Creating and Evaluating Aesthetics in Sonification

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1 The Importance of Aesthetics in Sonification

Sonification transmits information through sound. In order to render data understandable to the listener, the sonification designer must make aesthetic choices that support this transmission. The term aesthetics does not necessarily denote something “beautiful” or “pleasing.” Rather, aesthetics refers to what can be perceived by the senses. It describes a set of choices that inform a musical or sonic product; a sonification is necessarily aesthetic as it is perceived by our senses. Aesthetic design choices will determine how the sonification sounds, and what effect it produces.

Aesthetics can have an enormous impact on the success of a sonification within a research context. Sonification with appropriate “aesthetics and good sound design” is more likely to be chosen and used (Supper 2012, 180). The acceptance of a sonification is linked with a number of aesthetic attributes including pleasantness, loudness, noticeability, clarity and integration. However, one of the big challenges facing the field is its interdisciplinary nature. Its difficulty lies in “integrating concepts from human perception, acoustics, design, the arts, and engineering” (Walker and Kramer 2004, 7). Calls for an increased collaboration between experts and researchers, as well as an increased focus on sound aesthetics have been commonplace in the field for decades (Blattner et al. 1989; Kramer 1994; Walker and Kramer 2004; Vickers and Hogg 2006; Barrass and Vickers 2011). Unfortunately, successful collaborations between researchers from scientific and musical disciplines remain too scarce; sonification researchers predominantly stem from the musical field (Neuhoff 2019, 328). Attention-grabbing projects such as the CERN’s Collide Program which chooses an Artist-in-Residence have been criticized for producing impressive aesthetic results but little transmission of knowledge. Rioji Ikeda’s 2015 *Supersymmetry* was described by a journalist as “a lot of sound and light, signifying nothing” (Jones, 2015). There is still much scope for researchers to investigate the
aesthetics and information transmission within the field of sonification, whether for functional or artistic purposes.

The best aesthetics for a given sonification will depend on its objective. When designing an aural display, we need to consider a number of factors, including the original data and what meaning we are seeking to extract. For sonifications that run over a long period of time (for example, a heart rate monitor), “improved aesthetics will likely reduce display fatigue” (Kramer 1994, 53). We should reiterate that “aesthetics” does not necessarily refer to “pleasant” music and sound; it can include unpleasant auditory experiences too. Alarms are loud and unsettling, and unsuitable to prolonged listening. Their aesthetic is highly appropriate to their function as they should raise the listener’s attention and prompt them to act. The sonic environment of a hospital provides an insight into the link between a sonification’s purpose and its aesthetics. A hospital environment demands quick and precise sonic information. A heart rate monitor should be clearly discernible within a dense sonic environment, without becoming irritating over a long period of time, when there is no emergency. It should be precise and correlated to the severity of an emergency, and raise immediate concern in the listener (Sinclair 2012). The aesthetics of a sonification must be linked to its meaning and purpose.

There is a strong case to suggest that aesthetics are important in research, as they are in music and sound art. Paul Dirac proposed the idea of ”beauty” in his *Principle of Mathematical Beauty*. He stated that a mathematician, for example, should strive for beauty in their work because the “simple, that is, the beautiful, brings understanding more readily” (Dirac 1939). This a useful consideration in sonification design too, as simpler displays can bring a greater understanding of the data. Furthermore, aesthetics can support the concept of “usefulness”: the “function of the task it is being used to support” (Barrass 1997, 21). The same dataset could be approached with different aesthetics depending on its usefulness (i.e., the purpose it is trying to fulfil) (Barrass 2012, 178). An appropriate aesthetic approach helps to cross the boundary between data and information transmission (Barrass and Kramer 1999). Without context, data does not provide information (Roddy and Furlong 2014, 75); the context is created through aesthetics.

