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The Influence of Structural Elements of Sound on Emotional Regulation and Psychological Wellbeing

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Abstract:
Since sound is a wave, it has all the properties pertaining to any wave, including frequency, amplitude, waveform, and duration, which, translated into musical terms, describe pitch, dynamics, tone, and duration. These four structural elements of sound each alter the listener's experience and, by extension, the arousal, valence, and, in particular, emotions elicited by them. The significance of emotions and music within both modern society and ancient cultures suggests that any correlation or causation between the two must be inherently important, and the near universal ubiquity and experience of both music and emotion is further evidence of this. However, in order to determine if there was a relationship between the two factors, meta-analysis of both qualitative and quantitative data was conducted, revealing that the alteration of any single or combination of structural elements resulted in variation of the onset predictability, creating psychological engagement and reward. This positive correlation between sound and the degree of response on emotional, arousal, and valence levels within both the qualitative and quantitative data suggests that, depending on the pitch, dynamics, timbre, and tempo of the auditory stimuli, the affective state experienced by the listener varies. Additionally, the higher valency and arousal ratings expressed upon listening to expressive auditory stimuli, which involves the augmentation of tempo as well as an increase in pitch and dynamics and a decrease in duration, ultimately result in surprise, fear, or, most typically, happiness.

Keywords: Valence, structural elements of sound, music-evoked emotions, predictable pitch, auditory stimuli, limbic and paralimbic brain structures.

Introduction and Background

The purpose of this study is to provide a comparative analysis of the elements of different sounds and the emotions elicited by them across modern global populations. Emotions refer to a complex reaction sequence in which personal experiences, physiological responses, and behavioral patterns are expressed in response to stimuli, which is, in this case, music [8]. The latter has been proven to be a powerful stimulus, evoking psychological and physiological responses through its various elements and activating shared brain regions and psychological processors [1,2]. This neural correlation is not only due to the resolution and disruption of predictive behaviors such as syncopations, unexpected changes in pitch and chords as well as their resolutions [5,6], but also the association between music and episodic memory. This form of memory is responsible for maintaining and recalling personal experiences and events, including context like time, place, and particularly emotions, suggesting a connection between music and emotional responses [2]. This emotional response to auditory stimuli is a result of not only the structural elements of sound and the different areas and processors of the brain that are activated as a result, but also the association between memories and past experiences [1,2,3].

Literature Review

Memory – Episodic Memory

According to Eischrich et al. (2008), the conscious recall of music was tested to evaluate the response of arousal, valence, and emotion to different types of music, allowing for greater understanding of memory within music-evoked emotions. Additionally, the use of emotional compared to less emotional music revealed that strong emotions related to the musical experience facilitate memory formation and retrieval.

Timbre – Tone Quality

Jiang et al. (2017) suggest that timbre refers to the tonal quality of sounds and allows for the distinction between familiar and unfamiliar melodies as well as instruments. Through qualitative ratings of these melodies and instruments, it was concluded that people who did not suffer from congenital amusia, a disorder of musical processing, expressed a tonal familiarity effect on tension ratings for Western melodies, whilst amusics provided similar tension ratings for both melodies on varying timbres. This reveals that, within the control population, the predictability and, by extension, emotional and arousal quality were due to both the tone and pitch of the melodies.

Rhythm - Duration and Tempo

As stated by Fernández-Sotos et al. (2016), Suave et al. (2017), and Liu et al. (2018), the role of rhythmic unit and note value, also referred to as duration, alludes to more than the speed of a piece, but rather a structural element of music, similar to grammar. Since duration operates on multiple hierarchical levels, including beat, subdivision, grouping, phrasing, and structure, neuroimaging revealed that subtle changes evoked vastly different emotions.

