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Exploring the Practicality of Portable EEG Equipment for Visualising Emotional Responses When Listening to Meaningful Songs:

A Position Paper

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Abstract

Portable EEG technologies have gained popularity in investigating the effect of music on people's emotional responses by affective neuroscience, music psychology, and music therapy researchers. This paper provides a brief overview of current literature on music, emotion, and EEG, and a reflection on Kim's use of one portable EEG technology (Emotiv Insight) to explore distressed young people's emotional responses during intentional listening of their meaningful songs. Inconsistent results in Kim's study and across music and emotion research studies revealed the reality of the still-emerging state of EEG technologies and thus, researchers should approach the tool with vigilance and some suspicion. In our experiment, the Emotiv Insight offered distressed young people novel and interesting opportunities to reflect on their emotional distress with a new lens. However, distressed young people did not perceive that the EEG visual data actually represented the complexity of their emotional worlds. Rather, they suggested that listening to their meaningful songs, selecting emotion-related words from self-report scales, and discussing their emotions with someone was more useful to better understand their emotional worlds.

Keywords: portable EEG technologies; Emotiv Insight; distressed young people; music therapy; intentional music listening; self-report scales

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Introduction

This position paper originated from my (Kim's) ongoing interest in the topic of distressed young people's emotions and well-being and the emerging body of knowledge within affective neuroscience. Over the past decade, I worked with diverse groups of young people who have struggled with psychological and emotional distress with different interpersonal and cultural backgrounds (South Korea, United States, and Australia). As a humanistic and resource-oriented music therapy practitioner, I deeply value meeting people where they are at and guiding them to discover their internal strengths and own resources through music and the therapeutic relationship. As an interpretivist music therapy researcher and strong advocate for empowering next generations of young people with insights and opportunity, I was inspired to provide distressed young people with novel opportunities to explore their emotions by looking at the EEG signals and 3D brain visualisation using a portable EEG headset called Emotiv Insight.

Emotiv Insight was first introduced to me by my research supervisor for my master's final project; one of her previous PhD supervisees incorporated this product for her PhD thesis, and it has become her research focus. The more we investigated the headset, the more fascinated we became by the proprietary software and its empowering potential. Essentially, we wanted to empower distressed young people to gain insights into their emotions and realise their position as active agents over their emotional distress and lives. Lastly, we acknowledge our limited expertise in using the EEG devices and interpreting the data, however, our research aims of including the EEG component was not to analyse the EEG signals meticulously, but to provide opportunities for young people to experience their emotional worlds more innovatively. Eventually, this led me to conduct extensive review on the past and current literature on music therapy, emotions, and EEG.

Neuroscientific research is an arena for both excitement and restraint when trying to better understand music therapy processes (O'Kelly et al., 2016). This excitement stems from the tantalising possibility that being able to see what is happening in people's brains would help us better understand why music therapy is reported to be very helpful sometimes, whilst at other times minimal change is experienced under similar conditions. However, restraint may be needed in that technologies are still emerging, and whilst some discoveries have been made, the ability to see what is happening in actual music therapy situations is still limited by issues of physical restriction, technological possibilities, and recognition that understandings of the brain are still in their infancy. For this reason, rigorous testing of portable electroencephalography (EEG) technologies is required to confirm its potential.

This intersected with a feeling of astonishment on reading the literature that emanated from how simple the relationship between music and emotions seemed compared to our combined music therapy practices and critical understandings of music and emotions (McFerran, 2016) which suggested a wide variety of experiences between individuals. This then led to a sense that the way authors described the value of brain-based technologies for understanding emotions might be inflated and a desire to examine this more closely through practical testing to inform more critical readings of the literature based on our experiences.

