GO WITH THE FLOW: WHEN LISTENERS USE MUSIC AS TECHNOLOGY

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ABSTRACT

Music has been shown to have a profound effect on listeners' internal states as evidenced by neuroscience research. Listeners report selecting and listening to music with specific intent, thereby using music as a tool to achieve desired psychological effects within a given context. In light of these observations, we argue that music information retrieval research must revisit the dominant assumption that listening to music is only an end unto itself. Instead, researchers should embrace the idea that music is also a technology used by listeners to achieve a specific desired internal state, given a particular set of circumstances and a desired goal. This paper focuses on listening to music in isolation (i.e., when the user listens to music by themselves with headphones) and surveys research from the fields of social psychology and neuroscience to build a case for a new line of research in music information retrieval on the ability of music to produce flow states in listeners. We argue that interdisciplinary collaboration is necessary in order to develop the understanding and techniques necessary to allow listeners to exploit the full potential of music as psychological technology.

1. INTRODUCTION

When the word *technology* is used in the context of music, it generally relates to the development of new digital devices or algorithms that support the production, storage, and/or transmission of music. In this paper we break from the conventional use of the word *technology* in regards to music, reprising a conception of music as a technology *in and of itself.*

In order to understand precisely what *music as technology* means, it is helpful to take a closer look at the meaning of the word *technology*. Specifically, we use *technology* in the sense of *a manner of accomplishing a task especially using technical processes, methods, or knowledge*[1]. We do not contradict the generally accepted perspective that music may exist for its own sake. However, we do take the position that other considerations may also be at stake when listeners listen to music. Specifically, we hold that there are cases when listeners use music as a tool that is directed towards accomplishing a task. In these cases, music can be considered as part of a method applied by listeners to achieve a goal.

The notion of music as technology was already coined in the area of sociology by DeNora at the end of the millennium [8]. This work characterized music as part of the continuing process of self-development, and posited that individuals use it to maintain and develop a social identity as well as a means to self-regulate emotions, moods, energy levels, or for the purposes of 'self care'. In effect, it was suggested that people outsource various sorts of 'emotional work' to music, based on their goals within a given context.

We argue that the moment is now ripe for the music information retrieval (MIR) community to revisit this notion. In the intervening years, social psychology and neuroscience have considerably advanced our understanding of how music is used in everyday life, and how it effects the brain. Further, music recommender systems show signs that they are already reorienting themselves from music that users "like" to music that users find useful in a particular situation. This development is evident in the evolution of how the purpose of music recommender systems is described in the literature. A 2002 publication [36] characterized this purpose as recommending *music that the user will be interested in*, which contrasts with the statement of a 2011 publication [12] that *a good recommendation system should...maximize the user's satisfaction by playing (the) appropriate song at the right time*. Currently, the unprecedentedly large amount of music available online offers new possibilities of finding a tight fit with listener needs. Reflecting this focus, a 2015 publication [32] stated the purpose of music recommender systems to *provide guidance to users navigating large collections*. We draw on these contemporary findings and theory to understand how users may better use music as a tool in everyday life.

The contribution of this paper is to revisit and update the notion of music as technology, and to link it to a Call to Action for MIR and neighboring psychology-oriented communities. It should be noted that the socio-psychological concept of music preference as a potential indicator of personality, values and beliefs (and as a 'social badge') is relevant to music consumption behavior, fitting into the concept of considering music as a technology (to establish belonging), and not yet taken into account sufficiently in the context of music recommender

[1] http://www.merriam-webster.com/dictionary/technology

systems [19]. However, in our paper the focus will not be on social listening, but rather on the complementary situation in which the listener consumes music on their own, in relation to achieving a personal goal.

In our consideration of a technological role of music, we go beyond 'self-care', and describe music as a tool that a listener may use to achieve the internal state necessary to accomplish their goal. We hypothesize that this connects to the concept of flow [24]: a desirable internal state that has been characterized by complete and total attention, a loss of a sense of self, a loss of a sense of the passing of time, and the experience that conducting the activity is, in and of itself, intrinsically rewarding. In other words, a listener in flow state is enjoying the feeling of being absorbed in their task to such a degree that the passing of time is not noticed, and is therefore able to push past obstacles to carry out activities and achieve goals. In later sections, we will elaborate on theories regarding the possible neurophysiological nature of flow states, the effects of music on the brain, and how it is that music may assist in achieving these internal states. As an initial indication of the growing importance of music that allows users to accomplish goals, we point to the growing number of artists[1] and services[2] on the Internet that are providing music to help people focus.