Furthermore, listeners rated fast tempo music as highest in positive valence (pleasantness), while medium tempo yielded the highest arousal but lower valence. This was corroborated neurologically through the use of fMRI's, in which fast-tempo music triggered stronger activity in bilateral auditory cortices, matching the higher valence. Additionally, musical training modulates the effect: musicians show stronger activation in the left inferior parietal lobule (IPL) compared to non-musicians, especially in response to tempo, and behaviourally they rate fast music with higher valence than non-musicians. This suggests durational structure may interact with the listener's musical experience in shaping emotional reaction.

Pitch – Key Stability and Expectancy

Suave et al. (2017) as well as Lei et al. (2021), explained that when pitch sequences were manipulated to be less predictable, listeners rated melodies as having higher arousal and lower valence, compared to predictable sequences. Conversely, predictable pitch sequences tended to yield more pleasant, calm, or emotionally "safe" feelings.

In their manipulated-melody condition, it was observed that changes in pitch predictability produced corresponding changes in emotional ratings — supporting the idea that pitch structure (not only other musical elements) plays a direct role. Importantly, while pitch matters, the same study found that timing and onset predictability had greater influence than pitch on emotional responses.[4]

However, pitch structure at the harmonic level, not just individual note predictability, also shapes how we process and respond to music. When tonality is stable but not overly predictable, it maximizes engagement, anticipation, and possibly emotional tension and release.

Correlation – Bidirectional Transfer and Neuroimaging

Based on studies conducted by Hailstone (2009), Koelsch (2010), and Koelsch (2014), it can be concluded that as one listens to music, they form internal predictions through the structural elements of the music. When the music violates or meets those predictions in different ways, the brain experiences prediction errors, which are then resolved, offering a psychological engagement and reward, as was seen through neuroimaging.

Thus, an element of music's ability to evoke emotion is its engagement of core brain mechanisms designed for prediction, learning, and resolution, which confer intrinsic value to fulfilment of predictions and resolution of uncertainty. This emotional impact is also embodied, as music also utilises motor and interoceptive systems, resulting in physiological changes.

Methodology

In order to ensure that the data that had been collected and collated allowed for extensive meta-analysis, mixed methods were used. This approach involved the analysis and comparison of previously existing studies sourced from Google Scholar and scientific journals with high impact factors to ensure the validity and applicability of data, which was essential in developing a reliable and useful data foundation. This resulted in greater definition and more accurate understanding of both types of data through the correlation of quantitative and qualitative data sets, as well as the further sample sizes of the research. Furthermore, this utilization of diversity created measurable patterns, which ultimately allowed for more in-depth analysis of trends, patterns, and relationships.

Results and Discussion

Due to the use of this mixed-method approach, it was necessary to include the use of tables as well as graphs to ensure that both the numerical and non-numerical data were represented clearly and effectively. Additionally, the data from several case studies were represented in neuroimaging graphs, and so were implemented as structural and functional photos and images.

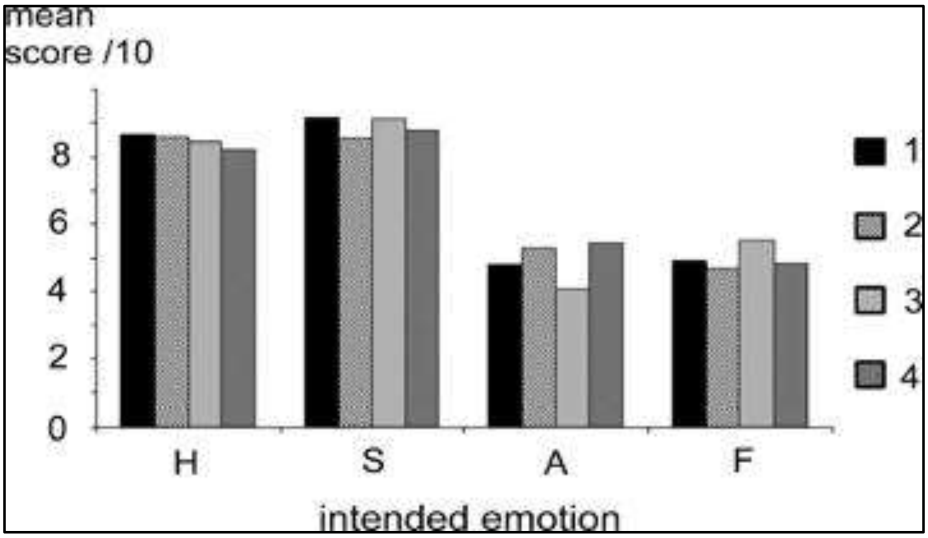

Figure 1.1: Mean scores (/10) for each intended emotion (H, S, A, F) for synthesized timbres 1–4 (Hailstone, 2009)

