

The Sound Challenge to Visualization Design Research

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ABSTRACT

This paper is an introduction to the emotional qualities of sound and music, and we suggest that the visual and the aural modalities should be combined in the design of visualizations involving emotional expressions. We therefore propose that visualization design should incorporate sonic interaction design drawing on musicology, cognitive neuroscience of music, and psychology of music, and identify what we see as key research challenges for such an approach.

Author Keywords

Emotion; music; sound; multimodal visualization design.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

User interaction is of importance in many types of visualizations. As emphasized by recent developments in interaction design and UX, the potential significance of users' emotional states for the outcomes of the interactions cannot be ignored. Consequently, a user's possible emotional state should be considered already during the design phase. Design is not only about enabling users to solve problems; it operates also on emotional levels, stimulating affective and visceral reactions in users. Visualization research has traditionally limited itself to a rather utilitarian stance, effectively missing out on the emotional potential inherent in conscious and purposeful design. Extending the design palette to multimodal representations, and specifically to sound and music, is a particularly powerful approach when it comes to emotional impact. This position paper is an introduction to what is known about the emotional qualities of sound and music, and a few corresponding research challenges for visualization design.

THE EMOTIONAL QUALITIES OF SOUND AND MUSIC

Research on sound, music and emotion is interdisciplinary

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and covers music psychology, music cognition, and cognitive neuroscience of music [1], as well as musicology and philosophy of music. According to the *expression theory*, the expressiveness and meaning of music arises from emotions experienced by the composer. In contrast, the *arousal* or *evocation theory* states that emotions expressed in music are aroused by expectations of the listener [2]. Even though the origin of the emotions evoked by the music differs between these two standpoints, what they have in common is that emotions are evoked by music and that these emotions are part of the music. This suggests that music, and to some degree sound in general, evokes emotions in the listener. Furthermore, it has been suggested that experiencing emotions when listening to music is the main reason why people listen to music [3]. Research has also shown that everyone has the possibility to have meaningful musical experiences [4], which in turn implies that the emotional state of every listener can be affected by music.

It has been shown that music conveys emotions, and that music as well can elicit the same emotions in the listener [5]. This was shown by comparing two musical excerpts, one with fast tempo and in major tone and one with slow tempo in minor tone as these musical structures are known to convey happiness and sadness, respectively. Subjective ratings of the listener's emotions showed elevated levels of happiness after listening to music expressing happiness as well as elevated levels of sadness after music expressing sadness. As the intended emotion was aroused in the listener, the music conveyed as well as elicited the emotion. Music is one of the most common ways of having peak experiences [6]. A peak experience is an intricate, transcendent, and intense experience that is crucial for the development of the person. Intense musical experiences can result in lasting changes in a person's values, social relationships, and development [7].

Musically induced emotions elicit similar frontal brain regions compared to emotions activated by other stimuli [8]. For example, joyful and happy sections of a musical piece are associated with increased activity in the left frontal lobe, while fearful and sad musical sections are associated with increased activity in the right frontal lobe activity [9]. This corresponds to research showing that the right hemisphere of the brain is of importance for

processing primary emotions such as fear or sadness, while the left hemisphere is important for preprocessing social emotions [10]. Social emotions, as compared to basic emotions, are emotions that require the interpretation of mental states of other people [11]. This might indicate that the joyful sections in music increased the activity in the left frontal because of feeling happy is associated with social sharing of a happy event or a happy memory, while feeling sad rather is an emotion connected to loneliness. Furthermore, the intensity of the perceived emotions as measured by the overall frontal region activity, increased as the musical stimuli became more intense [9]. This suggests that the degree of emotional response can extensively be manipulated by the musical stimuli.