The idea of music as technology should not be considered a paradigm shift, but rather as the explicit identification of a common phenomenon. This phenomenon has thus far escaped the attention of the MIR community because the focus of music information retrieval research has been firmly set on *what music is*, rather than on *what music does*. However, there are many examples of work that illustrates the breadth of areas in which music is used as a tool to accomplish an end. Most widely known is perhaps the use of music as a meaning-creating element in storytelling, especially in film and video, e.g., [35]. Currently expanding is the use of music in branding, e.g., within the rise of the concept of corporate audio identity [2]. Less comfortable to contemplate is the use of music for torture e.g., as studied by Cusick [7]. Finally, we mention the therapeutic uses of music, as covered recently by Koelsch [17].

Our work differs in a subtle, but important way from these examples. We look at music as technology from the point of view of listeners who make a conscious decision to *expose themselves to the experience of music to alter their internal state in order to achieve a goal that they have set for themselves*. Later, we will return to the importance of listener control over the choice of music for the effectiveness of music as a tool.

Music as technology has serious implications for music information retrieval. If listeners may choose to use music as a psychological tool, then it is important for music search engines and recommender systems to be sensitive to the exact nature of the task that users wish to accomplish. It also is important for researchers to judge the success of these systems in terms of their ability to support users towards accomplishing tasks.

To understand music as technology more profoundly and fundamentally, collaborations between MIR and the neuro-, cognitive, and social psychological sciences, will be essential. Joint research lines involving collaborations between these fields will allow for the potential to determine when and how flow states occur, if they vary in any way based on context, and how exactly these states are aided by music.

In summary, this implies two places in which the MIR community should be active: i) learning and understanding what users need to put themselves into a flow state, and how this depends on what they are doing and on the surrounding circumstances, and ii) understanding how new music search engines and recommender systems can be designed to allow listeners to achieve flow states.

In the remainder of this paper, we first will review how music is used as part of daily life. After this, we consider the effects of music on the brain, subsequently connecting to insights in relation to achieving flow state. Based on our proposed viewpoint and the reviewed literature, we discuss how the MIR research agenda can be broadened in this light, and finish with a Call to Action for interdisciplinary work worth investigating.

2. LISTENERS USING MUSIC

2.1 Music as part of daily life

In the everyday life of the modern human, music has become a constant accompaniment to all manner of daily activities [27, 29, 34]. The advent of portable music devices capable of housing vast collections, the ubiquity of available musical data via streaming services, and the development of technology that allowed for greater ease of music production, have all lead to the consumption of music on an increasingly individual basis across an increasingly broad range of activities and contexts [10].

Music listening is a common occurrence in everyday life, yet rarely the sole focus of an activity. A number of studies have pointed to this conclusion, and we mention some key examples here. In an experience sampling study where participants completed brief surveys at random intervals throughout their day, 44% of the surveys were completed while music listening had taken place within any 2-hour period, yet less than 2% of episodes involved listening to music as a main activity [32]. A later study showed that 38.6% of text messages sent to participants randomly throughout the day occurred during music listening occasions; on occasions where the participants were not listening to music, 48.6% indicated that they had listened to music since the last text message, yet only 11.6% of these episodes occurred when music listening was the main activity [27]. A more recent survey study has shown similar results, with respondents indicating a mean of less than 1 hour of active music listening per day, yet 2-4 hours of passive music listening [15].

Along with an increase in music consumption accompanying other activities is the emergence of the belief that individual music selections function as a means to

[1] e.g., Delta Notch, https://www.youtube.com/user/DDRfrosh1
[2] e.g., Focus at Will https://www.focusatwill.com

achieve various emotional, motivational, or cognitive effects to the benefit of accomplishing various activities [27]. Individuals will report that music is expected to perform different functions based on different situations [26], an awareness of the specific songs expected to fulfill these functions, as well as the expected psychological benefits from listening [8]. As such, people have come to use music as a piece of technology in their daily lives, effectively attempting to outsource various psychological tasks to specific song selections. We now go on to discuss the factors that contribute to listeners successfully using music to achieve internal states that may be described as flow, which, in turn, support activities or goals.