As we delved deeper into the literature with excitement, our desire to understand distressed young people's emotional experiences when listening to meaningful songs also deepened. So, this led to a small-scale test as part of my PhD research. At the University of Melbourne, our research team consists of music therapy scholars who have experience in brain imaging technologies (Bower et al., 2024), in exploring portable EEG technologies (Kim, 2017-2020) and we consulted carefully with music psychology colleagues about potential limits and restrictions (Chin, 2019). Simultaneously, we became aware of an increasing research trend that exaggerates the lens of "neuroscience imperialism"

(Fumagalli, 2017) to explain complex human phenomena, such as emotions. Ruud (2024) also observed this tendency of overinterpreting the language of neuroscience in understanding human emotional life and expressed concern about simplifying the connections between music and emotions.

As researchers in the music and emotions field, we have actively engaged with the EEG technologies with hope and vigilance about its potential and this Position Paper communicates our shared current stance. This follows from Hunt and Legge's (2015) review of the most common neuroimaging techniques in music and music therapy studies for mental health, describing EEG as the most accessible due to its low invasiveness, high temporal resolution, low machine noise and affordability. Whilst noting the general limits of EEG, such as the challenges of reading activity deeper in the brain, Hunt and Legge elaborated on the exciting potential of recently developed brain-computer interfaces and the recently released Emotiv headsets—the focus of this article.

In this position paper, we will share our experiments exploring the intricate connection between music, emotions, and the brain and point out the limits of portable EEG headset that we used (Emotiv Insight) for elucidating emotional experiences. Despite these limitations, we enjoyed playing with the technology and noted that university students were enthusiastic about participating in the study. It seems that music therapists are not alone in wanting to explore what technology can tell us about our emotional lives, especially in relation to music.

EEG Studies in Music Therapy

EEG technologies have been increasingly used in music therapy research, with several studies highlighting their applications and findings (Fachner, 2017; Fachner et al., 2019 & 2023; Farquharson, 2021; Hunt et al., 2021; Peterson & Thaut, 2007; Thaut, 2010; Thaut et al., 2005; Tucek et al., 2022). In the US, Hunt's team conducted a mixed-methods case study (2021) that utilised EEG to compare the pain responses in three cancer patients listening to entrainment music versus preferred music. In South Africa, Farquharson (2021) employed EEG readings to assess the therapeutic effect of different music therapy interventions on 18 geriatric patients with varying severities of dementia.

Michael Thaut, an innovator in investigating the connection between music therapy and neuroscience, also employed EEG technologies to study cognitive function and verbal training improvements after music therapy interventions. A 2005 study showed enhanced word order memory and verbal recall in Multiple Sclerosis patients using rhythmic-melodic and verbal forms in conjunction with EEG graphic analysis (Thaut et al., 2005). In Peterson and Thaut's subsequent study (2007), they modified the process to eliminate physical interactions between participants and the person administering the test to reduce the risks of EEG artifacts. Their EEG outcomes showed similar results to the initial (2005) study, showing that when people learned words in a musical form, their brains displayed stronger neural connections and synchronous oscillations in prefrontal cortical networks. This led Peterson and Thaut (2007) to conclude that music has proven to be a suitable mnemonic device for attaining better memory and word-learning skills for people with or without neurologic conditions. These findings were based on their visual observation of the amplitude shifts and temporal synchronisations of EEG activity in broad cortical networks, suggesting that the visual data of EEG is valuable in examining music-related processing within various cortical areas. In addition, a subsequent study indicated increased neuronal synchrony of the lower alpha waves in bilateral prefrontal cortices, highlighting that patients' memory recall was improved in the music mnemonic condition compared to the spoken condition (Thaut, 2010).

Jörg Fachner has also been instrumental in advancing EEG applications in music therapy, focusing on neural mechanisms of changes and social neuroscience approaches. Fachner has championed the use of wireless and portable EEG devices for capturing neural dynamics during music therapy sessions (2017). His interest has more recently focused on microanalysis of moments-of-interest (MOI; Fachner et al., 2019) as well as EEG-hyper-scanning method studies (Fachner et al., 2019; Tucek et al., 2022). In his most recent study (Fachner et al., 2023), Fachner used a mixed-methods, non-blind, randomised-controlled trial to investigate the feasibility of music therapy in a substance misuse community treatment service. They combined EEG-hyper-scanning technology with audio-video recordings of individualised music therapy sessions to explore neural dynamics of emotional processing, precisely focusing on people's emotionally challenging moments in the therapy, such as a craving state. All these investigations aimed to observe synchronised patterns of brain waves between therapist and patient in their musical and social interactions.

