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## USING PARTICIPATORY VISUALISATION OF SOUNDSCAPES TO COMPARE DESIGNERS' AND LISTENERS' EXPERIENCES OF SOUND DESIGNS

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### Abstract

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There are numerous rules and well-established guidelines to help designers with the visual appearance of interactive technologies. In contrast, when it comes to the use of sound, there is a paucity of practical information regarding design for euphony, excepting musical composition. This paper addresses this hiatus by describing a theoretically based, practical method for evaluating the design of the auditory components of interactive technologies and media. Specifically, the method involves eliciting the auditory experiences of users of these technologies and media and comparing them with what the sound designers had intended. The method has been comprehensively tested in trials involving 100 users (listeners), and the results have been described as “useful” and “invaluable” by a group of 10 professional sound designers.

### 1. Introduction

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As human-computer interaction (HCI) and interaction design abandons the desktop in favour of our pockets and purses, the hands of children, and the wider environment, so issues of non-visual modalities of interaction are being foregrounded. We currently rely on a sound or vibration to inform us that a text message has arrived, or that we are late for the dentist. Beyond these simple alerts, sound is used to great effect in the design of virtual environments (Finney and Janer 2010; Nordahl 2010; Serafin and Serafin 2004), video games (Collins 2013; Murphy and Neff 2011; Nacke, Grimshaw and Lindley 2010), and artistic installations that embrace an existing site in order to enhance and empower spaces (Batchelor 2013; LaBelle 2006; Torehammar and Hellström 2012). The use of sound in these technical systems mirrors, to some degree, the place of sound in the real world, where it provides a broader “picture” of our surroundings which, in turn, orient us within the complexities of these “information” spaces wherein we daily find ourselves.

The issues of how interaction designers should design sound for use within HCI remains unresolved, as even talking about it, much less reasoning about it, is difficult. Barrass (Barrass 2005) refers to the novelty of his 1994 approach to sonification and how that laid the foundations for a comprehensive framework for auditory display design. Brazil (Brazil 2010) stated that there was still no systematic approach to auditory display and sonic interaction design, but that there was ongoing work. MacDonald and Stockman (MacDonald and Stockman 2013) highlight that auditory display design techniques are still not unified or easily understood. The expert knowledge upon which such design depends remains locked up in the professional practice of sound designers and ranges

from what Anderson (Anderson 1974) refers to as the available propositional or observable, through to what Polanyi (Polanyi 1951) describes as the unarticulated tacit or yet to be formally systematized.

Notwithstanding these problems, there have been a number of attempts at systemising the design of sound within interactive technologies. Perhaps the most widely known is Brewster (Brewster 1994), who proposed guidelines for the design of earcons. Earcons are the abstract representations of some information using sounds, first introduced by Blattner, Sumikawa, and Greenberg (Blattner, Sumikawa and Greenberg 1989). Mynatt concentrated on the usability of auditory icons, proposing a method of design that addressed identifiability, conceptual mapping, physical parameters, and user preference (Mynatt 1994). Auditory icons are everyday sounds that correspond to computer events, as first developed by Gaver (Gaver 1986). Dombois and Eckel (Dombois and Eckel 2011) have developed guidelines for audification – the process of transforming data waveforms into sound, first discussed by Frysinger (Frysinger 1990) – and are most concerned with the suitability of the source material (data-set). Despite the many different approaches to sonification, such as audification, that have been developed since the 1980s, there is still no complete set of guidelines for their design (Walker and Nees 2011), although attempts have been made to formalise the process since (Kramer et al. 1999).

Frauenberger and Stockman (Frauenberger and Stockman 2009) have evaluated the work of Barrass (Barrass 2003), suggesting that patterns of auditory design can be developed and tagged with keywords to enable specialist and non-specialist designers to access this knowledge. In the style of Alexandrian patterns (Alexander 1979), the approach is to describe typical design problems and solutions. They note that identifying patterns from individual sound design solutions is difficult and that this problem could be lessened by increasing the size of the community contributing patterns as well as allowing sufficient time for patterns to be generated and shared. Despite these efforts, sound design for auditory displays remains something of a “black art”, being confined to a gifted few (Alves and Roque 2011).

While sound design within interaction design is poorly understood, this is not the case for sound in other design disciplines. Sound designers for games typically specialize early in their career to learn the craft and the professional tools that are required for their trade. Sound designers of soundscape installations in public buildings are often musicians who have a deep knowledge of how to affect people’s feelings and behaviour through sound (Hellström, Dyrssen, Hultqvist, Mossenmark and Sjösten 2011). Sound designers for radio and theatre predominantly train as recording studio or live music engineers first, and of course film schools provide another specialist route for film sound designers (Touzeau 2008). Within film, Walter Murch was the first to describe his work as sound design, as he moved the sound between mono, stereo and quadrophonic for the film *Apocalypse Now* (LoBrutto 1994). Ben Burt was the first to work as what is now the recognisable role of a sound designer on *Star Wars Episode IV – A New Hope*, being credited for special dialogue and sound effects (Whittington 2007).

However, as sound becomes an increasingly mainstream part of interaction design, we need to find ways of accessing the design knowledge of these specialist designers by mainstream interaction designers. Sounds rarely exist in isolation, so designers need to be able to represent the whole “soundscape” of an auditory display, including the direction and loudness of the different sound events and how the display changes over time. There is a simple equivalent for the quick sketch of a visual designer: vocal sketching is an effective approach for creating monophonic sounds using the human voice. There are issues with the length of sounds and breath as well as creating complex sounds and requiring multiple contributors for harmonies (Ekman and Rinott 2010; Tahiroğlu and Ahmaniemi 2010a; Tahiroğlu and Ahmaniemi 2010b). There are a small number of professional practitioners who can successfully create complex sounds and who are less limited by the length of breath required, although they predominantly specialise in animation for film, games and television (F. Newman, 2004). Giordano, Susini and Bresin (Giordano, Susini and Bresin 2013) point out that if continuous evaluation is required, then it is advisable for participants to listen to recordings as passive listeners rather than vocally sketch the sounds themselves. While a visual sketch remains fixed on the page, sound is temporal by nature, so it can be difficult to prototype a soundscape for user evaluation. It is, of course, easy to create and play a tune, or a sound effect, but even with current software, it remains difficult to present this in a way that designers can understand what it will be like when it is fully orchestrated and deployed as part of an overall user experience.

Our way of dealing with these issues is to visualize the soundscape, so that complex temporal data can be captured and analysed in order to highlight similarities and differences in listening experiences. Visualisations

can allow designers to view data quickly, identify problems and provide a consistent form of interpretation. Just as a web site designer will provide a wire frame of the design to get reactions from the clients, so we seek to provide a visualisation of a proposed soundscape design. This needs to capture the foreground and background sounds, the different types of sound, and of course the change of the soundscape over time. Allowing designers to use a visual form to represent a sound design allows them to validate their designs quickly and with confidence.

### Listening, soundscapes, and sound design

Listening and hearing are different (Handel 1989), and Szendy (Szendy 2008) tells us that we can choose to listen. Madell and Flexer (Madell and Flexer 2008) define hearing as the acoustic mechanism of sound being transmitted to the brain, whereas listening is the process of focusing and attending to what can be heard. Thus, listening is an active process comprising conscious choice and subjective interpretation of what is heard (Blessner and Salter 2007).

A soundscape can be defined as the surrounding auditory environment that a listener inhabits (Porteous and Mastin 1985; Rodaway 1994; Schafer 1977). The soundscape surrounds the listener and is an anthropocentric experience (Ohlson 1976). The definition has not been standardized, but there is on-going work to create an ISO standard in order to establish its definition, conceptual framework, as well as methods and measurements of its study (Brown, Kang and Gjestland 2011; Davies et al. 2013). There is no complete model of the soundscape, as interpretation is affected by the sounds which can be heard, the acoustic space which affects the sounds, and listeners' interpretations based upon what and how they are attending to the sounds (Davies 2013).

