experience. Its influence is massive, based on a complex set of perceptive-motor and cognitive dynamic processes, linked to previous experiences mediated by memories, emotions and imaginations, that induces us to attribute a meaning while listening (Brattico, 2017).

A neurobiological predisposition to music listening and enjoyment is based on important perceptual dimensions that emerge as the result of a large interaction between cortical and subcortical areas, involving an integrated network underlying musical codification and its unique role in integrating multiple brain functions to develop new memory circuitries and networks reediting innate brain organization (Salinpoor, 2011). Even musical preferences and personality are linked to cognitive styles and leave their footprints into the brain, suggesting a correlation between empathy and the melodic/relaxing music-preference dimensions.

Neuroimaging studies have illustrated the brain architecture where music resides in areas related to hearing and motor function (Blood & Zatorre, 2001). On the other side, neurophysiologic recordings from the human brainstem and from the auditory nerve clarified the nascent features of tonal music (e.g., consonance/dissonance, pitch salience, harmonic sonority) in functional terms, already evident at subcortical levels of the auditory pathway. Since evoked potentials provide a direct assessment of nervous system functioning, we aimed in the present study, to assess the possibility of short-term neurophysiologic changes to take

place, by exploring the influence of preferred music on non-hearing areas, with Visual Evoked Potentials (VEPs) and Motor Evoked Potentials (MEPs) to Transcranial Magnetic Stimulation (TMS).

II. METHODS

Eighteen voluntary subjects, aged between 20-35 years, nine women and nine men, without ocular pathology were enrolled in the study.

The participants were music fonder, but not musicians. They were divided in two groups, depending on the type of music indicated as mostly preferred. Subjects preferring melodic and relaxing music were attributed to a group denominated 'Narrative group', while those fond of more energetic and rhythmic genre were grouped in a category named Music Releasing Movement (MRM).

The protocol, formulated in a pre/post experimental design, contained two separate neurophysiologic sessions, that preceded and followed a musical phase, where subjects were asked to listen through headphone to a piece of their favourite music for about 45', while lying comfortably.

Neurophysyologic investigation consisted of Visual and Motor Evoked Potentials (VEPs and MEPs) recorded immediately before and after the music listening session, according to the following sequence:

a) Pre-listening VEPs; b) Pre-listening MEPs; c) Music listening session; d) Music activated (Post-listening) MEPs; e) Music activated (Post-listening) VEPs.

VEP to checkerboard pattern reversal performed at 15' and 60' were analysed for changes in the N75-P100 amplitudes (Creel, 2012).

The stimulus configuration comprised the transient pattern reversal method in which a black and white checker board is generated (full field) on a VEP Monitor by an Evoked Potential Recorder (Kothari, 2014).

MEPs obtained in response to the technique of paired TMS were analysed for changes in the threshold (as percentage of stimulator maximal output) and amplitudes (in mV) in order to evaluate differences in the intracortical inhibitory profile of 1msec to 10 msec interstimulus intervals (ISIs; Kujirai, 1993; Caramia 1993). Statistics included comparative analysis of VEP and MEP recordings achieved between pre and post music, using means and paired two test analysis with significance set at 0.5 SDs.

The statistical analysis was done by One Way Analysis of Variance (ANOVA).

During the music listening phase, subjects were filmed in order to document behavioural, emotional or motor reactions accompanying music perception.

III. RESULTS

A first notable result of the present study is the presence of neurophysiologic changes related to brain areas not directly connected with hearing function. Namely, changes in the visual pathways were documented in VEP recordings of those subjects who preferred melodic/relaxing music (Narrative group); whilst significant changes in the motor areas were found in the subjects preferring rhythmic/energetic music (Music Releasing Movement group), in whom the normal profile of intracortical inhibition was lost after music exposure. A statistically significant difference was derived between means of N75-P100 amplitude for 15 and 60 minutes with reference to Pre versus Post-music listening only in the Narrative group (Fig. 1). Post-listening VEPs to checkerboard pattern reversal at 60', resulted in a significant increase of N75-P100 amplitudes. Baseline (Pre-listening) N75-P100 amplitude of 8 ± 2.9 μV was obtained with checks of 15 minutes, and 9 ± 3.1 μV with checks of 60 minutes. In the Narrative group, Post-listening values of N75-P100 amplitude of 10.2 ± 3.18 μV were obtained with 15 minutes, and 13.2 ± 3.98 μV with checks of 60 minutes. No significant MEP changes were measured after music exposure.

On the opposite, the MRM group showed no VEP modification, with post-listening values remaining similar to pre-listening basal values, but demonstrated significant changes in motor excitability, with the presence of MEPs at those intervals known to best suppress the motor output. Disinhibited MEPs in response to paired stimulation were found at 2 msec, 3 msec and 4 msec ISIs ($p<0.001$), indicating loss of intracortical inhibition induced by music listening; (Fig. 2-3).

