Pilot study on music-heart entrainment in a pianist during a live performance

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***Abstract*— Entrainment between music features and heart rhythms have been reported but, to date, evidence in support of music-heart synchronization are still inconsistent. We studied the possible music-heart entrainment in a skilled pianist during a live performance before an audience. We recorded ECG before and during the concert. We derived the beat-to-beat RR time series and analyzed heart rate variability in the time domain and with non linear analysis, to evaluate the autonomic changes associated with 4 different music pieces. Results indicated an autonomic modulation specific for each piece and the decrease and increase of parasympathetic and sympathetic tone across the whole session. Also, for each music piece, analysis of correlation between the music envelope and the RR series revealed a negative correlation which could be the expression of the entrainment of music on heart rhythm.**

I. Introduction

Music influences many aspects of our lives and has the power of modulating behavior, cognitive and emotional processes (Trost et al. 2015). Music typically makes our body move, modifies heart activity and generates emotions, and its effects at different levels of the organism have been reported to be obtained through the *entrainment* of brain activity (Trost et al, 2015, 2017). How can music entrain our brain and body rhythms? Neuronal activity may synchronize to an external periodic signal and, indeed, most music has a temporal periodic structure. Thus, neurons can resonate at the frequency of the musical rhythm (Trost et al., 2017).

Music entrainment occurs in the motor and limbic systems. The occurrence of involuntary movements in people listening to the music is the typical expression of music-motoneurons entrainment. These motor effects could also be the results of the *emotional experience* evoked by the music. In fact, music-evoked emotions are typically associated with spontaneous movements and strongly correlate with the activity in the motor areas (Trost et al., 2017). However, *music-evoked emotional experience* may be generated in itself either by the direct *entrainment* of neurons in emotional-related brain regions (e.g., *insular cortex)*, or by feedback mechanisms (i.e proprioceptive receptors) activated by the music-evoked movements (Vuilleumier and Trost, 2015).

Music entrainment effects in the limbic system also suggest the possible entrainment between music and heart rhythms although, to date, the evidence in support of music-heart synchronization are inconsistent. This is mainly due to the lack of standardized experimental protocols but also to the fact that most of the studies focalized on the effects of specific music pieces and/or the emotional valence of the music, while only a few on its peculiar structural features. In this regard, previous studies showed that specific acoustic features are linked with particular emotional responses (Gabrielson and Juslin, 2003, Schubert, 2004, Juslin and Laukka, 2000) and modulate the activity of regions involved in emotional and cognitive processing. For example, energy-related musical features and dissonance are negatively correlated with the activity in left amygdala and nucleus accumbens (Trost et al, 2015).

II. Pilot study

We studied the effects of music on the heart activity of a skilled pianist during a live performance before an audience.

In studying the music effect on heart we have to consider that heart changes may be both performance related and/or the results of music-brain entrainment. Among the performance-related effects we can consider effort, fatigue, attention but also social stress (worry for the audience's negative evaluation) and motor control. During a motor performance, in fact, the control centers activate physiological (e.g. cardiorespiratory) changes in parallel with the movement, necessary to supply the increased energy needs.

As for the entrainment effect, we can expect a direct entrainment between music and the autonomic nervous system or the entrainment between music and emotional-related brain areas, so that heart changes would be the physiological expression of music-evoked emotions.

We recorded heart activity by means of a wearable telemetry device (Bioharness 3 Zephyr). We recorded ECG during a basal period (10 min of relaxation) preceding the concert and the whole performance before the audience. For analysis, we derived the beat- to-beat RR intervals thus obtaining the RR time series, and carried on the analysis of heart rate variability in the time domain as well as non linear analysis, in order to evaluate the autonomic changes associated with 4 different music pieces. The pieces were played in the following order: Rachmaninov (19 min), Liszt (13 min), Chopin (6 min), Verdi-Listz (15 min). The time interval between the music pieces was about 1 minute. For analysis in the time domain we focused on the root mean square of successive RR differences (RMSSD) and on the Stress index (SI, the square root of the Baevsky's stress index); for non linear analysis on the Standard deviation 1 (SD1) and 2 (SD2) of the Poincaré plot and on Approximate Entropy (ApEn). RMSSD and SD1 are considered appropriate