Luigi Russolo, as part of his 1913 Futurist manifesto, encouraged musicians to analyse noise in order to expand their sensibilities (Russolo, Filliou, Pratella and Press 1967). Granö differentiated between the study of "sound" and "noise" in 1929. He mapped auditory phenomena with reference to the "field of hearing" rather than "things that exist". Granö did not use the term soundscape; instead the concept of proximity was applied, which represented the area immediately surrounding an inhabitant (Granö 1997). The concept was revisited in 1969 when Southworth tried to establish how people perceived the sounds of Boston and how this might affect the way they experienced the city (Southworth 1969). Schafer (Schafer 1977) and Truax (Truax 2001) attempted to formalise the concept using descriptions derived from existing terms such as soundmarks, rather than landmarks. Schafer (Schafer 1993) argued that all soundscapes should be designed or regulated to display what he terms high-fidelity (distinct, easily interpreted sounds), rather than low-fidelity (indistinct, difficult to interpret sounds). Soundscapes and the individual sounds that make up a soundscape have been shown to have a physiological and psychological impact upon listeners (Cain, Jennings and Poxon 2013). Sounds that are considered unpleasant cause a reduction in heart rate, and pleasant sounds lead to an increase in respiratory rates (Hume and Ahtamad 2013).

The work of the sound designer is to create an aesthetic combination of sound events, to produce a soundscape that is informative and/or evokes an emotional response in the listener. For example, in film and other linear media, sound may be used as a sleight-of-hand, making the audience believe that something has happened (Chion 1994). Video game sound designers have adopted many of the techniques associated with film sound (R. Newman 2009), but have added interactivity so that some of the sound events are directly controlled by gamers' actions, whilst other sounds remain passively experienced within non-interactive sequences (Collins 2008).

Sound designers routinely manipulate the attributes of sound as part of their everyday practice. These include the sound's pitch, loudness, timbre (or overall quality of the sound), duration, and direction. For example, the length of a sound can be used to convey a character's emotions, such as a longer doorbell ring suggesting impatience (Kaye and Lebrecht 2000). The length of a silence (or lack of sound) can be useful to convey the passage of time or a change of location (Beaman 2006). Changing a sound's pitch can make objects seem larger or smaller or alter the age or gender of a character (Beauchamp 2005; Collins 2008). Spatial cues, such as panning, can provide an insight about what a character is attending to (Beck and Grajeda 2008; Kerins 2010).

In interaction design, designers of auditory displays are concerned both with sounds being considered informative as well as creating appropriate acoustical properties (Brewster 2008; Buxton 1989). For example, Gaver's Sonic Finder used auditory icons such as a scraping sound for objects being dragged across a computer desktop and a scrunching sound for putting a file in the wastebasket. Similar sounds are used on Apple's

operating system to this day (Gaver 1989). Microsoft's Outlook email client, in contrast, uses abstract earcons, such as a soft tinkling when an email arrives in the user's in-box.

### Classifying listening experiences

Before designers can present and evaluate their designs for sound events and soundscapes, they need to establish what characteristics of sounds are most important – in short, they require a vocabulary. Each researcher describes sounds from their own perspective: some focus on the spatial characteristics of sounds, others on the dynamics or the aesthetics, and others may include additional qualities such as whether a sound is a background noise. The following brief treatment of some key writers in this field offers a flavour of the resulting uncertainty.

Schafer (Schafer 1977), in one of the definitive treatments of sound, was concerned with a sound's estimated distance and its environmental factors such as reverberation. Gabrielsson and Sjögren (Gabrielsson and Sjögren 1979) identified the feeling of space and nearness associated with sound events, while Amphoux (Amphoux 1997) added orientation and reverberation. Hellström (Hellström 1998) tended this by proposing enclosure, extension, centre, distance and direction, and Mason (Mason 2002) highlighted the width, diffuseness and envelopment.

Attributes concerned with the dynamics of sound have also been highlighted: Schafer (Schafer 1977) focuses on the intensity of a sound, Gabrielsson and Sjögren (Gabrielsson and Sjögren 1979) identified loudness, Amphoux (Amphoux 1997) was concerned with scale, and Hellström (Hellström 1998) specified strong and weak dynamics.

Temporal attributes included duration (Schafer 1977), atemporality (Amphoux 1997), and rhythm (Hellström 1998). Spectral attributes related to both frequency and timbre, with Schafer (Schafer 1977) identifying the brightness or darkness and fullness or thinness of timbre. A full sound has a broader range of spectra, while a thin sound has a much narrower range. Hellström (Hellström 1998) focused on both pitch and timbre, and Mason (Mason 2002) referred to timbral frequency.

Aesthetics were considered by Gabrielsson and Sjögren (1979) and Amphoux (1997). Clarity was specified in terms of "hi-fi" or "lo-fi" environments by Schafer (1997) and as clearness and distinctness by Gabrielsson and Sjögren (1979).

This is by no means exhaustive. However, our own recent work in this area aims to simplify and clarify this diversity.

### What listeners hear

While sound designers can guide listeners by providing clues about what they should be attending to (Kerins 2010; Sonnenschein 2001), there has been relatively little work on directly comparing listener and sound designer experiences. There has, however, been much work distinguishing between musicians' and less experienced listeners' experiences in the field of psychoacoustics (Bharucha, Curits and Paroo 2006; Marie, Kujala and Besson 2012; P. M. Paul 2009). Listening tests have been conducted within product design for the last 50 years or more and involve experienced (trained) listeners (Engelen 1998; Frank, Sontacchi and Höldrich 2010; Soderholm 1998).

Rumsey (Rumsey 1998) tells us that there are high levels of agreement when participants are experts, whereas non-experts' responses are likely to vary more. Bech (Bech 1992) suggests that increasing the number of participants can improve the level of confidence in the findings. Yang and Kang (Yang and Kang 2005) highlight the differences between measurements and evaluations and how much they can vary, especially when it comes to different types of sound sources and levels of pleasantness. Listener testing is limited to products such as audio reproduction equipment and vacuum cleaners and has not migrated into mainstream media, and only partially into computing (Bech and Zacharov 2006). Tardieu, Susine, Poisson, Kawakami and McAdamas (Tardieu et al. 2009) found that laboratory tests of sound signals (earcons) do not fully correspond with tests conducted under real world conditions.

In a previous study, the authors attempted to establish whether listeners have the same listening experience as the person who designed the sound (McGregor and Turner 2012). Surprisingly, there was little evidence as to whether what is designed to be heard is what is actually heard. A repertory grid technique was adopted using

listener and designer generated constructs. One designer and 20 listeners rated 25 elements using the same attributes (descriptors) used in this study, within a surround sound recording created by a soundscape generative system. The listeners' modal response was compared to the designer's. The results suggested that it is perfectly feasible to compare designers' and listeners' experiences and to establish points of agreement and disagreement. The authors demonstrated an ontology of sound based on user experience rather than a designer's training, with an approach based upon long-term experiences and listeners' conceptualisation of sound.

### Visualising Soundscapes

We are, of course, not the first to propose visualizing sound and its attributes. The painter Wassily Kandinsky translated atonal music into canvases (Brougher and Zilczer 2005). Another artist, Roy de Maistre curated in 1919 the exhibition *Colour in Art* where the musical notes A to F were converted to colours (A = red), paintings were accompanied by music, and colour charts were made available for the audience (Alderton 2011). Gibson (Gibson 2005) displayed different frequencies using colour, as did Matthews, Fong and Mankoff (Matthews et al. 2005). Circles have been regularly used to represent sound and can be found in a variety of visualisation schemes (Azar, Saleh and Al-Alaoui 2007; Frecon, Stahl, Soderberg and Wallberg 2004; Helyer, Woo and Veronesi 2009). Servigne, Kang and Laurini (Servigne et al. 2000) proposed that the varying intensities of noise could be visualized by altering the radius of circles. Gibson also adopted this approach by indicating the volume of a sound in a mix by the object's size, with louder being larger than quieter. Shape has been used to designate the articulation of musical notes: legato = rounded, staccato = polygon (Friberg 2004).

Abstract shapes have also been applied to visualize phonemes that are not recognised by a phoneme recognition system, with high frequency sounds having spiky irregular forms (Levin and Lieberman 2004). Opacity has been used to a limited extent to communicate the volume or loudness of a sound event (Mathur 2009; Radojevic and Turner 2002; Thalmann and Mazzola 2008). Servigne, Laurini, Kang and Li (Servigne et al. 1999) suggested that graphic semiology would be appropriate for displaying sounds, proposing that smiling faces overlaid onto a map could be used to display a participant's preferences, a smile represented "nice", a neutral expression "neutral", and a frown "not so good". Bertin's 1967 theory of cartographic communication was used to create the visualisation. Bertin proposed that the visual variables of shape, size, value, orientation, hue, texture, x and y coordinates could be applied to point, line, and area symbols. Monmonier (Monmonier 1993) argued that Bertin's variables were also suitable for text, which could act as symbols within visualisations.