Overall, these music therapy researchers recognised the value of employing EEG applications and have continued to include EEG as a crucial part of their research designs in validating the efficacy of music therapy for various population groups.

Understanding Emotions Using EEG Technologies

Music therapists have shown interest in EEG technologies but have not primarily focused on emotions. Nevertheless, significant research on emotions has been conducted in various laboratories in Sweden (Juslin et al., 2008), Finland (Särkamo et al., 2014a; 2014b), Norway (Koelsch, 2015; 2018) and Montreal (Zatorre, 2003). In fact, the initial conceptualisation of the emotional brain emerged from early EEG technologies, leading to Paul MacLean's (1949) formulation of the limbic system, which highlighted the broader neuroanatomical networks involved in emotional processing than previously recognised. MacLean (1952) conducted clinical experiments with his neuropsychiatric patients to obtain strychnine neuronographic (i.e., a neuroanatomical research technique used in the mid-1970s), EEG, and phenomenological data. From these experiments, he obtained detailed visual evidence of neuroanatomical activations related to emotions (Lautin, 2001), which strengthened his proposed idea regarding human emotions. Ultimately, his discovery was that the emotional brain encompasses the extensive and reciprocal connections between various cortical regions of the brain, and he was the first theorist who discovered that the activation of the amygdala and prefrontal cortex are implicated in emotional processing.

Many affective neuroscience researchers using EEG signals have subsequently focused on exploring emotion recognition, accuracy, classification, and hemispheric activation with certain EEG frequency bands. For example, Jatupaiboon et al. (2013) used EEG signals to explore the classification of positive and negative emotions in response to pictures as visual stimuli. They found higher frequency bands (gamma and beta) showed more accurate results than lower frequency bands at 81.91% and 80.64%, respectively. Regarding channel locations, frontal pairs of electrodes (F7 and F8) showed more activations to valence emotion stimuli at the accuracy rate of 66.14% in comparison to other channels. These findings led the authors to conclude that classifying emotional valence using minimal EEG channels in real-time is achievable without affecting its accuracy rate using the Support Vector Machine (SVM).

Studies by Wang et al. (2011) and Lin et al. (2010) indicated similar findings. Wang et al. (2011) used EEG devices to investigate four distinct emotions (joy, relaxation, sadness, and fear) of five young adults watching a movie clip for a particular duration in-between black screen. After the clip, participants were asked to complete a valence-arousal rating (SAM) of the visual stimuli. These self-reported responses were used to verify people's emotional states measured by the EEG data. The EEG data results revealed a 66.51% accuracy rate for all four emotions via SVM, and the activation in the frontal and parietal cortices was more correlated with these emotions than other brain regions. Similarly, Lin et al. (2010) used the same classifier, SVM, and the 2-D valence emotion model to investigate four similar emotional states (joy, anger, sadness, and pleasure) in music listening. These outcomes mirrored those of Wang et al. (2011), highlighting the significance of the frontal and parietal cortices in assessing emotional states.

Around the same time, Trochidis and Bigand (2012) explored hemispheric activation using EEG during classical music listening and proposed that the alpha waves were associated with emotional valence and theta waves with emotion processing. In their study, left hemispheric activation appeared to be associated with positive emotions, whilst the right hemisphere activation was linked to negative emotions. In contrast, Pham and Tran (2012) used a 14-channel Emotiv EPOC to test emotional responses to videos, and suggested beta and gamma waves were relevant in emotional responses.