### 2 The Importance of Evaluation in Sonification

Research is carried out according to established methods of inquiry. The scientific method stipulates that a question is formulated and, in order to reach an answer, a hypothesis is derived and tested, and experiments are analyzed and evaluated. Assuming that a sonification is designed for a purpose, it should also be tested and evaluated to ascertain whether it is fit for the intended purpose. Unfortunately, evaluation is not sufficiently carried out in the field of sonification. At the International
Creating and Evaluating Aesthetics

Conference on Auditory Display (ICAD) in 2012, for example, only 1 out of 53 papers included an evaluation (Degara et al. 2013, 167). The 2019 ICAD featured a higher number of papers that included a robust evaluation or testing aspect, but it was still not a ubiquitous practice. One of the challenges that researchers face in this regard is that there are no established or prescribed methods for evaluating sonifications. There are no “specific guidelines” on developing sonifications either (Ibrahim et al. 2011, 77). This gap in the field can result in a lack of rigor and accountability in the research methods of sonification designers. Kramer proposes adopting a “methodical research approach” with a “benchmarking framework that allows for the comparison of sonification algorithms” (Kramer 2004; Degara et al. 2013), as this will contribute to raising the quality and profile of the field.

The question of evaluation becomes more complex because of sonification’s interdisciplinary nature, which requires a mixed method approach that borrows testing methods from scientific and artistic research. Functional aims of an auditory display are mostly evaluated through task-based testing and statistical evaluation. Musical evaluation is a far more divided question because of its subjective qualities, as well as a reticence to evaluate the “musical.” This argument might stem from a romanticized idea of music as an art that requires inspiration and cannot be fully described. However, composition is largely determined by musical craft and skills that can be taught and learned. Genres are based on common conceptions and rules. It is, therefore, possible to evaluate music according to certain guidelines while accepting that there is an inherently subjective element to musicality that cannot be fully described in words or numbers. The concept of the evaluation of music is important because it introduces accountability in musical research. How can we understand whether we have achieved our research aims and objectives if we have no criteria to answer research questions? To sum up, the evaluation of the aesthetic aspects of sonification is not only possible, but necessary.

Some researchers have proposed evaluation frameworks for sonification. The 2004 Listening to the Mind Listening competition asked different composers to produce a sonification on the same EEG dataset (Barrass et al. 2006). It included an “aesthetics” category rated on a scale from 1 to 5. Degara et al.’s Sonification Evaluation eXchange proposes a community-based platform that enables the definition and evaluation of standardized tasks for the formal comparison of sonification methods, supporting open science standards and reproducible research in the context of ICAD (Degara et al. 2013). While this framework recognizes the urgent need for a community effort to create a standardized process and criteria for evaluation, no specific aesthetic criteria are defined either. Vogt’s evaluation criteria includes interesting elements such as “Gain” (what is gained from using sonification over other representation methods) and “(Sound) Amenity,” which asks whether the sonification is sonically pleasing (Vogt 2011). Finally, Williams proposes a set of questions to evaluate musification (a sonification with the data subjected to a “set of
These also ask whether the display is “audibly pleasant” (Williams 2016). While some existing frameworks do take aesthetics into consideration, they do not query their correct application sufficiently.

3 Creating Aesthetics

Creating suitable aesthetics for a sonification requires a framework that accounts for every step in the sonification process. Previous research by Barrass and Vickers (2011) and Vickers and Hogg (2008) provides further discussion around the importance of aesthetics and useful design concepts in sonification. The Data-Mappings-Language-Meaning framework (Bonet et al. 2016a) incorporates these discourses and divides the process into four parts, which influence aesthetic decisions. The process is not always chronologically linear and the individual factors affect the rest of the process. While the framework was first developed for “artistic sonifications,” its principles are applicable to auditory displays with a variety of purposes. It is intended for Parameter-Mapping Sonification (PMSon) (see Goudarzi’s Chapter in this volume), but could be adapted to other forms of auditory display such as audification or Model-Based Sonification.