2.2 Choosing music for a purpose

As mentioned above, our perspective on music as technology regards music as a tool in the hands of listeners themselves. In this section, we examine in more detail the importance of listener control of music. The perceived benefits of music listening have been shown to be more positive when the individuals had the ability to choose the desired music [27]. Participants indicate preferring playlists they created rather than automatically curated content [15], and those who chose the music they were listening to reported enjoying it more [27]. Furthermore, with greater control on the choice of music selection, individuals reported experiencing greater changes in mood along three bipolar factors: 1) positivity, 2) present mindedness, and 3) arousal [34].

Listeners' preference for control is consistent with the idea of music being a means to an end. A number of studies have shown that listeners use music as psychological tool to optimize emotion, mood, and arousal based on the very specific needs of a given situation and/or activity [8, 27, 34]. Interviews have shown that individuals have an awareness of specific songs they feel will assist in accomplishing various emotional tasks, such as decreasing or increasing their arousal, motivating them to take action, adjusting their moods, or assisting them to focus [8]. Reasons for listening to music have also been shown to vary by activity (e.g., doing housework, travelling, studying, dating, getting dressed to go out etc.) [8, 15, 29].

Along with the constant growth of the music corpus, a means to organize, retrieve and discover appropriate music selections is a growing challenge. Despite the prevalence of current playlist curation technologies, individuals report self-generated playlists to be the organizational method of choice [8, 15], an indication of the specificity of song selection requirements, above and beyond the specificity of individual preference. In the final section of the paper, we will return to discuss how, in order to use *music as technology*, users must have at their disposal appropriate music information retrieval technology. Next we turn to the neuroscience perspective on music as technology.

3. MUSIC AND THE BRAIN

Research in the field of music and emotion suggests there are multiple means for music to affect the individual, and that underlying physiological and neurological mechanisms should be researched [14]. We highlight two posited mechanisms relevant to our discussion: a) brain stem reflexes, and b) musical expectancy.

The degree and manner in which each mechanism results in a physiological or neurological response, and by extension arousal, may be key in understanding why listeners select specific songs given the tasks they have set out to accomplish. As the demands of each situation vary, the effect of acoustic stimuli on the brain of the listener may function to moderate arousal such that an optimal internal state is reached. In other words, listeners may be selecting songs, and by extension sequences of acoustic stimuli, to alter their internal state in order to best meet the needs of their situation.

3.1 Brain stem responses

The brain stem is believed to be a very old part of the brain, and has been shown to be sensitive to loud, low frequency, dissonant, suddenly changing sounds [5, 9, 22]. It is posited that sounds indicative of a sudden change, a strong force, or something of large size may coincide with an event that requires immediate, urgent and reflexive attention. These acoustic qualities shift attention to the stimulus, giving rise to muscular and cardiovascular responses as well; a by-product of this may be the reason bass drum sounds inspire people to dance in sync with the music, and why music with faster tempos is more arousing (see [14] and [17]). Furthermore, a greater number of brain regions have shown activation at the onset of musical samples as opposed to the middle or end of these samples [23].

As such, music that contains such acoustical stimuli, or dramatic changes in its acoustic features (e.g., dramatic build ups and “drops”), may shift attention to the music arousing the listener in the process. Conversely, music that is relatively constant may instead serve to 'drown out' distracting ambient sounds instead: for example, the difference between silence and the rustling of papers is far greater than the difference between the rustling of papers and background music. As such, music may provide a constant acoustic backdrop thereby reducing the amount of arousal and attentional shifts caused by distracting sounds in the listener’s environment.