Figure 1 holds the set of symbols we have developed iteratively based on the literature highlighted above to represent the components of a soundscape (McGregor, Crerar, Benyon and Leplatre 2008; McGregor, Leplatre, Turner and Flint 2010). Each attribute of a classified sound event is visualised according to the symbols below, and then placed on a grid according to its perceived spatial location.

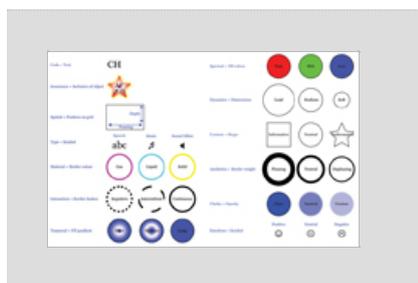


Figure 1: Symbols used for visualising sound events within a sound design

## 2. Method

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The same sound design can be experienced differently by listeners based upon their personal interests and training. Visualising soundscapes provides an insight into listeners' experiences so that they can be easily compared. To be effective for designers, the soundscape visualisations need to be applicable to a wide range of soundscapes, such as auditory displays, games, films, and so on. Accordingly, ten sound designers for different media were asked to design a soundscape that they would be interested in having visualised (see Table 1).

Listeners listen to a sound design, classify all of the sound events that they are aware of using the attributes shown in table 2, and then the results are collated and visualised to illustrate both the designer's and listeners' experiences.

Design	Description
01	Auditory Display (sounds to communicate information in electrical appliances)
02	Seismograms (game wave acceleration trace of racing team)
03	Simulation (nonlinear sequencing model of a multimedia lab)
04	Games sound effects (library file for commercially released console video game)
05	Short Film (independent film with music and sound effects only)
06	Soundscape composition (constructed composition to convey environmental context)
07	Radio Drama (manual sound effects created using physical props)
08	Audio logos (audio branding, music sound effects, and dialogue)
09	Composition (immersive abstract auditory environment)
10	Film sound effects (audio only sequence, vehicle, media, and musical sound effects)

Table 1: Summary of sound designs provided by the designers for visualisation

## Participants

Ten professional sound designers were recruited via email. They worked professionally in a variety of fields from interface design through to games, film, television and radio. The 100 listeners were either staff or students at Edinburgh Napier University. None of the listeners had previously taken part in a listening study before. The participants all considered themselves to be without hearing difficulties and ranged in age from early twenties to late fifties. Both male and female participants took part with a ratio of approximately 3:2.

## Materials

The ten sound designers were asked to supply a sound design that they would like to have visualised. The choice of design was left to the sound designer, and no guidance was given about length or complexity. The tests were conducted in a quiet office with stereo loudspeaker reproduction, except for design 9, which required a surround sound system located in an isolated, acoustically untreated room.

## Design

For six of the designs, participants were asked first to listen to the complete design and then classify the sound events. For the other four sound designs, participants were played short sections and asked to rate specified sound events based upon what they had just heard. The decision as to which approach was adopted was left to the designers. Questioning about the attributes of each sound event was conducted verbally, with listeners having access to the grid (for identifying spatial attributes) and the list of attributes (see Table 2). The classification itself was based on the principle of a common language, having been derived from a lexicon generated from descriptions used by participants to describe what they were listening to (McGregor, Leplatre, Crerar and Benyon 2006) and a questionnaire where audio professionals were asked for terms that they used to describe sounds (McGregor, Crerar, Benyon and Leplatre 2007). This meant that the resultant terms should be meaningful to both groups.

<b>Awareness</b>	Aware/Unaware
<b>Spatial cues</b>	x/y axis
<b>Type</b>	Speech/Music/Sound effect
<b>Material</b>	Gas/Liquid/Solid
<b>Interaction</b>	Impulsive/Intermittent/Continuous
<b>Temporal</b>	Short/Medium/Long
<b>Spectral</b>	High/Mid/Low
<b>Dynamics</b>	Loud/Medium/Soft
<b>Content</b>	Informative/Neutral/Uninformative
<b>Aesthetics</b>	Pleasant/Neutral/Displeasing
<b>Clarity</b>	Clear/Neutral/Unclear
<b>Emotions</b>	Positive/Neutral/Negative

Table 2: Attributes for classification

## Procedure

The procedure involved classification, visualisation, and a survey. The designers rated their designs based on the specified attributes and forwarded them for visualisation. Listeners then classified the designs using the same attributes, and the results were visualised.

Listeners were randomly assigned to each sound design until 10 participants had experienced each design. All of the participants were able to complete all of the tasks without prompting. The responses from the listeners were

collated, and the mode for each attribute was calculated for each sound event. The results were translated into two different visualisations. The first visualisation represented the designer's intentions, the second one the combined listeners' experiences. For this iteration the visualisations were generated manually. However, an automated version has been proposed, so that listeners and designers could create their own visualisations in the future. The results for all twelve designs are shown in the following section along with brief discussions.

### 3. Results

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Four case studies were chosen to highlight in order to illustrate the procedure. The remaining six designs are briefly reported in section 3.5. The experts' evaluation can be found in section 4.1.

#### Design 01: Auditory Display

Auditory displays have been defined by Kramer (Kramer 1994) as an interface between users and computer systems using sound and are considered a natural extension of the way in which sound is used in the physical world. Auditory displays differ from auditory interfaces in that they operate unidirectionally. An interface allows audio to be used as input as well as an output, but does not require audio to be used as an input, whereas a display provides only output (McGookin and Brewster 2004). Speech interfaces are a specialist type of auditory interfaces that are predominantly confined to speech (Raman 2012). Auditory displays can be split into the user interface audio and audio used in visualisation. User interfaces include earcons, auditory icons, sound enhanced word processors (text to speech), and other applications, whilst sound in visualisation includes audification, sonification, and auralisation (Vickers 1999).

The sound events for the auditory display had been designed for a large manufacturer of electrical appliances for a variety of their products (Audio 1). The designer recorded no spatial cues, as the sound events were tested in isolation rather than within products (see Table 3). The designer made limited use of the material and interaction attributes, recording this information for only 9 of the 32 sound events. However, all of the other attributes were applied (see Figure 2). The majority of the sound events were considered by the listeners to be *informative* (square) and *clear* (opaque) (see Figure 3). Three of the sound events that were considered to be *pleasing* by the designer were found to be *displeasing* by the listeners (border width). There is a clear difference between the designer's and listeners' classification of *music* (musical notes symbol) and *sound effects* (loudspeaker symbol), with the designer considering the majority of sound events to be *music*, possibly due to the prominent use of earcons, which are often considered to be musical in nature by designers. The listeners predominantly classified these sound events as *sound effects*. They considered the aesthetics of the sound events to be more evenly distributed than the designer, who considered more to be either *pleasing* or *displeasing*. The listeners also classified more sound events as *neutral* than the designer, who considered the majority to be *positive* (emoticons).



Code	Description	Code	Description	Code	Description
AA	Low Battery	AL	Washing Machine	AW	Teach SS
AB	Navigation Warning	AM	Power On	AX	Failure
AC	No Key Area	AN	Phone Music	AY	Notification
AD	No Signal	AO	Air-Refresh For GSM	BA	Low Battery Alert
AE	Power Off	AP	MP3 Beating Sound	BB	I'm calling you/Man
AF	Power On	AQ	Message Sring	BC	I'm calling you/Man
AG	Power On	AR	Message Music	BD	Warning Siren
AH	Routing Completion	AS	Message Music 2	BE	Warning Siren
AI	System Warning	AT	Message Knocking	BF	Warning Siren
AJ	Recharge Power On	AU	Phone Power On		
AK	Refrigerator Power On	AV	Phone Power Off		
AL	Air conditioner Power On	AW	Trouth SS		

Table 3: Key for figures 2 and 3

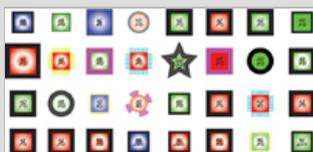


Figure 2: Designer's auditory display visualisation

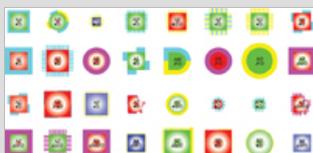


Figure 3: Listeners' auditory display visualisation

As an auditory display, the sound design might be regarded as successful, as 26 out of the 27 sound events that were classified as *informative* by the sound designer were also classified as *informative* by the listeners (see Table 4). Similarly, 31 sound events were classified as *clear* by the listeners. The 3 sound events that were rated by the listeners as *displeasing* (AR, AT and BD) along with the 2 that were found to be *uninformative* (AT and AX) might benefit from further review. The major difference in the listeners' and designer's rating of the auditory display was in terms of the sound events being considered as *sound effects* rather than *music* by the listeners. The similarities were far more prevalent, especially in terms of the Temporal, Spectral, Dynamics, Content and Clarity attributes. This might mean that listeners did not fully appreciate the hierarchical associations that are inherent in earcon design. Listeners may perceive each earcon as a separate sound effect, which would require them to learn each icon individually, rather than recognise musical similarities.