3.1 Data

An excellent understanding of data is required to choose a dataset, apply transformations to it, and choose appropriate mappings and musical context. This refers to an understanding of the dataset’s content, but also its meaning. Once we understand both the content and the meaning of the dataset, we can make informed choices regarding the next steps in the sonification process: mappings, aesthetic language and meaning.

The data needs to be suitable for aural display as not all datasets benefit from aural, rather than visual, representation. Thus, the choice of data is an aesthetic choice. At this point we should warn of the danger of the “big data fetish,” which refers to using complex data in the belief that bigger data implies scientific credibility (Bjørnsten 2015). Often, the opposite is true because complex data is more difficult to handle and transmit, resulting in an incomprehensible aural display. Furthermore, humans tend to prefer music with average complexity (this is heavily influenced by factors such as age and musical experience, for example); excessive complexity or randomness is commonly disliked by listeners (Güçlütürk and van Lier 2019).

Sound is inherently temporal. Datasets that have a chronology or timeline can therefore offer the designer an obvious starting point for mapping. However, not all types of data have an order that can create a timeline. There are different types of data. Barrass (1997, 43) describes qualitative and quantitative data types that can
Table 15.1 Data types describing different phenomena

<table>
<thead>
<tr>
<th>Data types</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal</td>
<td>Difference without order</td>
<td>Banana, apple, orange</td>
</tr>
<tr>
<td>Ordinal</td>
<td>Difference, order and metric</td>
<td>Green, crisp, ripe</td>
</tr>
<tr>
<td>Interval</td>
<td>Difference, order and metric</td>
<td>Temperature</td>
</tr>
<tr>
<td>Ratio</td>
<td>Difference, order, metric, and natural zero</td>
<td>Rainfall</td>
</tr>
</tbody>
</table>

Barrass, 1997, 43.

be defined as “nominal,” “ordinal,” “interval” and “ratio” (see Table 15.1). Where there is no time vector, a time dimension needs to be extrapolated from correlations between other vectors to create a chronology; temporal relationships need to be found in the dataset (Rhoades 2014). Adderley and Young’s sonification of Sahelian soil samples, *Ground-Breaking*, creates a “timeline” in the non-temporal data. This data manipulation introduces an element of decision-making on the outcome of the sonification by its designers (Adderley and Young 2009, 408). The handling of data before its mapping is paramount to the outcome, but we must be aware of the possibility of skewing its meaning. Referring back to Barrass’ (1997, 43) description of data types, those with an “order” describe a temporality, even where it might not appear obvious at first (e.g., an apple – “green, crisp, ripe”).

Handling the data before mapping it to sound is integral to the sonification process as we choose what information we want to transmit. Common data handling choices include filtering and compressing. Huge datasets (of dark matter data, for example) require filtering in order to bring forward salient features in the data (Rhoades 2014; Bonet et al. 2016b). Preliminary work with the data can in fact reveal interesting patterns that the designer might choose to highlight in the sonification.

An understanding of music perception can be useful to choose a suitable dataset. Data that presents some sort of musical structure might be inherently more appealing to our ears because we can make use of proven aesthetic constructs. Sonifications that include a form of repetition mirror musical conventions (e.g., chorus in a song). Being able to recognize shapes or patterns in a sonification can encourage the listener to choose and use a sonification because of the “something to hold on factor … useful musical devices that support the listening experience” (Landy 2007, 23). This is shown, for instance, by the multitude of existing sonifications of DNA (Ohno and Ohno 1986) and EEG waveforms (Wu et al. 2009). Finally, data that has salient features can be sonified in a manner similar to a melody and an accompaniment. A complex dataset might be filtered so that salient data features are assigned more salient sound mapping, while other data points might be sounded as an accompaniment to the main patterns of the sonification (Bonet et al. 2016b).