Music and sound can be seen as high priority communication, as the psychoacoustic elements affect the listener immediately and unconsciously. Psychoacoustics is the scientific study of sound perception; that is the psychological and physiological responses associated with sound. Psychoacoustic elements of sound are: pitch, loudness, time, and timbre to mention a few [3, 12, 13]. Pitch is the perceived frequency of the sound. Tones of different pitch are combined together to form melodies, and an ascending pitch is generally perceived as more positive (such as happiness) while a descending pitch is perceived as more negative (like sadness or anger) [3]. Loudness is the perception of amplitude, the sound level. Loud sound levels might, for example, lead to increased blood pressure or increased annoyance [14], and thus might be more activating and engaging compared to less loud sounds. The feeling of fear is usually associated with a low sound level, while happiness and sadness are expressed at medium sound level, and anger at a high sound level [3]. Time is about the duration of the sound, but it also involves rhythm, meter, and tempo. A faster tempo is more arousing and engaging compared to a slower and more relaxed tempo [14] and a slow tempo evokes more calm emotions (such as sadness or tenderness), while a faster tempo evokes more active emotions (for example happiness or anger) [3]. Timbre means the harmonic content of the sound, which creates the character of the sound. A more complex timbre is more captivating with a greater emotional response as a result, compared to a simpler timbre [14]. Emotions such as tenderness and sadness are aroused with a soft or dull timbre, while happiness is evoked with a bright timbre, and anger with a sharp timbre [3].

Listening to music starts and affects physiological activities such as heart rate, perspiration, and respiration in a similar way as other emotional responses [15]. Furthermore, when listening to music, neurochemicals such as dopamine [16] and serotonin [17] are released, leading to intensely pleasurable feelings. Studies have shown that varying musical performance variables in the music, such as tempo, dynamics (differences in loudness), and articulation (how the music is expressed via the musical instrument), communicates different emotions [18]. Some studies have

used experienced musicians in the experimental settings, which might suggest that these individuals have a level of expertise and musical understanding that is not necessarily representative for the general population, as musical training has been considered one of the most influential aspects for emotional responses to music [19]. This suggests that it is of great importance to know the target audience to be able to choose the right level of musical complexity when designing. Furthermore, a listener is fast, as fast as less than an eighth of a second, in judging whether the music is good or bad [20], and in determining the musical genre [21]. Additionally, the listener's music preferences influence the experienced emotions elicited by music [19]. This further underlines the importance of choosing the correct music in the design process to achieve the right emotional impact on the target audience.

Music and sound have been used successfully to create mood and emotional settings in film for quite a long time [22]. The dramatic underscore, the so-called unheard melodies used in film and computer or video games [23], can be seen as an invisible, unheard, carrier of emotions that creates narrative and connotative clues to help the viewer interpret and understand the visual information and the course of events, while simultaneously contributing to continuity and cohesion [22]. Even though the sonic stimuli in this text so far have mainly been phrased as music, the same theoretical considerations also concern sound meaning and interpretation [24].

VISUALIZATION DESIGN AND EMOTIONS

Measuring emotion among users of visualizations could lead to more effective and efficient communication. Our position extends this idea in two ways.

First, we would like to draw attention to the fact that visualization traditionally addresses mainly visual expressions, whereas it is known that expressions in other modalities offer even greater potentials to evoke affective reactions. Specifically, our interest lies with aural expressions – musical sounds and other types of sounds – in combination with visual expressions (compare how Tweedie et al. [25] argued already in the late 1990s for the relabeling of visualization to externalization to accommodate the by-then new possibilities for multimodal expression).

Secondly, we want to emphasize the vast body of existing knowledge and best practices when it comes to designing visual and aural expressions with specific affective goals in mind. In graphic design as well as in sound design and music composition, the ability to anticipate the affective outcomes of certain expressions, and the ability to design an expression in order to achieve a certain affective outcome, are highly developed and accurate in many design situations. However, from an academic point of view, these abilities have traditionally been somewhat overlooked since they are based on a body of experiential knowledge that is

passed on through apprenticeships and practice rather than through scientific communication and academic literatures.

In recent years, however, an independent field called design research is starting to form [26]. That field is characterized by exploring forms of scientific communication in which designerly knowledge becomes a first-class topic. It is further characterized by its recognition of design practice as part of knowledge production, and its orientation towards producing designerly yet well-grounded knowledge.