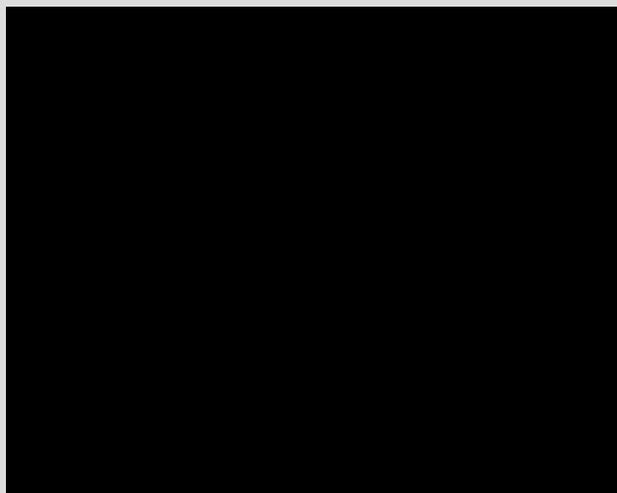
		Designer	Listeners
Type	Speech	3	8
	Music	25	4
	Sound effect	4	21
Material	Gas	3	8
	Liquid	2	13
	Solid	4	14
Interaction	Impulsive	6	16
	Intermittent	1	7
	Continuous	2	13
Temporal	Short	13	15
	Medium	15	14
	Long	4	3
Spectral	High	15	15
	Mid	13	18
	Low	4	4
Dynamics	Loud	2	7
	Medium	30	24
	Soft	0	3
Content	Informative	27	26
	Neutral	4	8
	Uninformative	1	2
Aesthetics	Pleasant	21	13
	Neutral	9	14
	Displeasing	21	13
Clarity	Clear	26	31
	Unclear	5	4
		1	0
Emotions	Positive	19	16
	Neutral	5	16
	Negative	8	4

Table 4: Summary of classifications<sup>[1]</sup>

## Design 02: Sonification

Sonification refers to a technique for transforming data into an audible stream that is analogous with data visualisation (Kramer et al. 1999). It can be argued that a sonification method must be objective, systematic, reproducible as well as suitable for use with different data (Hermann 2008). Data can be split into auditory streams where each stream is linked to a specific audio variable such as pitch, volume, note duration, fundamental wave shape, attack (onset) envelope, and overtone (harmonics) wave shape. This can make the data not only more informative, but potentially increase the amount of information that can be transmitted concurrently (Bly 1982).

This soundscape consisted of a 56 second video of an acceleration trace from a four man coxless rowing team sonified using a continuous tone that varied in pitch (Video 1) (Schaffert, Mattes and Effenberg 2010). The sonification is designed to help athletes improve their performance (see Table 5).



VideoObject1: Video 1: Sonification

The designer classified all of these sound events as *sound effects*, with values of *gas* for the material, *informative* for the content, and *clear* for the clarity attribute. Interactions varied from *impulsive* to *intermittent*, with a single instance of *continuous* (see Figure 4). The listeners were aware of all 8 sound events, and considered all but 1 to be *informative*. The listeners grouped the materials of the sound events into 1 *gas* (magenta border), 5 *liquid* (cyan border), 1 *solid* (yellow border), and 2 as both *liquid* and *solid* (see Figure 5). Listeners experienced a greater range of spectral attributes than the designer.

Code	Description	Code	Description	Code	Description
AA	Acceleration trace	AD	Front catch	AG	Front reversal
AB	Drive-phase	AE	Mid catch	AH	Back reversal
AC	Recovery-phase	AF	End catch		

Table 5: Key for figures 4 and 5



Figure 4: Designer's sonification visualisation

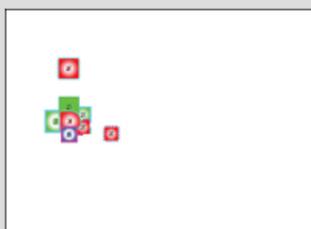


Figure 5: Listeners' sonification visualisation

The sonification could be considered as successful, as almost all of the sound events were considered informative, and listeners were able to distinguish between the differences in pitch (see Table 6). The range of pitch variation could be increased so that it extended into the low range and some form of panning might be considered, if only to move the sound events into the centre of the stereo field. The designer's and the listeners' ratings for Type, Dynamics, Clarity and Emotions were identical. The Spectral, Content and Aesthetics attributes only differed slightly. The main differences between the designer's and listeners' responses were with the Y axis (depth),

Material, Interaction and Temporal attributes. Whilst listeners found all of the elements informative they did experience the sound events as being further away, as well as sounding more *liquid* like than *gas*, and the Interaction being more *continuous* than *impulsive*.

		Designer	Listeners
Spatial	X	0	0
	Y	4	8
Type	Speech	0	0
	Music	0	0
	Sound effect	8	8
Material	Gas	8	3
	Liquid	0	7
	Solid	0	0
Interaction	Impulsive	4	3
	Intermittent	3	1
	Continuous	1	4
Temporal	Short	7	5
	Medium	1	2
	Long	0	1
Spectral	High	5	4
	Mid	3	3
	Low	0	1
Dynamics	Loud	4	4
	Medium	4	4
	Soft	0	0
Content	Informative	8	6
	Neutral	0	1
	Uninformative	0	0
Aesthetics	Pleasant	0	0
	Neutral	8	7
	Displeasing	0	1
Clarity	Clear	8	8
	Neutral	0	0
	Unclear	0	0
Emotions	Positive	0	0
	Neutral	8	8
	Negative	0	0

Table 6: Summary of classifications

### Design 03: Simulation

A variety of systems exist for simulating soundscapes and/or acoustical environments. The simplest is to record an auditory environment using a multichannel microphone or multiple microphones and then to reproduce the recording through multiple loudspeakers (Bertet, Daniel and Moreau 2006; Holman 2000). More complex interactive systems are available, where a sound designer records all of the original samples and composes, or creates, a set of rules and parameters for real time soundscape generation (Schirosa, Janer, Kersten and Roma 2010; Valle, Lombardo and Schirosa 2009). Procedural audio systems, where all of the sounds are generated artificially, are also available and are commonly found in video games (Farnell 2011; L. J. Paul 2010).

A 7 minute and 25 second simulation of the soundfield of a multimedia laboratory and its immediate environment was created for this soundscape (Audio 2). A soundfield can be defined as the auditory environment surrounding a particular sound source. A soundfield represents the quantifiable characteristics of a sound source or event (Ohlson 1976). The simulation was created using a non-linear sequencing model called GeoGraphy (Valle et al. 2009). GeoGraphy had previously been tested by comparing simulations with recordings from real environments and asking listeners to identify which was which. Each sound event is a single zone, and the descriptions represent the sounds that were used to create the zone (see Table 7).



The designer considered the content of 9 of the sound events to be *informative*, 5 *neutral* and 5 *uninformative*. These were visualized as in Figure 6, showing different shapes to represent the different content. Sound events such as the photocopier and the film were *informative*, the sounds of people's actions such as drying their hands or footsteps were *neutral*, and room tones were *uninformative*. Listeners were unaware of two of the sounds associated with the washing of hands (AJ and AK) (see Figure 7). The listeners thought that 14 sound events were *informative*, 1 *neutral* and 2 both *informative* and *neutral*. Listeners might have been trying to make sense of what they were listening to and constructing a narrative in order to understand the sequence of sound events. This could be attributed to the number of sound events that the listeners found to be *clear* (15), which contrasts with the designer, who rated 9 of them as *clear* and the remaining 10 as *unclear*.