3.2 Mappings

The mapping of data to sound is the process whereby data becomes audible by mapping data parameters to sound parameters. This process might be considered the most creative aspect of the sonification because it is “as arbitrary as it is decisive” (Adderley and Young 2009, 408). The designer has an enormous range of mapping possibilities which will strongly determine the outcome of the sonification process. PMSon offers a lot of flexibility because mappings can be chosen specifically to suit the dataset (Hermann and Ritter 2004, 734). However, the near infinite possible combinations of data to sound mappings are a challenge in themselves as there “is a very large set of possible mappings but a notoriously small subset of perceptually cognitively, valid mappings” (Roddy and Furlong 2014, 70). Because there is a limited set of effective mappings, they need to be carefully considered and chosen according to the purpose of the sonification. The aesthetic strategies described below can be used by designers to do so.

The concept of primary and secondary data and sound parameters is useful when thinking about effective mappings. Some sound parameters are easier to differentiate and understand; the ear perceives more detail in certain sound characteristics. Pitch and rhythm are parameters that humans can understand precisely as they provoke a neurological response (Large 2010), while differences in other sound parameters, such as panning or timbre, are more difficult to hear. Most sonification designers are empirically aware of it: a 2013 survey shows that pitch is the most-used parameter (23.8 percent) (Dubus and Bresin 2013, 15). In complex datasets, some data parameters are also more cognitively important than others. Some of the features or patterns in the data are more salient or relevant to the information and meaning in the data. Thus, the data can be divided into primary and secondary data parameters.

We can also define primary and secondary sound parameters. Respective data and sound parameters can be mapped to each other. “Primary cues” are attributed to sound parameters to which we are particularly sensitive and capable of perceiving even small changes. These sound parameters could include “pitch, tremolo rate, rhythm and attack time.” Secondary cues can include “volume, pan position, number of harmonics or envelope shape” and are more difficult to perceive accurately (Ballora 2014, 31). However, supporting auditory cues can help differentiate primary cues. Ballora gives an example: “data points in an increasing pattern may produce a primary cue of ascending pitches, but these pitch changes may be complemented with corresponding changes in harmonic content and/or pan position” (Ballora 2014, 31). The concept of primary and secondary cues has clear parallels with the musical concepts of melody and accompaniment, where an accompaniment can help shape and elevate the perception of a melody. Designers often use primary parameters intuitively (Bonet 2019a, 91); however, a purposeful approach that accounts for human perception can help to produce more successful sonification quicker.
An emotional connection between data and sound can help a sonification to be more successful. Arbitrary data-to-sound mappings and a lack of emotional connection between data and sound often fail to engage the listener (Smith 1990). Intuitively, we feel that medical images, for example, ought to sound different from demographic data or satellite imagery (Smith 1990). Two different datasets could be mapped in a similar manner and produce near-identical results, yet the emotional connection between data and sound might be lacking. How this connection might be achieved depends on the choice of mappings, but also on the aesthetic language. Another aesthetic mapping spectrum is called \textit{indexicality}, which denotes how strongly a sound “sounds like the thing that made it” (Vickers and Hogg 2006, 213). High indexicality describes a literal mapping while a low degree of indexicality might denote a more metaphorical mapping, using, for example, musical motifs to transmit data. Gresham-Lancaster uses the term “second order sonification” to describe a mapping that takes advantage of cultural connotations, musical structures and the connection between frequency, timing, timbre, etc. (Gresham-Lancaster 2012, 210). He argues that second order sonification affords more flexibility because it is not a literal mapping; more abstract sonic relations and concepts can be used to effectively transmit information. The challenge of this approach is to retain an emotional connection between data and sound. Once again, the designer must carefully consider the best approach for a given dataset in order to convey the intended meaning.