3.2 Musical expectancy

Recently, an increasing amount of attention has been devoted to expectancy as it relates to music (e.g., as in Huron's recent work [11]). The ability of the human brain to predict events is thought to have been vital to survival, and thus plays a prominent role in all cognition. As such, meeting or violating expectations in music should result in physiological and neurological effects (see [30] and [31]). Given that music is essentially an organized pattern of sounds, our brains generate predictions as the music unfolds over time based on our knowledge of the specific musical piece, but also our knowledge of all music [31].

As only so much information may be encoded at a time, the more complex the piece, the greater the number of potential prediction errors, the more exposure is required to become familiar [31]. In fact, as far back as Berlyne's [3] studies, it has been shown that familiarity of a particular sequence of notes in relation to a corpus results in less physiological arousal than unfamiliar sequences of notes, as does simplicity in the melody as opposed to complexity. These expectations may be used deliberately by composers of music to create a sense of musical tension, only to resolve the tension later on in the piece, resulting in relaxation and pleasure [18]. In addition, familiarity of a piece may lead to anticipation of the pleasure to be experienced at peak moments in the music, resulting in the activation of midbrain dopamine neurons causing attention to be paid to potential upcoming rewards [31].

Relevant to our topic, such arousal may divert attention from the task to the music [e.g., 13]. On one hand, music that adheres to expectations, such as a collection of very familiar pieces, may result in less overall arousal than pieces that are unfamiliar, very complex, or of an unfamiliar genre. On the other hand, familiar pieces that result in pleasure and anticipation may also be arousing, diverting attention from the task to the music as well.

4. MUSIC AND FLOW

Flow is characterized as a mental state in which one's complete attention is focused on a task, one has lost sense of self and of time, and one's perception of the experience is positive and rewarding [24]. In this research tradition, the definition of flow also includes a sense that one's subjective level of skill is balanced with the subjective challenge of the activity: a too-simple task evokes relaxation then boredom which in turn causes attention to drift, and a too-challenging task evokes vigilance then anxiety [24]. As with music use in everyday life, the concept of flow is also intertwined with context and activity.

More recently it has been theorized that flow states may emerge during media enjoyment, resulting in neural states where attentional and reward centers in the brain are activated synchronously [40]. Weber and colleagues [40] drew a theoretical link between engagement in linear media (e.g., books, films and video games) and flow states. They posit that linear media require mastery of mental models: video games require a level of skill that increases as one progresses, and films require an understanding of the characters and the narrative. It is suggested that these contribute the challenge, which in addition to pleasurable engagement, coincides with activations of the brain regions necessary to achieve flow. While music is not specifically discussed, it is a medium that can be consumed during various activities, and may function in conjunction with these activities to inspire flow states.

The dopaminergic pathway, which is involved in the experience of pleasure, is posited to be active during flow states [40], and has been shown to be active during experiences of pleasure while listening to music [31]. Of interest in this pathway is the nucleus accumbens, which is also thought to be involved in automatic consummatory behavior (e.g., drinking or eating), and the striatum which also has connections to the brain stem [40]: both also been observed in pleasurable responses to music [31]. In addition, regions thought to be involved in reward-seeking behaviors, such as the prefrontal and orbitofrontal cortices have also been implied in both [31] [40].

While it is not yet clear how specifically music and context may interact to produce a flow state, enough evidence has been accrued for us to suggest two aspects worthy of study. Firstly, during tasks in which boredom is likely, more arousing music may be selected to induce a flow state: by diverting attentional resources to the music the challenge of the task increases, as it now requires attention to be paid to both the activity and the music. As such, music that is more likely to be arousing either by a) resulting in responses from the brain stem (e.g., loud, frequently changing, or dissonant song selections) or b) causing prediction errors (e.g., less familiar, familiar and causing anticipation, or more complex) may be more suitable. Secondly, during tasks that are challenging or otherwise cognitively engaging (e.g., studying or reading) music that is likely to be less arousing either by a) resulting in less brain stem activation (e.g., relatively unchanging or consonant) or b) being predictable without anticipation (e.g., somewhat familiar and somewhat liked, more simple songs) may be more suitable.