The above Figure 1.1 depicts the mean scores (/10) for each intended emotion in young adult participants for synthesized timbres 1-4. These timbres were, respectively, piano, violin, trumpet, and clarinet, and despite a change between the timbres of the first section of the experiment and this second section, the interaction between timbre and perceived emotion in music continued to operate when the timbres were unfamiliar and unique. Furthermore, despite the absence of additional performer-dependent expressive cues, the intended emotions nearly all had a mean score over or around half of what had been anticipated. The identification of ‘sad’ and ‘happy’ timbres more readily than ‘angry’ and ‘fearful’ tones is indicative of the fundamental, evolutionary, and acoustic patterns within sound that resemble human vocalizations and emotional and arousal expressions [5,7,10].
The relative closeness of each timbre's emotional response across testing further reveals that a sound's tonal quality can be both manipulated and measured, suggesting that there is a strong correlation between timbre and emotion.

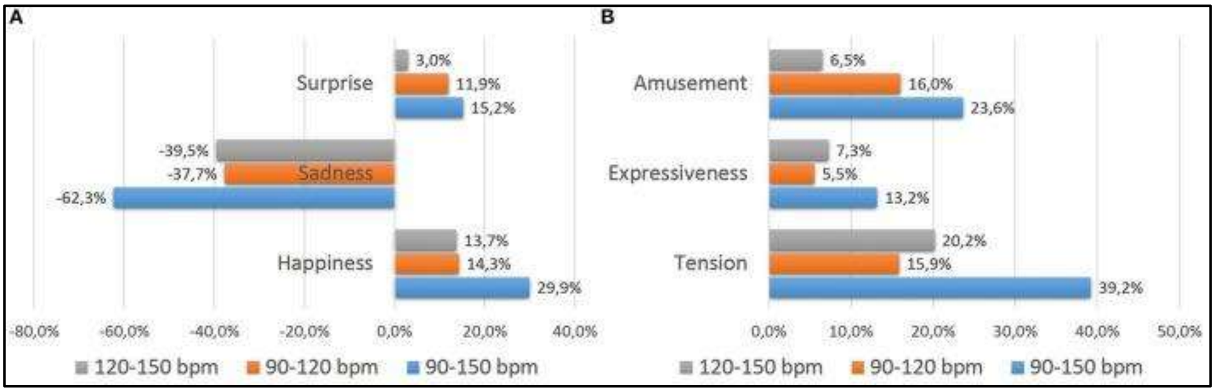

Figure 2 (A): Growth tendencies of basic descriptive emotions (Fernandez-Sotos et al., 2016)
Figure 2 (B): Growth tendencies in scales (Fernandez-Sotos et al., 2016)

Figures 2.1 and 2.2 depict the growth tendencies in basic emotions (A) as well as descriptive scales (B) from the same experiment testing tempo augmentations. Interestingly, in Figure 2.2, the amusement and tension patterns in the augmentation between 90 and 120 bpm are 16.0% and 15.9%, respectively, suggesting that the tension of predictive characteristics and structures of sound has a direct positive impact on valence, represented by amusement. This correlation is expressed across the differing augmentation patterns, as well as within the ‘expressiveness’ category, revealing that variations in tempo shift the structure of sound and impact the internal predictions that occur whilst listening to music [5,8]. This engagement of core brain mechanisms designed for prediction, learning, and resolution, which confer value to the fulfilment of predictions and resolution of uncertainty, directly corresponds to an emotional response to auditory stimuli [8]. This is an emotional impact that is also embodied, as music also utilises motor and interoceptive systems, resulting in physiological changes such as heart rate and breathing rate, muscle tension, and temperature regulation (homeostasis) [5,11].