During the listening session, noteworthy differences in the way of responding to music appeared between the two categories of music listeners: the Narrative group gave the impression to be deeply absorbed, relaxed, and mostly in a motionless state. They referred to be in a state of sensorial absorption as if they were visualising music induced images, like in a film (hence, their group denomination as Narrative).

By contrast, subjects belonging to the MRM group, while seated, showed a pattern of moderate to intense motor involvement, consisting in typical rhythmic gestures of the head, hands and lower limbs, accompanying the sound (hence, their denomination: Music Releasing Movements group).

A. Figures

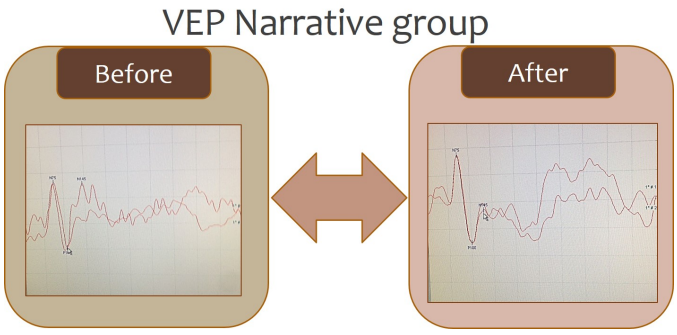

Figure 1. Pattern Reversal VEPs 60 minutes, ODX, recorded before (left panel) and after (right panel) music listening, in a subject whose preferred music was lyric. Recordings show a N75-P100 amplitude increase, along with a better synchronization of waves after music listening.

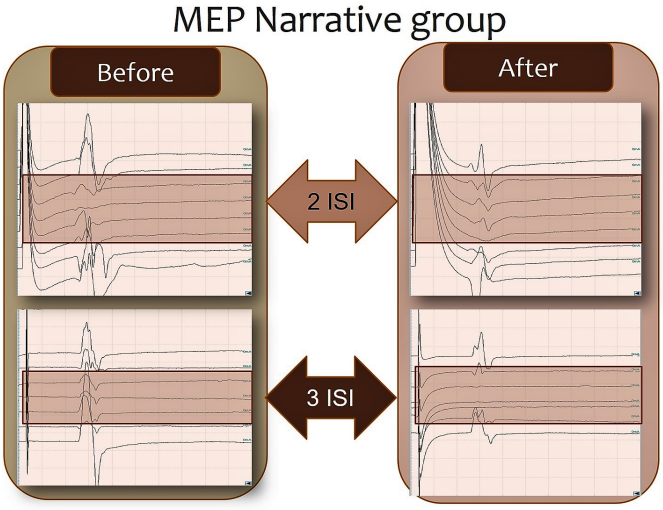

Figure 2. Narrative group MEPs before and after music listening.

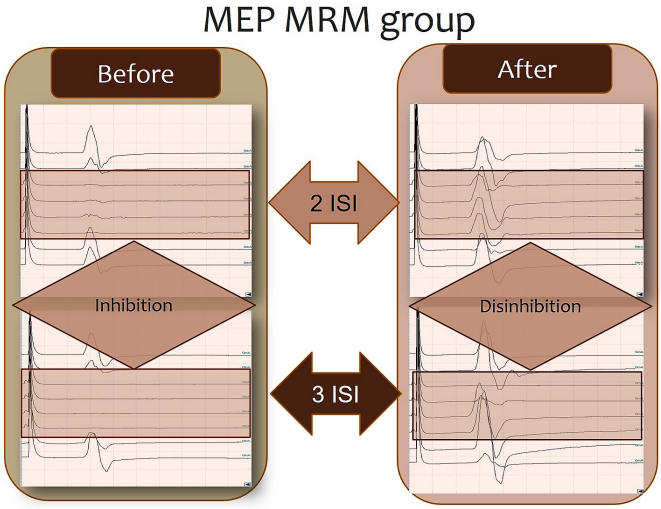

Figure 3. MRM group MEPs before and after music listening.

IV. CONCLUSION

The present study provides a first neurophysiologic evidence for an essential role of music in inducing short-term cortical changes in *non-hearing* areas. We used a shifted paradigm of research that investigated the effects of music listening, moving the exploration *from* auditory *to* visual and motor pathways.

Visual and Motor Evoked Potentials were carried out in subjects fond of music, but not musicians, who preferred two different genres of music, namely: melodic/relaxing and rhythmic/energetic.

Music listening produced a complementary pattern of neurophysiologic activation indicating the induction of synesthetic interplay amongst cortical areas: a significant increase of VEP's N75-P100 amplitude, with no MEP changes in the Narrative group, as opposed to the MRM group who demonstrated unaltered VEPs, but loss of intracortical inhibition, with the persistence of MEPs at those ISIs known to best suppress motor activity.

These findings support the perspective that music-induced neuroplasticity represents a functional reshaping of cortical connectivity that may be important for understanding dynamics regulating neurocognitive functions linked to learning and memory. Moreover, it shows "how the visual cortex continues to surprise and to awe" (Liu, 2016).

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