5. NEW CHALLENGES FOR MIR

We now turn back to discuss how *music as technology* connects with MIR. The ability of listeners to successfully use music as technology depends on the effectiveness of music information retrieval and recommender systems in supporting them. We argue for the necessity of multidisciplinary research that brings together neuro-, cognitive, and social psychologists, and music information retrieval researchers. Such collaboration will allow us to understand what makes music helpful for users and what makes it appropriate for different tasks. In this section, we point to several areas in which the music information retrieval is on the right track, and several areas in which more effort is needed if users are to truly benefit from music as technology.

First, we return to the relation between the user choosing music, and music being perceived as having positive benefits. Taking this connection seriously means taking the position that for music to be used effectively as technology, it must truly be a tool in the users' hands (i.e., fully under the control of the user). Other work that points out the critical role of user control over music selection includes [38], who observe that the context and the intentions of the user impact which music features are important. Their music selection interface provides users with control over factors such as tempo, mood, and genre, and their experiments show that users prefer this control. The findings are not surprising given the role of control in the success of recommender systems from the user point of view [28]. In order to make music a useful tool, MIR must start with the choice of the listener to change their internal state in order to accomplish a goal. The choice may be semi-conscious, or may simply consist of going to a place where certain music is playing, or accepting to stay in that place. Listeners who are unwilling or who are not themselves in control are not using music as technology. In other words, piping in focus music during an exam can be predicted not to improve students' ability to concentrate. MIR systems can make music useful as technology by providing results and recommendations that are transparent. The importance of transparency for recommender systems has long been recognized [33]. They should also minimize the effort needed from the user to provide feedback.

Second, serving listeners who want to use music as a tool requires extending today's context-aware recommender systems, which are described, for example, in [32]. Particularly promising is the development of systems to recommend music for activities, e.g., [39]. In [25] the authors propose a context-aware music recommendation system the monitors heart rate and activity level, and recommends music that helps the user achieve a desired heart rate intensity. The challenge of such activity-based recommenders is to provide music that serves the common needs of people engaging in an activity, while taking personal taste into account. One aspect of using music as technology is blocking out background noise. Context-aware recommenders will need to develop to be sensitive to the acoustic environment, so that they can recommend music that will mask it.

A challenge that has yet to be faced is moving music recommendation and retrieval away from music that listeners "like" the first time that they hear it, towards music that allows them to meet their goals. Currently, the ground truth that is used to evaluate the success of recommender systems does not differentiate “love at first listen” from an appreciation that a listener develops over a longer period of time on the basis of utility given the context and activity.

We suggest that collaboration between MIR and psychology may be appropriate to best determine not only how music can better be organized to suit different tasks, but also which specific features make certain music helpful, or make one selection more suitable for a given activity than another.

Recent years have seen progress in content-based and hybrid music recommender systems [32]. These systems make use of timbral features (e.g., MFCCs), features related to the temporal domain, such as rhythmic properties, and tonal features such as pitch-based features. Our discussion revealed the importance of content features that might point to a sudden, unexpected event in the music that would shift the listener’s attention. We point out that recent approaches to exploiting music content may only use very short segments of the music, such as the deep learning approach in [37]. A future challenge is to determine how long a window must be considered in order to determine whether the song contains features that disrupt focus. Here again, task specific as well as user-specific aspects are important.

Further, the role of familiarity is critical. The importance of music freshness is well recognized. For example, Hu and Ogihara [12] relate it to a memory model. However, playing the same familiar music repeatedly does not promote focus if the user's sense of anticipation becomes too strong. With the vast amounts of music currently available online, the possibility is open to creating a music recommendation system that never repeats itself.

When music is used as technology, it is important to keep in mind that it is the stream and not the individual song that is important. Currently, an increasing amount of work is carried out in the area of playlist recommendation [4]. Whereas many playlists are played on shuffle, playlists that most effectively allow the user to achieve internal state transformation may have a particular order, calling for more work on the generation of ordered streams of content items.

Finally, we anticipate that when listeners use music as technology they will want the possibility to query the system, instead of relying on a recommendation. Such queries, even though context-based, may not be well fitted to the goal that they want to accomplish. Here, it is necessary to understand the type of language that users use to express the complexity of their task. To this end, the MIR community should further foster insights in information seeking and user studies. However, an important difference with the existing paradigms under which these studies are conducted (e.g., [6, 20]) is that under the ‘music as technology’ paradigm, a query would be expressed in the form of a (non-musical) task to be accomplished, rather than a directed query to an explicit song (e.g., similarly to what was done in [21] on music and narrative).