Code	Description	Code	Description	Code	Description
JA	The opening of the front door	AH	The tonic of the laboratory, coinciding with ducts of the thematic station	AD	People at the staff talking with students
AB	The tonic (key-note) of the laboratory, coinciding with the sounds of personal computers.	AJ	A wash-basin, in the bathroom	AP	A staff member speaking with a student
AC	Keyboard and mouse of a pc.	AJ	A toilet in a bathroom	AQ	A tea-filler, someone walking in the passage, other noises, some steps, and air-con ducts
AD	Walking and speaking people	AK	Someone throwing a towel in a waste basket	AK	Sings in the passage and sounds emitted by aeration ducts
AE	Xerox machine	AL	The tonic of a laboratory, some servers, and wheels	AS	Shifting of a chair
AF	Drumming fingers on a desk	AH	A woman's voice on television		
AG	An auditorium, where a movie is projected	AH	The tonic of a laboratory, aeration ducts, and wheels of arch		

Table 7: Key for figures 6 and 7



Figure 6: Designer's simulation visualisation

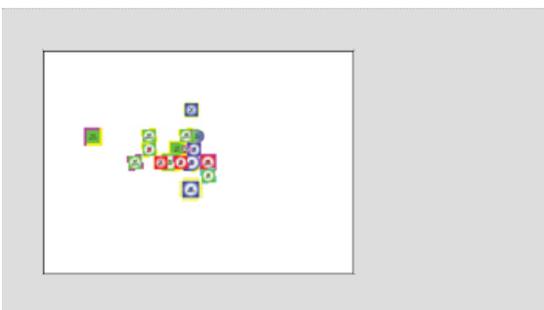


Figure 7: Listeners' simulation visualisation

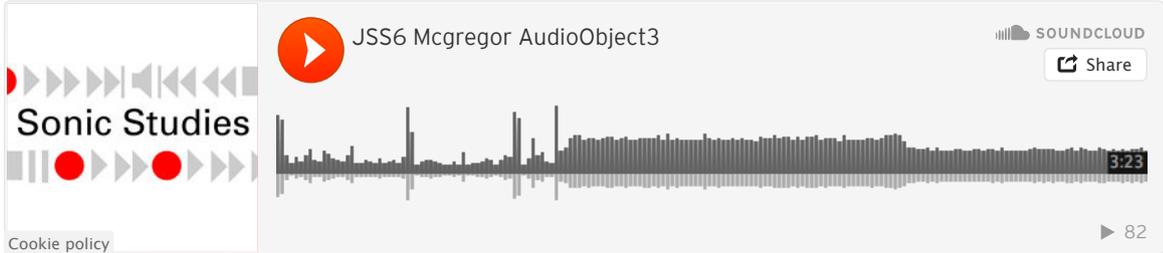
The sound types were consistent (see Table 8), with all of the sound events being categorized identically by both the listeners and the designer. Four of the sound events were considered to be *speech*, with the remainder (15) being *sound effect*. There were no instances of *music*. The designer considered the sound events to have a greater difference in dynamics: 7 were *loud*, 7 *medium* and 5 *soft*. The listeners found 3 to be *loud/medium*, 1 *soft*, and the remainder (16) *medium*. This might suggest that the variation in dynamics is too subtle and that a greater difference needs to be applied in order to convey the range intended by the designer. More sound events were considered *clear* and *informative* by the listeners than by the designer, which is probably due to the artificial nature of listening out of context. The Aesthetics and Emotions aspects of the sound design were not communicated effectively, with almost all of the sound events being *neutral*.

		Designer	Listeners
Awareness	Aware	19	17
	Unaware	0	2
Spatial	x	12	9
	y	6	9
Type	Speech	5	5
	Music	0	0
	Sound effect	14	12
Material	Gas	9	7
	Liquid	1	1
Interaction	Solid	9	12
	Impulsive	6	4
	Intermittent	8	7
Temporal	Continuous	5	6
	Short	5	2
	Medium	7	12
Spectral	Long	7	3
	High	2	4
	Mid	13	9
Dynamics	Low	4	6
	Loud	7	3
	Medium	7	16
Content	Soft	5	1
	Informative	9	16
	Neutral	5	3
Aesthetics	Uninformative	5	0
	Pleasant	6	3
	Neutral	5	12
Clarity	Displeasing	8	3
	Clear	9	16
	Neutral	10	2
Emotions	Unclear	0	0
	Positive	6	1
	Neutral	9	17
	Negative	4	0

Table 8: Summary of classifications

## Design 04: Game Sound Effects

The fourth design utilized sound effects used for a commercially released console video game. All of the sound events were part of a company’s sound library, for designers to use in the construction of games. Eight separate audio files were included; the shortest was less than 1 second long and the longest 1 minute and 19 seconds (Audio 3). Half of the files, which were all recordings of a female voice speaking single words, were single sound events, and the remaining 4 were atmospheric constructs with between 3 to 5 sound events (see Table 9).



The designer considered all of the 18 sound events to be *informative* (see Figure 8), and either *speech* or *sound effects*. Full use was made of the range of the remaining attributes. For the material attribute, *gas* was predominantly used to classify the voices, most of the “birds”, and some of the dogs. *Liquid* was consistently chosen for “water”, and *solid* was applied to “kiss”, “hit”, and some of the dog sounds. There was increased consistency for the Interaction attribute. The designer used *continuous* to classify only the water sounds, all of the birds were *intermittent*, and all of the voices were *impulsive*. Only the dog sounds were inconsistent, being either *impulsive* or *intermittent*. The majority (10) of the sound events were temporally *short*, only 3 were *medium*, and 5 were *long*. Atmospheric *sound effects*, such as the waterfall, tended to be temporally *long*, whereas *speech* was either *short* or *medium*.

The listeners rated only 12 of the 18 sound events as being *informative* (see Figure 9). Four were found to be *uninformative*, 1 was *neutral*, and 1 was both *informative* and *uninformative*, illustrating that there were contradictory responses. Each of the sound events classified by the listeners as *uninformative*, as well as the single *neutral* sound event, were *speech*. Three of these were also *unclear*, whilst the remaining 2 were *clear*. The designer regarded only 1 of the sound events as *unclear*.

Code	Description	Code	Description	Code	Description
JA	Female voice "Bye"	AD	Water	AM	Birds
JB	Female voice "Hello"	AE	Dog growl	AN	Waterfall
JC	Female voice "Goodbye"	AF	Dog barking	AO	Voice
JD	Female voice "Thank"	AG	Water	AP	Birds soft
JE	Dog growl	AK	Kiss	AQ	Birds high and loud
AF	Barking dog	AL	Hit	AR	Waterfall

Table 9: Key for figures 8 and 9



Figure 8: Designer’s game sound effects visualisation



Figure 9: Listeners’ game sound effects visualisation

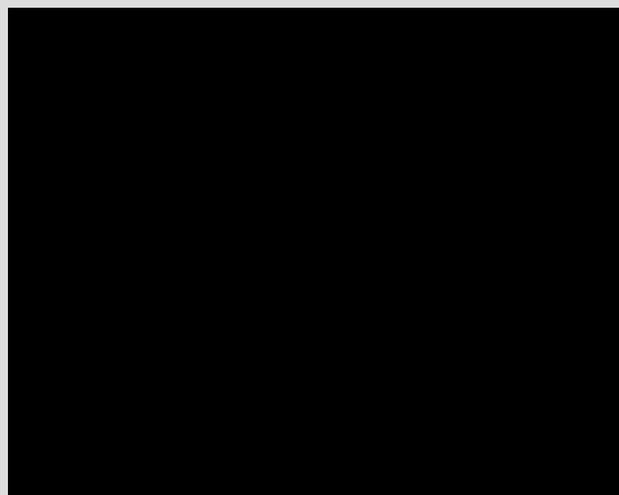
When considering the sound design as a whole, *sound effects* can be considered successful when they are informative and convey the required emotions accurately. There is a difference for the two groups with regards to *speech* (see Table 10). The emotions are not conveyed, being consistently considered as *neutral* by the listeners as well as predominantly *uninformative*. However, the designer judged them to be both *informative*, conveying either *positive* or *negative* emotions. This is perhaps due to a problem with the dialogue delivery rather than the sound design. More sound events were considered *clear* by the listeners than by the designer, which may be due to the artificial nature of the task, where sound events were listened to in isolation, without reference to a game.