Although these affective neuroscience researchers have used some common approaches of using EEG devices in conjunction with common emotion classifiers, models, and stimuli, their conclusions are contrasting. Researchers feel positive about their findings, but they are not yet consistent.

EEG Measurements Used for Young People with Emotional Distress

When it comes to understanding the emotional worlds of young people experiencing emotional distress, affective neuroscience researchers have used portable EEG technologies and discovered the significance of the cortical lateralisation and specific frequency waves. Especially with cortical lateralisation in emotion processing, there are various theories suggesting that electrical activity in certain parts of the brain indicates a person being at risk of depression onset (Allen & Reznik, 2015) or indicate a person's history of mental health issues (Stewart et al., 2014). This has been explicitly investigated with university students by Ameera et al. (2019), who analysed states of pleasure and displeasure using a 19-channel portable EEG device and identified correlations with the EEG frequency bands. Their results suggested that alpha waves were prone to be more activated in a pleasurable mental state, which they described as a relaxed mind. Conversely, Umemoto and colleagues (2021) argued that the same waves (alpha) were correlated with depressive symptoms of young adults and suggested that the right hemispheric activation is more involved with depressive, ruminative, and self-criticizing symptoms.

Interestingly, both of these studies employed additional tools to assess young people's mental health history and to strengthen their outcomes (Baumgartner et al., 2006; Umemoto et al., 2021), including self-report and physiological measures. The EEG was not the primary method of emotion investigation but was used as a confirmation tool to verify the self-reported depression-related symptoms. Umemoto and colleagues (2021) did not explain how they determined depression-related symptoms to be correlated with the asymmetrical activation of the alpha wave.

These mixed findings demonstrate a desire to verify the value of EEG results for better identification of specific emotions, but findings are not yet consistent. This inconsistency could be due to the use of different emotion classifiers, models, devices, or even stimuli and is the likely rationale behind the frequent use of a hybrid methodological approach that incorporates both self-report and EEG measures. Despite the conflicting findings, the various studies led us to consider integrating portable EEG technologies into a more extensive study examining whether young people experiencing emotional distress perceive guided music listening to meaningful songs as emotionally helpful. Part of the rationale for that study was to encourage strategies for expanding emotional literacy and self-understanding and we thought that both the EEG technologies and self-report tools might be useful strategies. We will report on the findings of that ongoing study elsewhere but focus here on exploring how practical the portable EEG technology was in our testing and subsequent investigation.

Exploring the Emotiv EEG Technology

To see whether visualising emotional activity in the brain would be helpful, we sourced a low-cost (499 USD) next-generation 5-channel wireless consumer EEG headset called Emotiv Insight (Emotiv, 2022a). Emotiv Insight claims to be a scientifically proven, research-based, user-friendly, cost- and time-efficient device primarily designed for research applications and personal use to monitor a person's daily cognitive health. Since EEG is an electrophysiological technology, the headset can, theoretically, record the electrical activity of neurons within the outer layer of the brain. The Emotiv Insight has five semi-dry polymer sensors covering all the cerebral cortex's prime areas implicated in emotional processing (AF3, AF4, T7, T8, Pz). In addition, the creators claim it can capture the electrical activities at 128 SPS (samples per second) or 2048 Hertz internal (cycles per second). The Emotiv Insight translates the amplified signals (raw EEG data) into distinct frequency waves using an algorithm, which for Emotiv Brainwear is Fast Fourier Transform (FFT) (Emotiv, 2022b). There are four main frequencies which are delta (0 to 4 Hz), theta (4 to 7 Hz), alpha (7 to 13 Hz), and beta (14 to 30 Hz) waves; the higher the frequencies, the more brain activities occur which can reflect different stages of minds and cognitive functions. The headset came with two pieces of proprietary software—Emotiv PRO and BrainViz. Emotiv Pro quantifies six prime cognitive and emotional metrics: attention, engagement, interest, excitement, stress, and relaxation (Emotiv, 2024b) and it provides real-time frequency bands in waveforms and bar graphs. BrainViz is a recently developed 3-D neuro-imaging program that displays real-time EEG activities of colour-coded projection of frequency bands in a 3-D visualisation of the brain with a detailed view of convexity and neuroanatomy of the forebrain.