6. CALL TO ACTION

In this work, we pointed out the notion of music as technology, which we feel currently is overlooked in MIR solutions. Connecting this concept to existing literature from the psychological sciences, it is clear that pursuing a joint research roadmap will be beneficial in both gaining fundamental insights into processes and internal states of listeners, and finding ways to improve music search engines and recommender systems. To concretize this further, we conclude this paper with a Call to Action, formulating interdisciplinary research directions, which will be beneficial for realizing the full potential of music as technology.

First, research should contribute to a better understanding of flow states. The evidence brought together in this paper points to the conclusion that flow is a desirable overarching internal state, and is the target state underlying a wide range of activities. We further argued that listeners choose music that complements an activity to result in a net optimal level of cognitive engagement. Under this view, music is not an end unto itself, but rather an inextricable part of the activity. More research is needed to validate flow as an overarching mental state in practice, as well as its antecedents. In addition, how music leads to and moderates flow state should be investigated.

Second, on the basis of a deeper understanding of flow, research should work to define new relevance criteria for music. Such work will involve understanding which kinds of music fit which kinds of tasks, zeroing in on the relevant characteristics of the music. We expect this to be a formidable challenge, since it must cover perceptual, cognitive, and social aspects of music. The contribution of users’ personal music experiences and music tastes must also be understood. On the one hand, we anticipate a certain universal character in the type of music that will allow a person to achieve flow state for a given activity. On the other hand, we anticipate that a ‘one size fits all’ solution will not be optimal, and that relevance criteria must also be flexible enough to capture individuals' needs and preferences.

Third, once we have defined relevance criteria, we should move from there to identify new features, new algorithms, and new system designs. We anticipate that features reflecting music complexity and unexpectedness will be important, as a few relatively isolated disruptive moments can potentially make an entire song unsuitable for an activity. This observation points to the need to consider the song as a whole, implying, in turn, new MIR algorithms. New system designs will be needed to help guide users' music choice without effort, and ideally without interrupting their flow state. System designs will need to take into account that users may not recognize the music that will make them most productive the first time they hear it. Further, even after listeners recognize the connection between certain music and their own productivity levels, they might not be able to express their music needs explicitly in music-technical terms. Systems must be able to accommodate the types of information and feedback that users are able to provide about the kind of music that will be most effective for them.

Finally, once new applications have been developed and deployed, they will provide an extremely valuable source of information about when listeners use music, allowing neuroscientists and psychologists to refine their theories of flow and how listeners achieve it in certain situations, against the backdrop of scalable and real-world use cases.

Our suggestion for MIR and the (neuro)psychological sciences to connect is not new; for example, it also was reflected upon in [1], and recently further interconnection possibilities between the disciplines were suggested in [16]. Both of these works rightfully point out that such collaborations are not trivial, particularly because of methodological differences and mismatches. However, we believe that the currently described possibilities offer fruitful research questions for all disciplines.

Ultimately, understanding music as technology has the potential to profoundly impact not only the MIR domain, but the whole ecosystem of music production, delivery and consumption. Currently, the success of music is judged by the number of downloads or the number of listens. The idea of music as technology opens up the possibility of evaluating the success of music also in terms of the goals that are achieved by listeners.

Besides considering music as technology, we believe that we also should continue to study and enjoy music for its own sake. However, the potential of music to help listeners achieve their ends opens the way for creative new uses of music, with respect to commercial business models, as well as promoting the well-being of listeners. We hope that ultimately, music as technology will support listeners in coming to a new understanding on how they can use music to reach their goals and improve their lives.

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7. REFERENCES

[1] Aucouturier, J., and Emmanuel B. "Seven problems that keep MIR from attracting the interest of cognition and neuroscience," *JIIS,* 41.3, 483-497. 2013.

[2] Bartholmé, R. H. & Melewar, T.C.: "The end of silence? Qualitative findings on corporate auditory identity from the UK," *Journal of Marketing Communications*, 29 Oct 2014, pp.1-18. 2014..