		Designer	Listeners
Spatial	X	9	10
	Y	4	8
Type	Speech	6	5
	Music	0	0
	Sound effect	12	13
Material	Gas	8	2
	Liquid	4	4
	Solid	6	12
Interaction	Impulsive	9	8
	Intermittent	5	5
	Continuous	4	8
Temporal	Short	10	10
	Medium	3	1
	Long	5	8
Spectral	High	2	7
	Mid	12	6
	Low	4	7
Dynamics	Loud	4	7
	Medium	7	10
	Soft	7	3
Content	Informative	18	13
	Neutral	0	1
	Uninformative	0	5
Aesthetics	Pleasing	3	5
	Neutral	9	10
	Displeasing	6	4
Clarity	Clear	8	15
	Neutral	9	0
	Unclear	1	4
Emotions	Positive	8	5
	Neutral	4	10
	Negative	6	4

Table 10: Summary of classifications

### Other designs

Design 05 was a short film that had music and sound effects, but no dialogue (Video 2). The designer identified 45 sound events, but only 23 of these were recalled by the listeners (see Table 11). Twelve of the events that listeners were unaware of were classified as uninformative by the designer, but all the events that the listeners were aware of were classified as informative (18) or neutral (5) (see Figures 10 and 11).



VideoObject2: Video 2: Short film

Code	Description	Code	Description	Code	Description
AA	Room ambience	AP	Layered industrial at/citysc	SE	Layered multi-gun layered sounds
AB	Synth pad ambience	AQ	Steps on wet concrete	SF	Low frequency boom chime of the alarm
AC	Printer-like sound	AR	Punch	SG	Layered distorted and sound
AD	Typing	AS	Outdoors ambience low wind	SH	Distorted screen audio
AE	Typing confirmation beeps	AT	Crow	SI	Distorted electric guitar
AF	Drum sticks instrumental	AU	They are over there vocal	SJ	Processed reverse screen
AG	Bells instrumental	AV	Helicopter	SK	Breathring entering mask
AH	Leather clothing	AW	Dub music	SL	Touch of the mass
AI	Floor crash	AX	Distorted arriving jet	SM	Low frequency ambient pad
AJ	Steps on wooden floor	AY	Gas release	SN	Small bells sound
AK	Hoarse sweep	AZ	Distorted scratch	SO	Drum stick
AL	Horror flash noise	BA	Gun loading	SP	Touch mask
AM	Low frequency kick	BB	Gun shot	SQ	Beating
AN	Short "ta" vocal	BC	Multi-layered industrial ssssss	SR	Pulling the mass off
AO	Outdoor ambience	BD	Wind branches coming out of ground	SS	Big gong sound

Table 11: Key for figures 10 and 11

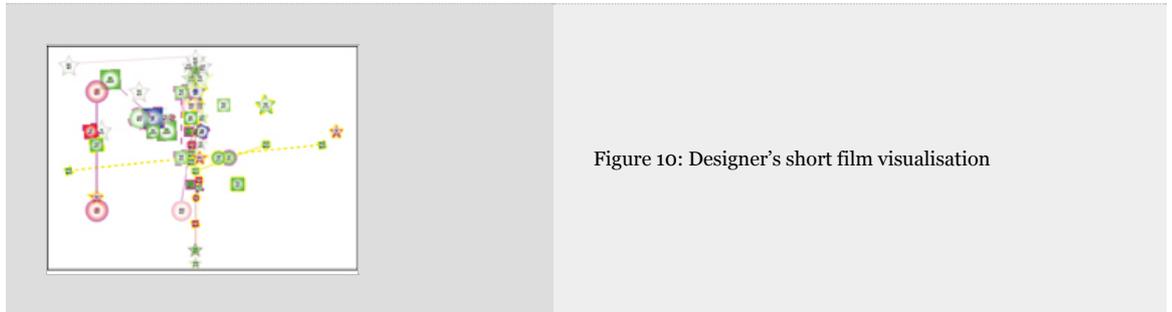


Figure 10: Designer's short film visualisation

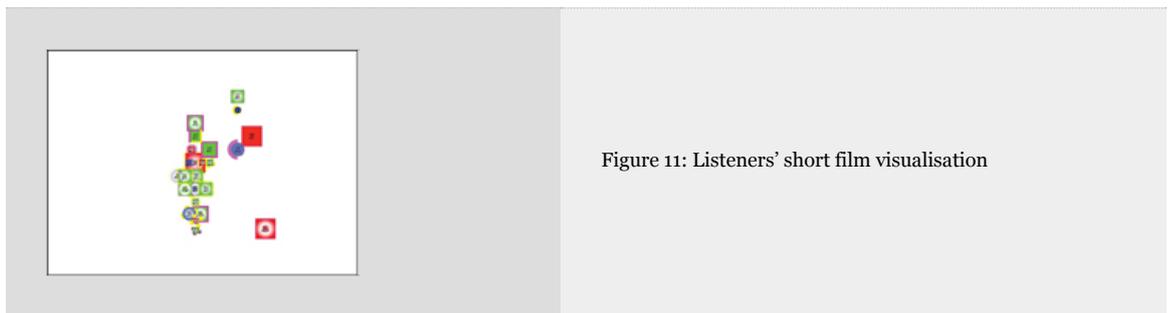


Figure 11: Listeners' short film visualisation

Design 06 was a 30 second soundscape composition, composed of a piece of music and sound samples of a person playing flute by a stream (Audio 4). The designer identified 15 sound events and made full use of the width and depth codes (see Table 12, Figures 12 and 13). The listeners were aware of 9 of the events and did not perceive such a wide spatial distribution. They combined the two pieces of flute music into a single sound event.

JSS6 McGregor AudioObject4

SOUNDCLOUD

Share

0:30

55

Code	Description	Code	Description	Code	Description
AA	Water trickling	AF	Type 3 Bird	AK	Slight leaf crunch
AB	Flute music A	AG	Odd chirp	AL	Big leaf crunch
AC	Flute music B	AH	Loud chirp	AN	Swirling disturbance (Airplane)
AD	Type 1 Bird	AI	Rock first hit	AO	Big disturbance (Airplane)
AE	Type 2 Bird	AJ	Rock bounce	AP	Far big disturbance (Airplane)

Table 12: Key for figures 12 and 13

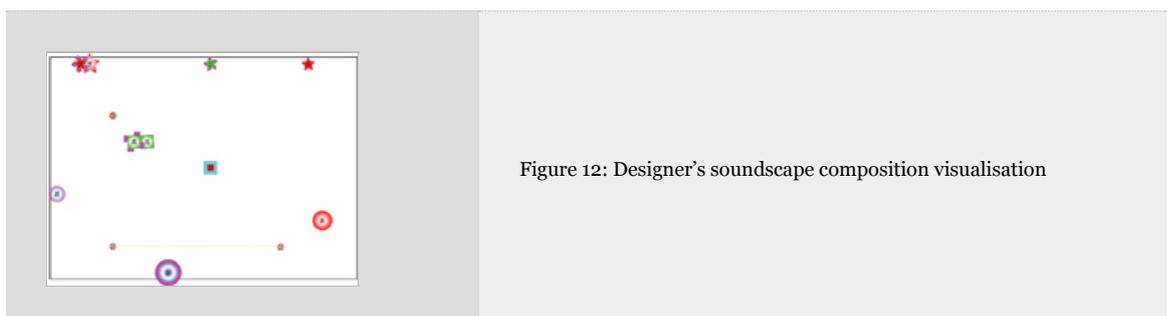


Figure 12: Designer's soundscape composition visualisation

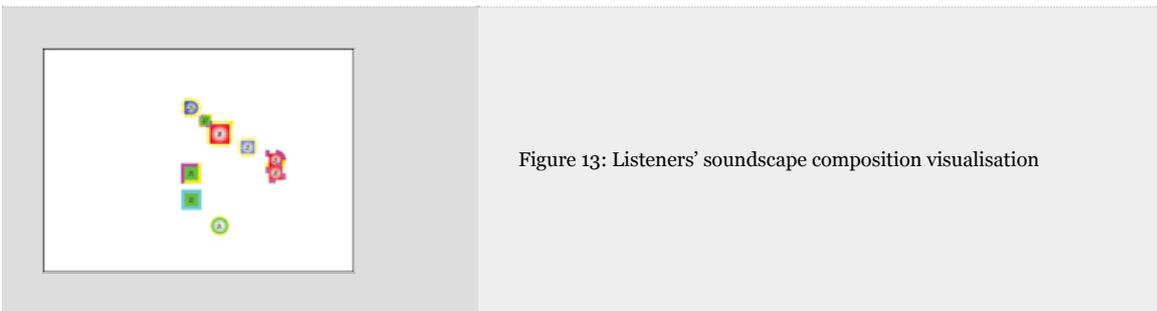


Figure 13: Listeners' soundscape composition visualisation

Design 07, a 42 second section from a radio drama, consisted of 14 sound events, 5 speaking characters, and 9 sound effects (Audio 5). One event identified as unclear by the designer was not noticed by the listeners, but otherwise they were aware of all the events (see Table 13, Figures 14 and 15). The characters were also classified in emotional terms, with the Aesthetics as being neutral, rather than pleasing or displeasing.