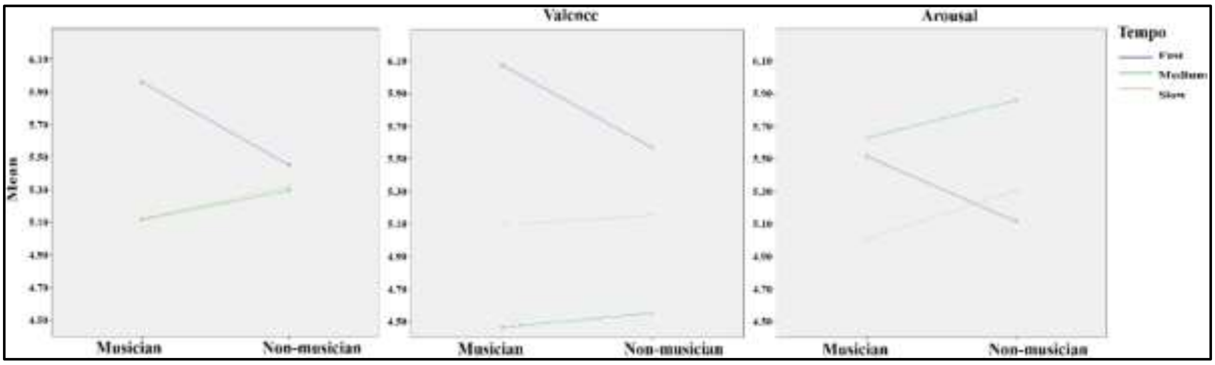

Figure 2.3: Mean scores of musicians' and non-musicians' emotional responses to varying tempos (Liu et al., 2018)

The left panel shows the positive activation of fast music to slow music in bilateral STG. The right panel result of comparison shows the positive activation of medium music to slow music in right HG, right precuneus, right MTG, right PCC, right IPL, left STG, and left culmen. The activation of the STG (superior temporal gyrus) within both the fast-slow and medium-slow augmentation of tempo reveals its significance in auditory processing. This increased activity within the bilateral STG for fast-slow music suggests that this could be used in therapies for sound-localization and basic speech perception [12], and the further activity within the left STG for the medium-slow tempo testing could be utilised to develop phonological processing within individuals who struggle with identifying the phonemes of spoken languages [8]. Furthermore, the processing of socio-affective information could be altered with the manipulation of sound elements [7].

Additionally, brain stem reflexes, evaluative conditioning, episodic memory, and visual imagery were controlled for by presenting novel stimuli with equal tempo, intensity, and timbre alongside a rating task [3,9], increasing the validity of the tests. This also suggests that singular structural elements of sound can be altered and manipulated to not only evoke different emotional responses but also to develop auditory processing [10], as discussed above.