The Emotiv manufacturers provide detailed instructions and tutorial videos about attaching specific electrodes to different parts of people's heads. Whilst there were some minor challenges with people's hair texture and some initial learnings about detectability, this part of the process was mostly achievable. Still, there was no way of knowing whether our attempts were accurate enough. Since the product is for profit, it is in the company's interests to make the process seem easy, and they successfully encouraged us to test its value. However, later problems in generating quality data representations may have been linked to a need for more specific and careful details here. For example, one female with thick hair texture could not participate in our testing because we could not achieve 100% connectivity between the headset and the software. Having the poor connectivity generated raw EEG data that was not translatable or readable which was frequently observed in our trials. Essentially, achieving 100% Bluetooth connectivity was the indication for having a stable connectivity between the headset and the software.

After acquiring the Emotiv Insight, we were able to gain basic knowledge about the setup of the portable EEG technology and different types of EEG data such as EEG frequency waves, 3-D visualisation of EEG, and performance metrics. This has further propelled us to test the practicality of the headset with more people.

Testing the Emotiv Headset

We asked four people from Kim's circle of friends to help us test using the Emotiv Insight. These friends were asked to bring three songs that they associated with happy, sad, and thought-provoking feelings so they could listen to them after attaching the electrodes to their heads. The friends were enthusiastic about joining in and expressed sincere interest in discovering whether they could see their emotions using the EEG technology.

Observing the graphic representations of brain activity, we noticed some commonalities in increased frontal cortex activations on the BrainViz. We also discovered that small facial movements, such as moving eyebrows or adjusting the headset, interrupted the flow of EEG recording, as shown by a stagnant and spikey waveform. Not surprisingly, when people closed their eyes (equivalent to a resting state), there was less activity on the BrainViz because there was less noise in the data. The difference between resting state with eyes closed and eyes open was significant, suggesting that much of the cortical activity might be mostly related to visual stimuli. The effect of movement on the connectivity of the Bluetooth technology was also noteworthy. Combined, we realised that we would need to establish almost laboratory conditions for the music listening to gather meaningful data. That meant being still, not talking, eyes closed and focusing intently on the emotions being afforded by the self-selected music. This was critical information for designing the subsequent research study and was not emphasised in the advertising material.

It was interesting to talk with these friends about their emotional responses to the music and how well they aligned with the graphics generated by the software. Despite the advertising for the accuracy of the product and the literature that suggested emotional activity could be visible via portable EEG technologies, their feedback was not affirming. In addition, we noticed that these non-therapy-trained friends did not have a vast repertoire of language to describe the emotions they were experiencing whilst listening as the basis for comparing their self-reported experience to the graphics generated about their brain activity.

Therefore, drawing on the tendency in the literature to use self-report tools for comparing and confirming the EEG findings to people's verbal descriptions, we undertook another phase of testing that also included providing people with an emotional vocabulary to draw on for their anecdotal reporting. For the next set of practices, we provided a copy of Russell's (1980) circumplex model of emotions and a mood wheel based on Hevner's (1936) theories. Both provided familiar vocabulary graphically depicted across quadrants to support people in finding the words that best suited how they were feeling so that these could then be compared to the graphic representations of their brain activity provided by the Emotiv Pro and BrainViz.