At this point, we have summarized some of the existing academic knowledge on the emotional qualities of music and sound, demonstrating the great potential of aural expression in evoking emotion. We have argued that the field of visualization should incorporate aural expressions in order to achieve greater emotional expression potentials, and finally we have argued that the focus of research in visualization for emotion should lie with designerly knowledge every bit as much as evaluative knowledge. To elaborate our position, we conclude with a number of research challenges that would follow from such a stance.

RESEARCH CHALLENGES

The first challenge we identify is simply to combine the visual and the aural modality in the design of effective and efficient visualizations involving emotional expressions. We therefore suggest that visualization design should incorporate sonic interaction design [27] but also encompass musicology, cognitive neuroscience of music [28], and psychology of music [12].

The two modalities have different inherent characteristics, to some extent. Visual information can be persistent, whereas aural information is necessarily transient. Visual information can convey much greater quantities and ranges of symbolic and propositional content than aural information. Visual information is spatially located, whereas aural information can pervade a room, which in turn relates to focal versus peripheral communication. From a genre-conventional point of view, also affecting the users' interpretations, visual information in the context of visualization is expected to be mostly factual or instrumental – whereas aural information is expected to be mostly about mood and affective qualities (cf. music, as discussed above, and specifically the role of soundtracks in movies or video games).

The visualization literature is scarce when it comes to multimodal expressions; early examples like Gaver's 1991 Arkola simulation for process control [29] or his Sonic Finder did not have much impact on the academic field of visualization, despite the promising nature of the results he showed through what he called "sonification". One of the most interesting findings in the Arkola factory simulation was the emergent, holistic nature of the soundscape generated by a number of independent sources of non-musical sounds from different parts of the manufacturing process. Essentially, Gaver was able to replicate to some

degree through sonification the robust results from previous process control research showing how experienced operators could pinpoint problems in a large physical factory by listening to the holistic soundscape on the factory floor. Furthermore, it was already known that the holistic assessment skill was jeopardized by implementing centralized control rooms remote from the actual processes, and using only visual information to convey process state.

We find early work like this quite promising, and we would like to argue that we have now perhaps reached the technical maturity required to make visual plus aural a more common choice in visualization design. The modality characteristics outlined above point to a number of approaches worth exploring, for example:

1. Using musical sounds to induce the required arousal level in monitoring tasks. For instance, if an intelligent air traffic control system predicts a conflict between two entities within a time frame that will shortly necessitate action on behalf of the operator, the ambient musical soundscape of the air traffic control room could change its mood from relaxed towards more tense to attract more attention and preparation for action.

2. Using non-musical sounds from individual entities of a large information set to form an emergent soundscape with combined rhythm and timbre that arouses different emotional qualities from which the current overall state can be experienced holistically and peripherally. This would enable full concentration on focal tasks with simultaneous peripheral awareness of significant changes in the overall state, for example in control and monitoring tasks as well as visual analytics.

3. Using musical sounds for sonification when visualizing complex data to support interpretation and comprehension of the visualization. These sounds could create emotional responses by means of harmony or disharmony to make relations between data variables subconsciously and pre-attentively perceptible. Also, these sounds might be used to illustrate the density of, as well as the blend between, the variables.

4. Using musical sounds when giving feedback during and after a user interaction could further improve the interaction by influencing the emotional state of the user. Musical elements, such as rhythm, amplitude, and harmonic content could be relaxing or soothing and thus reduce an excited and stressful tendency in the interaction. On the other hand, if swiftness is of importance, musical elements could urge the user to interact by means of faster rhythm and increased amplitude.

The second overall challenge to visualization research is a meta-challenge, and it involves adopting a design research perspective in order to capitalize on the vast body of existing designerly knowledge concerning the emotional qualities of visual and aural expressions. Similar calls to the visualization research community have been voiced before

[30-32], but apparently to little effect. Thanks to recent developments in design research, the time might be ripe for appropriating design research concepts and methods into visualization research, or to put it differently, to address multimodal visualization as a design research discipline.

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