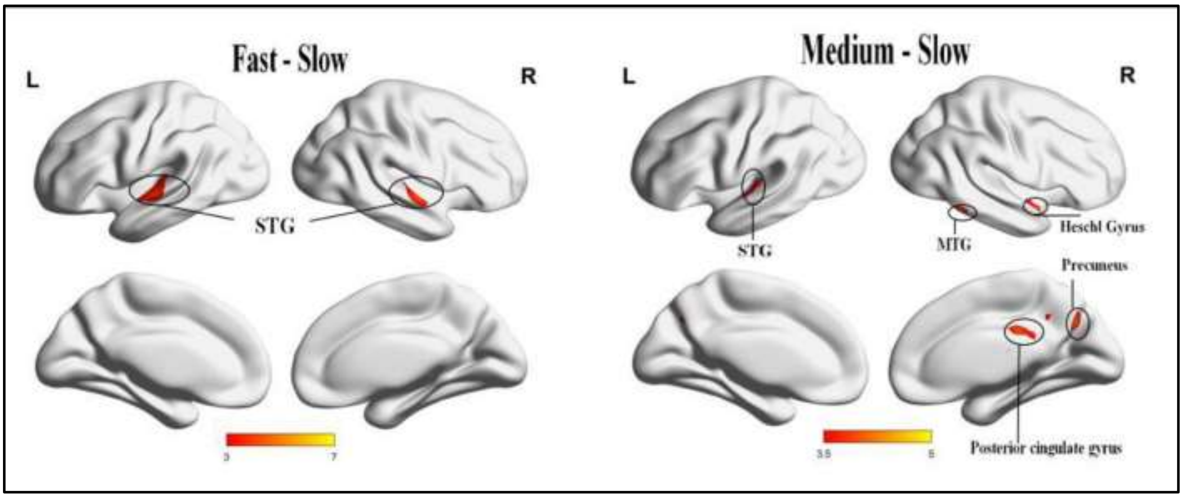

Figure 2.4: Activation of brain regions in response to variation in tempo (Liu et al., 2018)

The study reveals that fast music evoked positive emotional valence with activation in the bilateral STG, an area of the brain responsible for auditory processing, speech perception, and social cognition, and when dysfunctional, is associated with epilepsy and schizophrenia [11]. This suggests that auditory stimuli could be developed in music therapies by both revealing the psychological and physiological connections involved in these illnesses as well as by evoking emotional responses in order to reach an emotional equilibrium, increasing quality of life and capacity in living with the above illnesses.