3.3 Aesthetic Language

The aesthetic language used in any sonification must be chosen to serve the purpose of the sonification. We are referring to aesthetic, rather than musical, language to avoid limiting the scope of the framework solely to artistic applications; although the aesthetic conventions of sound display are closely linked to musical languages. The vast majority of sonification follow the aesthetic conventions of Western classical music, including a chromatic range of pitches, major and minor scales, regular key signatures, etc. The reasons for this are straightforward. Most sonification researchers are familiar with these musical conventions. Also, popular tools and technical standards, such as MIDI, are based on the Western scale.

Shared knowledge of an aesthetic language can be used to transmit information effectively between sonification designer and listener. Major and minor scales often have connotations of sounding “happy” and “sad,” while dissonance can be used to signify an error or an alarm. Furthermore, pre-existing sounds or music can be used as sonic material in mapping to create meaning. Auditory icons, for example, are aural metaphors that “provide an intuitive linkage” (Brazil and Fernström 2011, 325) between the world represented and the sound heard. They require “an existing relationship between the sound and its meaning” (McGookin and Brewster 2011,
339), such as the paper crunching noise of the Recycling Bin in Windows. Similarly, in PMSon an existing piece of music can be used as sonic material and modified through mappings to offer new meaning to the sound and the data (Bonet 2019b). However, converting any data into “Mozartian pastiches” is inappropriate as it disregards the needs of the individual dataset (Bjørnsten 2015). Different data types benefit from different aesthetic conventions in sonification. The designer needs to determine the best aesthetics in order to choose suitable mappings.

An important aesthetic choice must be made when considering sounds on either concrete or continuous scales. Most sonification use concrete frequency scales, for example diatonic pitches. The challenge with a concrete scale is that data might need to be arranged in concrete bands before mapping it to specific pitches. An infamous example of this procedure is the Higgs-Boson particle sonification by the LHC Symphony Orchestra (Vicinanza 2012) that mapped particle mass to diatonic notes. Pesic and Volmar (2014) describe this mapping as “pure artefact” because it misrepresents the actual difference in particle mass. A continuous, or even microtonal, scale would have been preferable as it would have translated the data more accurately. Discarding any scales using intervals smaller than a semitone is a waste of sonic resources because the human ear can only discriminate around a quarter of a semitone (varying depending on the frequency and musical experience) (Zarate et al. 2012, 987).

A sound-based aesthetic approach can also produce effective sonification results and create an emotional linkage between data and sound. Earcons use sounds with an existing meaning to describe the data and are particularly useful in functional applications. However, sound manipulation methods from the field of electroacoustic and acousmatic music can be appropriated for data-to-sound mappings, and offer new ways of communicating information. Possibilities of sound mappings when working with sounds include frequency filters, dynamics, granulation synthesis parameters and spatialization. The spatial aspect of pre-recorded sounds is particularly interesting for creating immersive sonifications that provide the listener with a new experience of data. Natasha Barrett’s work is of particular interest in this regard. Her piece *Viva la Selva* (1999) used spatial data collected from animal vocalization in a jungle over the course of 24 hours. The vocalizations were also recorded and mapped spatially (x-dimension by panning, y-dimension by pitch, z-dimension by filtering and reverberation) to create an accurate and immersive experience of the jungle environment (Barrett 2000, 22). Her work demonstrates potential uses of a sound-based approach to sonification, where the aesthetic language supports the transmission of information and meaning.

### 3.4 Meaning

The aim of a sonification should be to transmit the meaning of the data. As discussed previously, aesthetics provide the context to make the meaning apparent to the listener. It can be useful for designers to think about the ways that a message
Figure 15.1 Shannon-Weaver Mathematical Theory of Communication applied to the sonification process (in italics). The terms in boxes describe the five parts of the communication process, while the annotated arrows describe the transmission between parts. Noise is an external influence on the channel which can distort the signal and the feedback describes the message returned from the Receiver to the Sender.

gets transmitted to a listener, as described, for example, by the Shannon-Weaver Mathematical Theory of Communication. The model includes an information source, a transmitter, a channel, a decoder and a destination (Shannon and Weaver 1949, 33–34). The system can also contain noise, which is any interference to the signal which creates “distortions” or “errors in transmission” (Shannon and Weaver 1949, 8). Feedback denotes the return message from the destination (receiver) to the information source (sender), although it was introduced by later theorists (Chandler 1994). The Shannon-Weaver model can be applied to sonification: the information source is the sonification designer, the transmitter (or encoder) is the mappings, the channel is the aesthetic language, the decoder is the listener’s understanding of the mappings and language used, and the receiver is the listener (see Figure 15.1).