[3] Berlyne, D. E.: *Aesthetics and psychobiology,* New York: Appleton-Century-Crofts, Vol. 336, 1971.

[4] Bonnin, G. & Jannach, D.: "Automated Generation of Music Playlists: Survey and Experiments," *ACM Comput. Surv*. 47, 2, Article 26, 35 pages, 2014.

[5] Burt, J. L., Bartolime, D. S., Burdette, D. W., & Comstock, J. R: "A psychophysiological evaluation of the perceived urgency of auditory warning signals," *Ergonomics*, 38(11), 2327–2340, 1995.

[6] Cunningham, S. J. & Bainbridge, D: "A search engine log analysis of music-related web searching," In *N.T. Nguyen et al. (Eds.), Advances in Intelligent Information and Database Systems: Studies in Computational Intelligence*, Vol. 283, pp. 79-88, 2010.

[7] Cusick, S.: "You are in a place that is out of the world: Music in the Detention Camps of the 'Global War on Terror,'" *JSAM,* Vol. 2/1, pp. 1-26, 2008.

[8] DeNora, T.: "Music as a technology of the self." *Poetics*, 27(1), 31–56, 1999.

[9] Foss, J. A., Ison, J. R., Torre, J. P., & Wansack, S.: "The acoustic startle response and disruption of aiming: I. Effect of stimulus repetition, intensity, and intensity changes," *Human Factors*, 31(3), 307–318. 1989.

[10] Hargreaves, D. J., & North, A. C.: "The Functions of Music in Everyday Life: Redefining the Social in Music Psychology," *Psychology of Music*, 27(1), 71–83, 1999.

[11] Huron, D.: "Sweet Anticipation: Music and the Psychology of Expectation," *Music Perception*, 24(5), 511–514, 2007.

[12] Hu, Y. and Ogihara, M.: "NextOne Player: A music recommendation system based on user behavior," *12th Int. Society for Music Information Retrieval Conference (ISMIR'11),* pp. 103-108, 2011.

[13] Jung, H., Sontag, S., Park, Y. S., & Loui, P.: "Rhythmic effects of syntax processing in music and language," *Frontiers in Psychology*, 6(NOV), pp. 1–11, 2015.

[14] Juslin, P. N., & Västfjäll, D.: "Emotional responses to music: The need to consider underlying mechanisms," *BBS*, 31(06), 751, 2008.

[15] Kamalzadeh, M., Baur, D., & Möller, T.: "A Survey on Music Listening and Management Behaviours,"

13th Int. Society for Music Information Retrieval Conference (ISMIR'12), pp. 373–378, 2012.

[16] Kaneshiro, B., and J. P. Dmochowski. "Neuroimaging methods for music information retrieval: Current findings and future prospects," *16th Int. Society for Music Information Retrieval Conference (ISMIR'15),* pp. 538–544, 2015.

[17] Koelsch, S.: "Brain correlates of music-evoked emotions," *Nature Reviews Neuroscience*, 15(3), 170–180, 2014.

[18] Koelsch, S.: "Music-evoked emotions: principles, brain correlates, and implications for therapy." *Annals of the New York Academy of Sciences*, 1337(1), 193–201, 2015.

[19] Laplante, A. Improving music recommender systems: "What can we learn from research on music tastes?" *15th Int. Society for Music Information Retrieval Conference (ISMIR '14),* pp. 451-456, 2014.

[20] Lee, J. H.: "Analysis of user needs and information features in natural language queries seeking music information." *Journal of the Association for Information Science and Technology (JASIST)*, 61(5), 1532-2890, 2010.

[21] Liem, C. C. S., Larson, M. A., & Hanjalic A.: "When Music Makes a Scene-Characterizing Music in Multimedia Contexts via User Scene Descriptions," *Int. Journal of Multimedia Information Retrieval*, 2, pp.15-30, 2013.

[22] Masataka, N., & Perlovsky, L.: "Cognitive interference can be mitigated by consonant music and facilitated by dissonant music," *Scientific Reports*, 3, 2028, 2013.