Code	Description	Code	Description	Code	Description
AA	Ringing bell (doorbell)	AF	Sid's voice	AK	Woman's footsteps enters
AB	Butler's voice	AG	Door closes	AL	Woman's voice
AC	Girl's voice	AH	Sid's footsteps	AM	Chetwood enters
AD	Butler footsteps	AI	Safe door jiggled	AN	Chetwood's voice
AE	Door opens	AJ	Tools put down		

Table 13: Key for figures 14 and 15

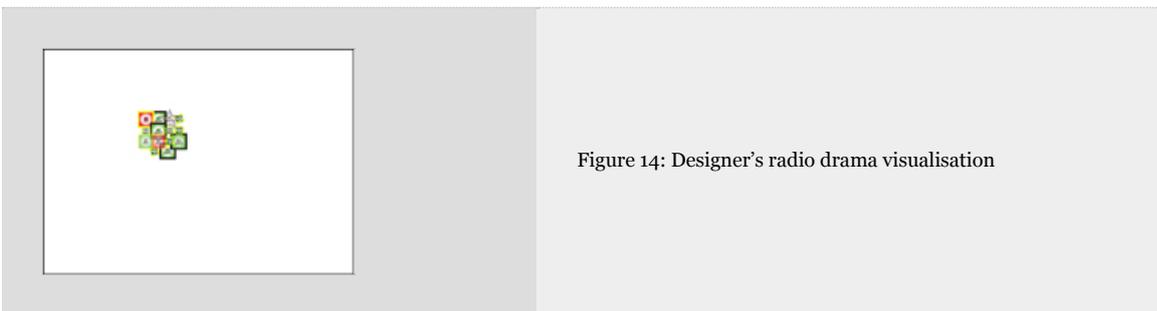


Figure 14: Designer's radio drama visualisation

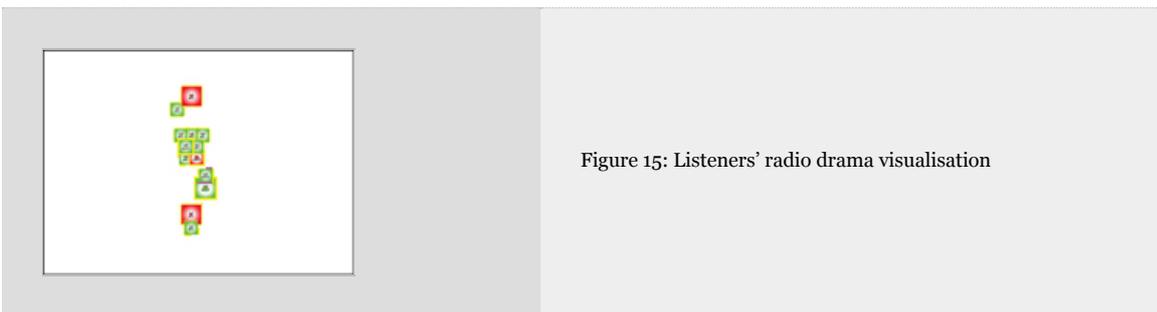


Figure 15: Listeners' radio drama visualisation

Design 08 was a set of audio logos (audio branding) that often form part of an advert; here the aesthetics, clarity, and emotional response were most important (Audio 6). The designer considered all but 4 of the sounds to be pleasing, whereas the listeners classified only 5 as pleasing (see Table 14, Figures 16 and 17). The outcome of this evaluation could be useful to feed back to the designers what people actually thought of the designs.

Code	Description	Code	Description	Code	Description
AA	Acoustic drum/lyriza door (Classical)	AF	Leather bass drum (Folklore)	AK	Voice "twaver" (Piano2)
AB	Pitched strings (Classical)	AG	Wood "twaver" (Folklore)	AL	Wood blocks (Piano2)
AC	Voice (Classical)	AH	Piano (Piano1)	AM	Leather bass drum (Piano2)
AD	Acoustic guitar (Folklore)	AI	Wood "twaver" (Piano)	AN	Piano (Piano 2)
AE	Classical guitar (Folklore)	AJ	Door (Piano 2)		

Table 14: Key for figures 16 and 17

Figure 16: Designer's Audio logos visualisation

Figure 17: Listeners' Audio logos visualisation

Design 09 was an abstract composition, included to see if the visualisations could be used for representing complex soundscapes (Audio 7). It was presented in surround sound to the listeners. There were 26 sound events, all classified by listeners and the designer as sound effects, and the listeners were aware of all of these (see Table 15, Figures 18 and 19).

Code	Description	Code	Description	Code	Description
AA	(0-7) opening rotary ice cascade	AJ	(21-22) background	AS	(104-106) rotary ice
AB	(8-7) intermediary ice cascade	AK	(23-27) ice cascade	AT	(108) thump
AC	(8-7) intermediary ice cascade	AL	(40-47) water flow	AU	(108-109) ice scrape pattern
AD	(27) pulsating ice cascade	AM	(40-47) rock back gesture	AV	(111) ice scrape deep gesture
AE	(9) ice click gesture	AN	(10-57) transition	AW	(112-113) ice bedrock
AF	(9-20) rotary ice cascade (to 10-10)	AO	(127-132) rotary cascade	AX	(122) rising
AG	(9-12) intermittent ice chunk activity	AP	(1-132) bearing	AY	(124) rising
AH	(20) closing scrape	AQ	(1-132) bass	AZ	(127-132) rising
AI	(23-24) tearing scrape open gate	AR	(1-132) intermediary ice cascade		

Table 15: Key for figures 18 and 19

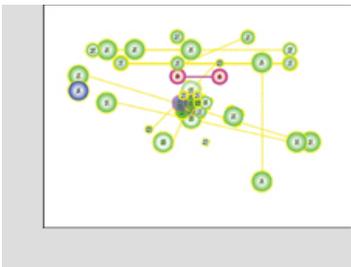


Figure 18: Designer's Abstract composition visualisation

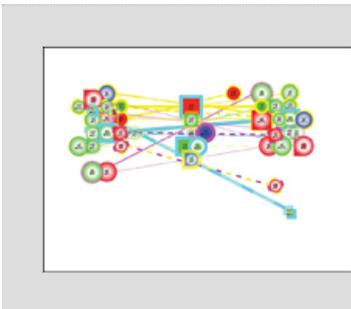


Figure 19: Listeners' Abstract composition visualisation

Design 10 consisted of a 30 second audio sequence of film sound effects (Audio 8). The listeners were only aware of 18 of the sound events out of a total of 32 (see Table 16, Figures 20 and 21). Listeners were *unaware* of all of the sound events that the designer classified as *soft*. However, it did not follow that listeners were *aware* of each *loud* sound event.