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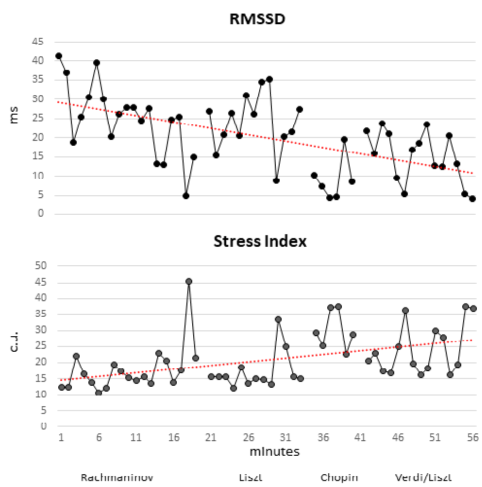
descriptors of the parasympathetic activity, while SI and SD2 reflect the sympathetic tone. ApEn decrease with respect to basal resting state values is considered an index of stress.

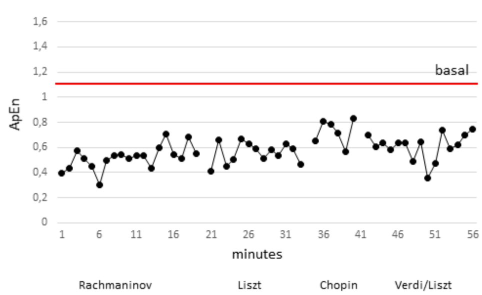
Results indicated a modulation of autonomic activity specific for each music piece. However, across the music session, RR, RMSSD and SD1 tended to decrease, while SI and SD2 to increase (Fig. 1). Moreover, a decrease of ApEn with respect to the basal values was present throughout the whole music session (Fig 2). These responses could likely be the expression of performance-related effects but, actually, our findings do not allow disentangling the specific contribution of effort, fatigue, attention and stress. For instance, SI is very sensitive to sympathetic tone rise related to both physical (effort, fatigue) and emotional stress. In addition, these findings, do not allow to exclude music entrainment effects.

Figur



RMSSD and Stress Index values associated with the 4 music pieces. Each point is the average of 1 min intervals. Linear trend lines are shown.

Figur



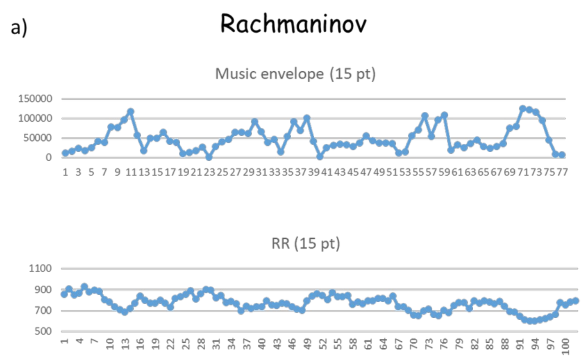
Approximate entropy values associated with music conditions. Each point is the average of 1 min intervals. The red line indicates the basal value calculated during the relaxation condition (10 min average)

We thus investigated the possible correlation between specific music features and heart rhythm. From the audio recording of the concert we derived the music volume envelope of the single pieces and studied its correlation with the RR time series during each piece. The two series have opposite trends and Pearson correlation analysis showed a negative correlation for all the analyzed pieces (Fig. 3). Is this association the effect of music entrainment or rather the consequence of motor learning? May be both mechanisms are involved.

III. Conclusion

This pilot study showed that there is an association between music and autonomic nervous system in regulating heart rate, that could be interpreted as a music-induced entrainment. Other performance-related or motor learning mechanisms may be implicated in this association. Thus, more studies in which the player and the public will be simultaneously recorded are needed to reinforce these preliminary data, to elucidate the potential mechanisms, and to verify other music parameters potentially implicated in this association.

a)



b)

Music piece	Pearson correlation index
RACHMANINOV	-0.55
LISZT	-0.38
CHOPIN	-0.40
VERDI_LISZT	-0.68

Figure 3. Correlation between RR and music envelope. a) the correlation between RR and the music envelope of the Rachmaninov piece is shown as an example; b) correlation indices for each music piece are shown.

Acknowledgment

The study was supported by the University of Pisa, IFC-CNR and ISTI-CNR of Pisa.

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