One of Kim's friends from the first test was intrigued by the experience and invited Kim to explain the portable EEG technology to her secondary school psychology class. We were fascinated to see their responses, and although the class was too brief to explore any details, there were some prominent learnings. First, they were very interested in the idea of being able to visualise their emotional responses whilst listening to music. Most teenagers in the room were enthusiastic, patient, and cooperative. Conversely, when the students who had the opportunity to try on the technology were asked if they were emotional when listening or not, the word "emotional" seemed to be perceived somewhat negatively, as seen by people's facial expressions and tone of expression. Achieving 100% Bluetooth connectivity was challenging due to time constraints in proportion to the number of young people who wanted to try the headset. However, despite the previous challenge of setting up the headset on people with thick hair, we achieved good connections for people with extremely thick hair in a few cases. In those times when it did work, alpha and theta waves were most observed frequency waves that were shown in their indicated colour-coded activities on BrainViz. Interestingly, there were a few people whose right frontal cortex consistently showed gamma wave activation. According to the hemispheric valence theory (Muller et al., 1999), this might suggest that negative emotions were elicited by their chosen music. Li and colleagues (2015) proposed that people with depression might show an abnormally increased coherence of gamma waves during emotional processing of visual stimuli in comparison to healthy controls.

The results of our tests ranged from wildly colourful visualisations to absolutely zero activity on BrainViz. Any movement, talking, or even open eyes resulted in much more activity and connectivity challenges than still, focused listening with eyes closed. However, regardless of the age of the people we practised with, everyone appeared interested and engaged in listening to the music and watching the EEG activity. As a result, we decided to include the EEG portable technology as part of the formal investigation but chose to companion it with self-report tools that would enable the development of an emotional vocabulary. We also chose to contain it as only one of the tools that we offered to explore distressed young people develop greater self-understanding of their emotions through intentional listening to meaningful songs.

In justifying the inclusion of self-report tools, we adopted the idea of *emotional granularity* (Warrenburg, 2020), which posits that people can specify their emotional states using descriptive words. Barrett (2004) similarly notes that some people innately have this skill to easily describe their emotions, whilst others may have to learn and develop it. Lindquist and Barrett (2008) suggested that people's emotional granularity may vary depending on how they use their emotional knowledge and for what purpose. We combined this idea with Robinson and Clore's (2002) proposition that self-report tools allow access to multiple sources of knowledge that impact how people express and report their emotions. We decided that young people experiencing emotional distress should have access to diverse tools of emotional reporting to apprehend the vastness of human emotional phenomena adequately.

Formally Investigating Distressed Young People's Experience of Portable EEG Technologies

The subsequent qualitative research investigation (Ethics approval #26840) involved five University of Melbourne students who were between 20 to 23-year-old who self-identified as being emotionally distressed. They participated in a four-week intentional music listening program which consisted of three intentional music listening sessions and one final semi-structured interview session. The focus of this program was on distressed young people's experience rather than the technology or the emotions per se. For each session, they listened to one of their chosen songs, which were either preferred, meaningful, or distress-relieving. Prior to listening to their chosen songs, Kim provided a brief induction to help them become more engaged with their in-the-moment physical conditions and emotions. The first session involved their engagement with their chosen songs with verbal discussion at the end. In the second and third sessions, they were given the EEG headset and emotion-related words from self-report questionnaires respectively and engaged in verbal discussions afterwards.

In this paper, we share our reflections on the practicality of the EEG within that more extensive study, and the qualitative analysis of the young people's experiences of intentional music listening will be reported elsewhere. Suffice it to say that after working with five young people, we applied for an ethics amendment and removed the EEG component to better focus on their emotionally meaningful experiences that moved beyond just their intellectual engagements. However, in examining the data from the second session only (five individual sessions with five different people), we noted some key distinctions from the other two conditions.