Visualizing the sonification process within the Shannon-Weaver model highlights the importance of aesthetics at every step, but also shows that every step is woven together. Decisions at either stage are not chronological or linear; the designer might need to reconsider the handling of the data, for example, once they have considered the language and mappings. Let us reconsider Roddy and Furlong’s statement that information is “data coupled with context” (2014, 75). The message is sent to the listener through the means of sonification. In order to understand this message, the listener needs to be aware of the medium (sonification), method of sonification (mappings) and aesthetics language to be able to decode it and access the message. Thus, the listener requires a context to understand the sonification (see Figure 15.2). This context is provided by a shared understanding between the designer and the listener of certain steps in the transmission process. The understanding stems from a shared sense of aesthetics.
The Shannon-Weaver Mathematical Model of Communication describes the Message, Signal and Received Signal as different types of forms that the information takes in the process. The vertical arrows indicate the composition of each within the context of sonification.

4 Evaluating Aesthetics

A mixed method approach is required for the evaluation of the aesthetics of sonification. The framework must combine functional and aesthetic criteria to determine the success of a sonification’s sound.

The subjective nature of the perception of aesthetic parameters in sonification renders a definitive evaluation improbable. It is useful, however, to consider some of the ways in which musical works – sonic aesthetic objects – are evaluated; school and conservatory music curricula contain evaluation criteria for performance and composition skills, for example. A musical work can be considered through a technical, cultural, contextual or emotional lens, amongst others. It is possible to assess whether a piece of music conforms to a required technical skill, an assigned genre, an intended meaning, etc. – whether it meets the specific assessment criterion. Such a criterion remains to some extent subjective, but can help towards a general consensus of the quality of a musical work. Similarly, the aesthetics and success of a sonification can be evaluated and statistical significance can be achieved with an appropriate framework and sufficient testing.

The evaluation framework proposed combines existing criteria proposed by Barrass et al. (2006), Vogt (2011) and Williams (2016) and adapts them to focus on the question of aesthetics. Table 15.2 shows the criteria organized according to overarching criteria used in the framework.

Gain describes what is achieved through the aural display of data. It asks about the purpose of a sonification – whether purely functional or with artistic intentions – and whether it has been achieved. It is also linked to the evaluation of the aesthetics, as these will contribute to this purpose. It asks whether the aesthetics serve its purpose. Finally, it might also consider the ‘congruency’ of a sonification, and whether it accompanies a visualization in a purposeful manner, (see for example Williams 2016). The criterion of Intuitivity, clarity and learning effort asks whether
*Table 15.2* Sonification evaluation criteria combining criteria from Barrass et al. (2006), Vogt (2011) and Williams (2016).

<table>
<thead>
<tr>
<th>Barrass et al.</th>
<th>Vogt</th>
<th>Williams</th>
<th>Proposed criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>/ Gains Clarity</td>
<td>/ Gain</td>
<td>Intuitivity, Efficiency</td>
<td>Gain</td>
</tr>
<tr>
<td>Accessibility Learning effort</td>
<td>/ Intuitivity, clarity and learning effort</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mapping</td>
<td>/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aesthetics</td>
<td>Amenity Amenity</td>
<td>Sonification method</td>
<td></td>
</tr>
<tr>
<td>/ Contextability</td>
<td>Congruency</td>
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<td>/</td>
<td>Immersion</td>
<td></td>
<td></td>
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<tr>
<td>Overall Impression</td>
<td>/ Listener feedback</td>
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</table>

the information transmission process is efficient. It also asks which learning effort the sonification requires and whether it is accessible to a wider audience. Within the context of aesthetics, it asks whether these provide the simplest learning effort possible for the listener. This criterion is concerned with the choice of mappings; are the chosen data-to-sound mappings effective? Assessing the Sonification method requires an examination of the aesthetic decisions taken during the process; it evaluates the application of the Data-Mappings-Language-Meaning framework. Listener feedback asks about the participant’s experience of the sonification.