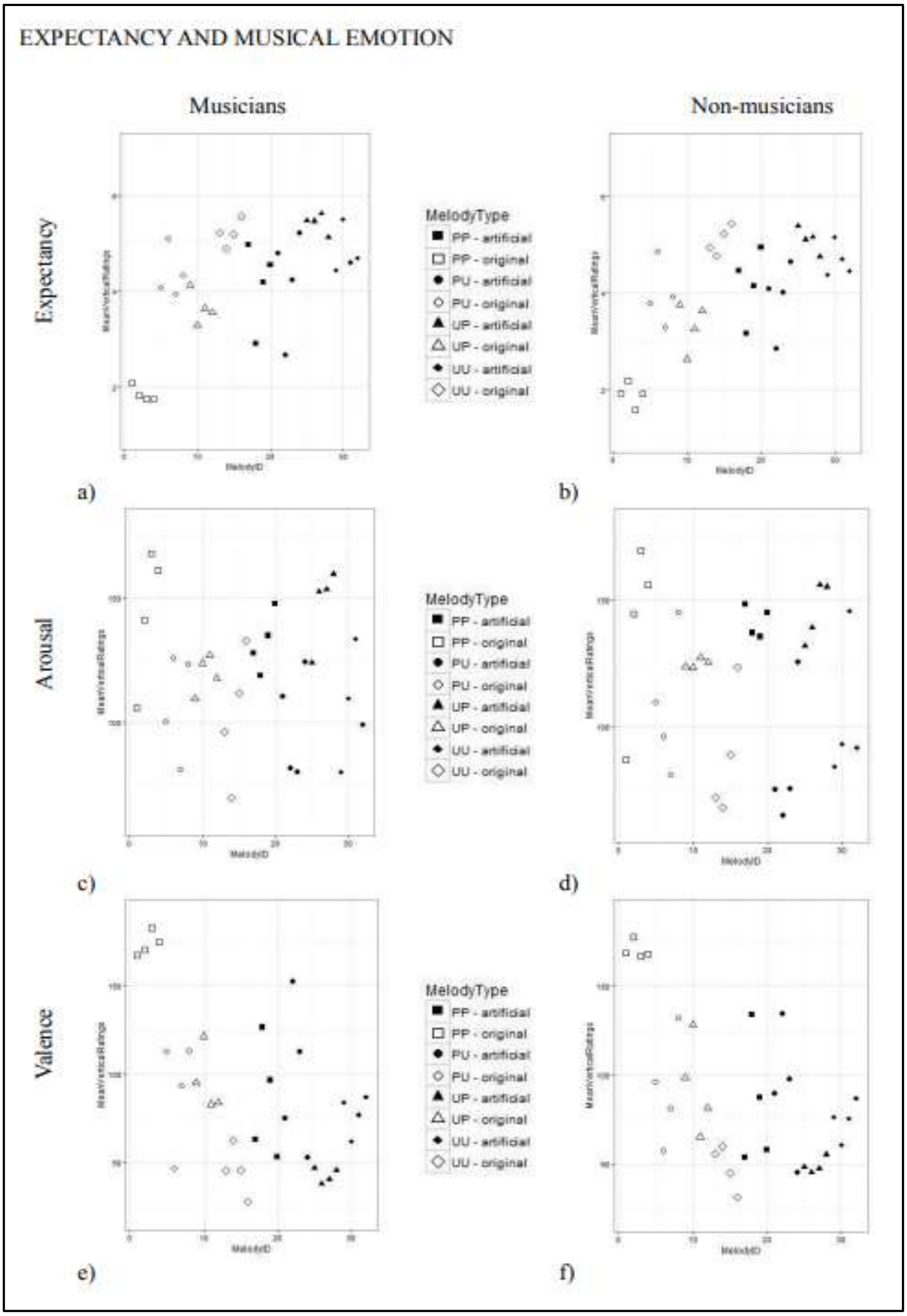

Figure 3.1: Predictable pitch and predictable onset of artificial and original melodies (Sauvé et al., 2017)

From a study by Suave et al. (2017) examining the effects of pitch and timing expectancy on musical emotion, Figure 3.1 discusses the continuous expectancy and affective state (arousal, valence) experienced by musicians and non-musicians when listening to artificial as well as original melodies. Three areas of measure were taken: subjective responses (i.e., the arousal levels or the ratings of musical expectancy, which changed continuously throughout the piece), expressive responses, using video and facial electromyography (EMG), and peripheral arousal measured by skin conductance, heart rate, respiration, and blood volume pulse [5]. This offers an insight into the role of pitch as well as onset predictability, and the resulting emotional responses [5][6]. These insights include that, despite all melodies being presented at the same intensity of dynamics, the emotional responses evoked differed greatly. These differences are represented through the high arousal (a, b) experienced in both the original and artificial predictable pitch and predictable onset (PP) compared to the original and artificial unpredictable pitch and unpredictable onset (UU).

In order to ensure that brain stem reflexes, evaluative conditioning, episodic memory, and visual imagery were controlled for, novel stimuli were presented with equal tempo, intensity, and timbre alongside a rating task [5]. This reveals that, whilst variation in more than one structural element of sound can evoke emotional responses and influence listeners towards an affective state, simply altering one element, in this case pitch, can change the expectancy as well as arousal and valence [13].

Conclusion

Considering this basis of studies and data, further meta-analysis of both quantitative and qualitative data is necessary to better understand activity, particularly within limbic and paralimbic brain structures such as the STG, which are crucially involved in the initiation, generation, detection, maintenance, regulation, and termination of emotions, including those evoked by emotions. Since dysfunctions in these structures are related to emotional disorders such as Alzheimer's disease, Schizophrenia, Post-Traumatic Stress Disorder (PTSD), as well as depression and anxiety [11], a better understanding of music-evoked emotions and their neural correlates could lead to a more systematic and effective use of music in therapy. Furthermore, within the limbic system, the superficial amygdala (SFA) is involved in the processing of basic socio-affective information, including music. This feature of the brain is imperative in understanding social cues and settings, which are often challenging and overwhelming for individuals with autism [12], and further knowledge of music's role within this system could aid in the development of music therapy networks.

Conclusively, the well-defined structural perceptual features of music can be manipulated simply and independently in order to alter the onset predictability and emotions elicited [5]. While research in this field is still developing, these connections that have been identified and tested could be further developed and utilised in order to increase the functionality of auditory stimuli within therapy and psychological studies.

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