First, the EEG sessions encouraged the participants to be attentive and engaged with active listening in our process of observing and interpreting the EEG data together. Our practices of using the Emotiv Insight and its software with people allowed us to gain adequate knowledge of interpreting the EEG signals. We intended to interpret the EEG signals, not to analyse them with analysis software, because our sole purpose was to give novel opportunities for participants to visualise the EEG signals and explore how they make sense of their emotional experiences. Additionally, we incorporated the most frequently used evidence-based theories which explain human emotional processing such as frontal alpha asymmetry (FAA) and frontal midline theta (FMT) (Fachner et al., 2013; Fachner & Stegemann, 2013; Fachner et al., 2019; Hunt & Legge, 2015; Tucek et al., 2022), to help participants make sense of the EEG data as they observe them and reflect on their emotions. While observing the performance metrics data, we provided a visual diagram of Russell (1980)'s circumplex or 2D valence-arousal model to help participants comprehend and interpret some of the indicated words, i.e., interest and excitement. Leading up to March 2024, on the Emotiv website, the word *interest* was referred to as "valence," and *excitement* was referred to as "feelings of physiological arousal" (Emotiv, 2024a). So, we considered the use of this model would be an additional supportive tool for guiding participant's process of interpreting their emotional responses. However, currently, these descriptions on the website have been changed into "attraction or aversion to stimuli" and "the intensity of reactions to stimuli or environments" (Emotiv, 2024b). The recent modification of this description reveals the ongoing development of Emotiv products and their proprietary software.

Nonetheless, from our research study, we found that as the EEG data provided real-time and time-specific information, the participants focused on the specific moments of the song and recalled what they experienced in that moment emotionally. Since the participants knew that we would have more discussion about their emotions afterwards, this appeared to empower them to stay interested and engaged during music listening, EEG data observation and interpretation, and verbal discussion.

Second, the participants were intentionally connecting their emotions to our interpretation of the EEG data. From the start, they were curious about the EEG component, and this somehow influenced them to be easily convinced by what the graphic representations showed. However, the participants did not solely rely on the EEG data; they reflected on the emotions experienced during music listening and examined whether the data could be interpreted as aligning with their emotions. Ultimately, these two components of their observation of the EEG data and their reflection on the interpreted data had to confirm each other for the participants to make sense of their emotional states.

Finally, the EEG sessions provided opportunities for the participants to translate their emotions in a more concrete and tangible way. For example, one participant related the movement of alpha and theta waves in bar graphs to her emotional ups and downs. Another participant found that 3D visualisation of the brain revealed the "biological" aspect of their emotions, making the data more "trustworthy." Another participant found having a scientific explanation of her brain activity allowed her to see her emotions less abstractly.

Overall, in comparison to the other two sessions (without the EEG headset), using the portable EEG technologies intrigued the participants to engage with the emotions evoked from listening to their meaningful songs with excitement and focused attention. This session revealed that the EEG data could potentially offer fun and interesting opportunities for distressed young people to explore their emotional experiences. Yet it was evident that the Emotiv EEG data alone could not offer a way of understanding their mysterious inner worlds.

Reflections on Portable EEG Technologies for In-Situ Explorations of People's Emotional Experiences

The use of portable EEG technologies and their data seemed to fascinate the participants in this study. They appeared more engaged and expected to gain new insights about their emotions from observing the data that was gathered whilst they focused on listening to their meaningful songs. As seen in testing the EEG headset with several individuals, challenges recurred with setting up the EEG headset, achieving 100% Bluetooth connectivity, and ensuring people remained still without any physical or facial movements. Although the interpretations we offered were quite repetitive and drawn directly from the written materials provided with the headset and evidence-based emotion theories, the young people were engaged and asked questions that seemed derived from their genuine interest and curiosity about their emotions and the data itself.

In reflecting on the generated data, it appeared to represent cognitive responses to stimuli, rather than emotional states. For example, the BrainViz data of three participants did not show any coloured activity, which they interpreted as being "emotionless," "not thinking a lot," and thus, felt confused about their emotions. This was challenging to navigate since this was an understandable yet incorrect interpretation of the lack of data. In these cases, having the other data, such as the bar graphs of alpha and theta waves and the performance metrics, were helpful to offer alternative graphics for people to observe and make meaning from. It clarified that whilst the novelty and engagement afforded by the portable EEG technologies were valuable, the most useful feedback and interpretations came from their self-generated reflections. Their anecdotal descriptions were clearly more valid than the graphics offered by the tools.