The evaluation criteria can be used for testing with listeners. The questions proposed below (see Table 15.3) show how each criterion can be examined. This a mixed method approach that allows for quantitative and qualitative enquiry. The questions can be answered by the listener with a rating (e.g., on a scale from 1 to 5) or a written answer. The combination of both will provide the designer with the nuanced feedback necessary to determine the success of the sonification and its aesthetics.

### 5 Conclusion

The field of sonification faces recurrent and persistent issues that have frustrated researchers for decades. Its challenges are paradoxical at times: while music researchers are in the majority, sonification aesthetics and success rates often remain unsatisfactory (Neuhoff 2019, 328). We have argued that a stronger focus on aesthetics and systematic evaluation are key to solving some of these long-standing issues. While calls for collaboration between scientists and composers are not new, sound designers might provide the expertise required to complement existing ideas and research in the field (Barrass and Vickers 2011, 164).

Sonification is often carried out on an empirical basis, as the vast differences in individual auditory perception (particularly between musicians and non-musicians) makes it difficult to generalize sonification methods. However, we can certainly synthesize guidelines that tend to be accepted as correct (Neuhoff 2019, 328); this chapter
Table 15.3 Proposed evaluation questions for sonification.

<table>
<thead>
<tr>
<th>Questions for evaluation of a sonification</th>
<th>Gain</th>
<th>Intuitivity, clarity and learning effort</th>
<th>Sonification method</th>
<th>Listener feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the data display derive gain from an auditory display?</td>
<td>A Rating: (esthetic)</td>
<td>Are the data and the information clearly heard?</td>
<td>Data: Is the data suitable for sonification?</td>
<td>A Rating:</td>
</tr>
<tr>
<td>Does the sonification serve its purpose?</td>
<td>F Rating: (functional)</td>
<td>Is the sonification accessible?</td>
<td>Mappings: Do the mappings best transmit the information (clearly, precisely, aesthetically)?</td>
<td>F Rating:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What does the listener need to know or learn to understand the data?</td>
<td>Aesthetic Language: Is the aesthetic language suited to this dataset?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Does the sonification create an emotional connection between the data and the sound?</td>
<td>Meaning: Does it transmit the intended meaning to the listener?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>What does the listener hear, understand and feel?</td>
<td>A Rating:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>How they rate the sonification overall?</td>
<td>F Rating:</td>
</tr>
</tbody>
</table>

in fact collates empirical findings from the sonification community. Continued work on the aesthetic perception of auditory display can only advance this endeavor.

The evaluation framework presented here has been developed from empirical experiences of sonification design, as well as listener feedback, in order to offer a method to assess and compare the success of sonifications. It will hopefully be applied and further refined as researchers turn towards a mentality that involves more thorough evaluation. There is no reason that sonification designers and researchers should not be held accountable through robust and universal evaluation methods. A solid research method that includes design and evaluation guidelines which take every step of the sonification process through an aesthetic lens will hopefully be a step in the right direction.

Notes

1 Parameter-Mapping Sonification is the most common sonification method. The sonifications are created by mapping data points to sound events, such as frequency, amplitude, duration, etc. (Hermann and Ritter 2004, 734).

2 See, for example, the suggestion to use Curtis Roads' "aesthetic premises and aesthetic opposition" in sonification (Roads 2004 in Barrass and Vickers 2011, 163–64).
References

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