[23] Mueller, K., Fritz, T., Mildner, T., Richter, M., Schulze, K., Lepsien, J., Möller, H. E.: "Investigating the dynamics of the brain response to music: A central role of the ventral striatum/nucleus accumbens." *NeuroImage*, 116, 68–79, 2015.

[24] Nakamura, J., & Csikszentmihalyi, M.: "The Concept of Flow," In *J. S. Snyder & S. J. Lopez (Eds.), Flow and the Foundations of Positive Psychology*, pp. 239–263. New York: Oxford University Press, 2014.

[25] Nirjon, S., Dickerson, R. F., Li, Q., Asare, P., Stankovic, J. A., Hong, D., Zhang, B., Jiang, X., Shen, G., and Zhao, F.: "MusicalHeart: a hearty way of listening to music," *10th ACM Conference on Embedded Network Sensor Systems (SenSys '12). ACM,* New York, NY, USA, 43-56, 2012.

[26] North, A. C., & Hargreaves, D. J.: "Situational influences on reported musical preference." *Psychomusicology: A Journal of Research in Music Cognition*, 15(1-2), 30–45, 1996.

[27] North, A. C., Hargreaves, D. J., & Hargreaves, J. J.: "Uses of Music in Everyday Life," *Music Perception: An Interdisciplinary Journal*, 22(1), 41–77, 2004.

[28] Pu, P., Chen, L., and Hu, R.: "A user-centric evaluation framework for recommender systems." *Proceedings of the 5th ACM conference on Recommender systems (RecSys '11)*, pp. 157-164, 2011.

[29] Rentfrow, P. J., & Gosling, S. D.: "The do re mi's of everyday life: The structure and personality correlates of music preferences," *JPSP,* 84(6), 1236–1256, 2003.

[30] Rohrmeier, M. A., & Koelsch, S.: "Predictive information processing in music cognition: A critical review." *Int. Journal of Psychophysiology,* 83(2), 164–175, 2012.

[31] Salimpoor, V. N., Zald, D. H., Zatorre, R. J., Dagher, A., & McIntosh, A. R.: "Predictions and the brain: How musical sounds become rewarding," *Trends in Cognitive Sciences,* 19(2), 86–91, 2015.

[32] Schedl, M., Knees, P., McFee, B., Bogdanov, D., & Kaminskas, M.: "Music Recommender Systems," *In F. Ricci, L. Rokach, B. Shapira, (eds.) Recommender Systems Handbook (2nd ed.),* pp. 453-492. Springer US., 2015.

[33] Sinha, R. and Swearingen, K.: "The role of transparency in recommender systems," *CHI '02 Extended Abstracts on Human Factors in Computing Systems (CHI EA '02). ACM*, New York, NY, USA, 830-831, 2002.

[34] Sloboda, J. A, O'Neill, S. A. & Ivaldi, A.: "Functions of music in everyday life: an exploratory study using the experience sampling method," *Musicae Scientiae*, 5(1), 9–32, 2001.

[35] Tagg, P. and Clarida, B.: "Ten Little Title Tunes: Towards a Musicology of the Mass Media," *The Mass Media Scholar's Press,* New York, USA and Montreal, Canada, 2001.

[36] Uitdenbogerd, A. and van Schnydel, R.: "A review of factors affecting music recommender success," *3rd Int. Conference on Music Information Retrieval (ISMIR '02),* Paris, France, 2002.

[37] A. van den Oord, S. Dieleman, and B. Schrauwen: "Deep content-based music recommendation," in *NIPS*, 2013.

[38] Vignoli, P. and Pauws, S.: "A Music Retrieval System Based on User-Driven Similarity and its Evaluation," *6th Int. Conference on Music Information Retrieval (ISMIR '05),* pp. 272-279, 2005.

[39] Wang, X., Rosenblum, D. and Wang, Y.: "Context-aware mobile music recommendation for daily activities," *20th ACM Int. Conference on Multimedia (MM '12). ACM,* New York, NY, USA, 99-108, 2012.

[40] Weber, R., Tamborini, R., Westcott-Baker, A., & Kantor, B.: "Theorizing flow and media enjoyment as cognitive synchronization of attentional and reward networks," *Communication Theory,* 19(4), 397–422, 2009.