Combining EEG and Self-Report

Despite the increasing use of neurotechnology in human emotion investigation across diverse research fields, various self-report measurements are still being integrated into those studies exploring the complexity of human emotions. As noted above, Lin and colleagues (2010) described the use of self-report measurements as a tool to confirm neuroscientific outcomes of emotion generation, causation, and processing. Furthermore, Tag and colleagues (2021) encouraged researchers to further the use of existing smart technologies in combination with traditional methods, such as self-report measurements, to create experiments that resemble natural settings.

In the larger study, we provided lists of emotion-related words from self-report questionnaires for the participants to use when they discussed their emotions after music listening activity in the session. When distressed young people observed only the EEG data, they were highly interested in the novelty of the technology and the tangible nature of the data, which provided a new lens to their emotional understanding. Distinctly, when provided with the lists of words from the self-report questionnaires, they were able to expand their vocabularies and freely mix up the words to describe their emotions more fulsomely. Essentially, the words offered them opportunities to not only express but also clarify and articulate their emotional worlds.

The Inherent Challenges of Investigating Music and Emotions

Exploring the emotional responses that are induced by music remains mysterious, despite the exciting yet emerging technologies. There are various definitions and explanations about emotions in music with some researchers seeking clarity by focusing on distinctions between emotions and other closely related phenomena. For example, Sloboda and Juslin (2001) differentiate the meaning of affect, emotion, and mood: Affect involves the overall emotional experiences that primarily feature the valence; emotions involve moderate to high intensity for a short duration (lasting minutes to hours); and moods involve less intense emotions for longer durations than emotions. The important distinction between these two words is that whilst the word *affect* represents the overall experience, which can be examined through people's voices, the word *emotions* consists of the subjective component of feelings as well as the physiological component of arousal, which can be analysed more thoroughly based on people's biological and experiential information.

Despite these somewhat clear distinctions of emotional terms, the words *affect* and *emotions* are still used interchangeably in research studies.

Other music psychology and neuroscience researchers provide detailed biological and psychological explanations of the sub-components of emotion. For example, Coutinho and Cangelosi (2011) propose that exploring the chemical and neural responses to external and internal stimuli is crucial to understanding emotions evoked in music. This focus is based on music psychologists' core belief that a person must experience feelings and arousals through the processes of cognitive appraisal, emotional expression, autonomic reaction, and action tendency (Eerola, 2018; Juslin, 2016). From neuroscientists' perspectives, in addition to examining a person's feelings and arousal state, it is important to examine a person's behavioural changes as one of the main components that display emotion.

This challenge of investigating music and emotions could be implicated in having no common beliefs across different disciplines on what emotions are and how music affects emotions. It seems impossible to come into agreement with one definition of emotions or constituents of emotions. However, it would be also unreasonable to argue with the power of music to evoke people's emotional responses that can be active electrical activities in certain parts of their cerebral cortices.

Conclusion

Overall, using the portable EEG technologies offered novel opportunities for distressed young people to reflect on their emotional worlds with a new lens. They reported finding the visual EEG data to be engaging in that they could observe real-time and time-specific data instantly. This evoked their curiosity further and helped them gain some knowledge about certain emotions related to their emotional distress through their meaningful songs. However, in contrast to a range of evidence-based findings from affective neuroscientists that solely use EEG data analysis to understand emotional states, our experiment with distressed young people has revealed that the practicality of portable EEG technologies should be approached more vigilantly and with some suspicion. We found that the visual EEG data representation did not represent the fullness of people's emotional responses, although it offered unique opportunities for distressed young people to engage with and reflect deeper on their emotions in guided listening of their meaningful songs. Perhaps it is justifiable to say that the complexity of people's emotional worlds can be truly comprehended when various emotion-related elements are put together—listening to meaningful songs, intentionally reflecting on music-evoked emotions, and verbally expressing and discussing those emotions with someone. We will continue to investigate this possibility.

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