Code	Description	Code	Description	Code	Description
AA	Film Camera	AL	Game Zippo	AF	Quick Synthesizer
AB	Sci-Fi Hit	AM	Vintage TV Knob	AX	Alien Synthesizer
AC	Synthesizer Pad-Crystaline	AN	Processed Reverse Cymbal	AY	Building Transitional Ambient
AD	Fant. Whoosh	AO	Train Horn-Entry	AZ	Synth with wave movement
AE	Processed Reverse Cymbal	AP	Train-On Tracks-Fast	BA	Shaker modulating
AF	Hi-Hat-Gallop	AQ	Train Horn-Depart	BB	Shake modulating
AG	Processed Cymbal	AR	Scrape-Transition	BC	modulating
AH	Jet-Entry	AS	Hi-Ding	BD	Clipping Level 2
AI	Jet-Engine Pines	AT	Electric Synthesizer	BE	Clipping Level 2
AJ	Jet-Exit	AU	Guitar power chord	BF	Clipping Level 3 (LH)
AK	Pistol Flash	AV	Shining Synthesizer		

Table 16: Key for figures 20 and 21

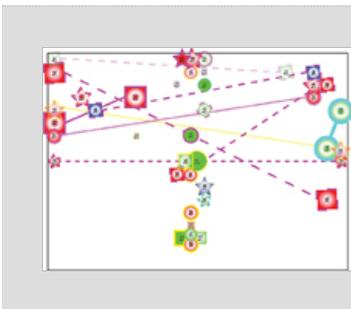


Figure 20: Designer's film sound effects visualisation

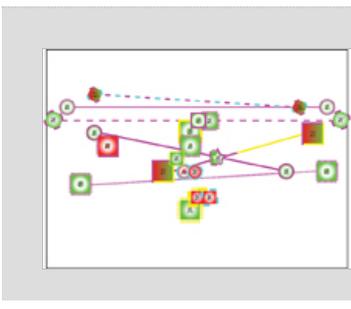


Figure 21: Listeners' film sound effects visualisation

In table 17 it is possible to see that a few of the attributes were rated similarly such as Type, Temporal, Spectral and Emotions. There were small differences in Material in relation to the rating of *liquid* and *gas*. There were pronounced differences in Interaction, Dynamics, Content, Aesthetics and Clarity. In terms of Interaction listeners rated more sound events as *continuous* than the designers. For Dynamics listeners tended more towards the mid value, whereas for Content listeners more often rated the sound events as *informative* than the designers did. Finally, listeners found a greater percentage of the sound events to *pleasing* and *clear* than the designers considered them to be.

		Designers		Listeners	
		n	%	n	%
<b>Type</b>	Speech	12	8%	9	8%
	Music	16	11%	12	11%
	Sound effect	115	80%	86	80%
<b>Material</b>	Gas	53	38%	35	31%
	Liquid	6	4%	13	12%
	Solid	79	57%	65	58%
<b>Interaction</b>	Impulsive	49	36%	49	40%
	Intermittent	53	38%	31	25%
	Continuous	36	26%	44	35%
<b>Temporal</b>	Short	71	50%	57	49%
	Medium	51	36%	38	33%
	Long	21	15%	21	18%
<b>Spectral</b>	High	45	31%	31	28%
	Mid	80	56%	64	57%
	Low	18	13%	17	15%
<b>Dynamics</b>	Loud	38	27%	31	27%
	Medium	70	49%	69	60%
	Soft	35	24%	15	13%
<b>Content</b>	Informative	56	39%	69	64%
	Neutral	52	36%	34	21%
	Uninformative	35	24%	5	5%
<b>Aesthetics</b>	Pleasing	14	10%	25	23%
	Neutral	102	71%	72	65%
	Displeasing	27	19%	13	12%
<b>Clarity</b>	Clear	95	66%	95	89%
	Neutral	21	15%	7	7%
	Unclear	27	19%	5	5%
<b>Emotions</b>	Positive	18	13%	18	16%
	Neutral	92	64%	74	65%
	Negative	33	23%	21	19%

Table 17: Summary of classification for designs 5-10<sup>[2]</sup>

## 4. Discussion

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Designers chose whether they wished the listeners to be able to listen only once or multiple times. When the listeners were able to listen repeatedly, they were aware of every sound, which led to a 100% positive score for awareness. Within the 6 designs that listeners could not listen to repeatedly there were a total of 144 sound events. Listeners were aware of 98 of the sound events, which represented a level of 68% awareness. Listeners were *unaware* of sound events that did not have a recognisable source, such as “synth ambience” in Short Film or “stretching in and out synth transition” in Film Sound Effects. Sound events that the designers considered *displeasing*, such as “bathroom sounds” in Simulation or “weird branches coming out of the mouth” in Short Film, also went unnoticed by the listeners. This lack of awareness might be due to the sound event being regarded as *uninformative* by the designer, for example “girl’s voice” in Radio Drama and “rock first hit” in Soundscape Composition.

Spatial cues were used by 9 out of 10 designers and are well reflected in the subsequent visualisations that show the differences between the designer’s intention and the listeners’ reactions. Listeners only perceived 2 of the designs as having motion (Composition and Film Sound Effects). They thought that the design with the greatest amount of motion was Composition, with 69% of the sound events being regarded as having motion. The designer of Composition considered 42% of the sound events to have motion. For stationary sound events, the designers used almost the entire X axis (panning) and the entire Y axis (depth). The listeners experienced slightly less panning and depth for the static sound events. For sound events that had motion, the entire X and Y axes were used by the designers. In contrast, the listeners experienced the entire range of panning but a lesser amount of depth.

The Type attribute (*music*, *sound effect*, *speech*) is quite intuitive. *Speech* was predominantly used to classify identifiable words or phrases by both the designers and the listeners, such as “I’m calling you (Man)” in Auditory Display or “Butler’s voice” in Radio Drama. *Music* was chosen for the most part when there was a clearly identifiable melody such as “dub music” in Short Film or “flute music A” in Soundscape Composition. *Sound effect* was used for a wide range of sound events; examples include “birds” in Audio Logos and “recovery phase”

in Sonification.

When classifying the Material attribute of sound events, *gas* was often chosen for sound events that involved the movement of air as in “the tonic (keynote)” of Laboratory, “the wheels of personal computers” in Simulation, or the “jet-entry” in Film Sound Effects. *Liquid* was predominantly selected for sound events such as the “waterfall” in Games Sound Effects and “water trickling” in Soundscape Composition.

For the classification of the Interaction attributes, *impulsive* was primarily used for percussive-type sound events, such as “message knocking” in Auditory Display, or “drumming fingers on a desk” in Simulation. *Intermittent* was chosen when sounds had a percussive element but had an underlying sustained element beneath it, as in the “dog growl” in Games Sound Effects or the “juddering anacrusis” in Composition. *Continuous* was applied when there was a sustained sound event without any obvious percussive elements; examples include the “room ambience” in Short Film and the “background ambience” in Composition.

Within the Temporal attributes, *short* was chosen for brief non-repeating sound events, such as the “poof flash” in Film Sound Effects or the “voice ‘xxxxx’” in Audio Logos. *Medium* was used when a sound event was of indeterminate length, neither *short* nor *long*; examples include “Sid’s voice” in Radio Drama and “sounds emitted by a key-holder while someone is walking in the passage, other noises, some steps, aeration ducts” in Simulation. *Long* was applied to extended uninterrupted sound events, such as “theme music” in Auditory Display or “water” in Games Sound Effects.

The Spectral attribute *high* was commonly applied to bright percussive sound events both natural and man-made; these included “loud chirp” in Soundscape Composition and the “front catch” in Sonification. *Mid* was chosen for sound events that fell between *high* and *low* as well as for sound events that had broadband spectral content. Examples of broadband content include the “distorted evolving pad” in Short Film and “jet engine fires” in Film Sound Effects. *Low* was selected for obvious bass content, as in “bass rumble” in Composition and “leather bass drum” in Audio Logos.

When Dynamics attributes were applied, *loud* was often used for short prominent sound events, such as “gunshot” in Short Film or “mid catch” in Sonification. *Medium* was chosen for moderate intensity sound events that provided context for a further action; examples include “gun loading” in Short Film and “safe door jiggled” in Radio Drama. *Soft* was used to classify gentle sound events that formed an auditory backdrop; examples include “background ambience” in Composition and “birds” in Audio Logos.

The most obvious examples of *informative* sound events for the Content attribute were those associated with warnings such as “low battery alert” in Auditory Display or “Ringing bell (doorbell)” in Radio Drama. *Neutral* was applied to sound events that were neither regarded as necessary nor unnecessary to comprehend the sound design. Examples include “chirping beeps 1” in Film Sound Effects and “big leaf crunch” in Soundscape Composition. *Uninformative* was retained for those sound events which were considered unnecessary, as in “leather bass drum” in Auditory Display or “voices” in Games Sound Effects, the latter of which was only *uninformative* from the listeners’ perspective.

Within the Aesthetics attributes, *pleasing* was predominantly applied to *positive* sound events that came from an acoustic source; examples include “birds high and loud” in Games Sound Effects and “classical guitar” in Audio Logos. *Displeasing* was often chosen for sound events that had negative associations, such as “dog growl” in Games Sound Effects or “distorted scream” in Short Film. *Neutral* was used for abstract sound events that had no physical analogue, such as “back reversal” in Sonification or “ripping detritus-drop” in Composition. The aesthetic ratings appear to be closely related to emotional responses rather than to whether a sound was considered beautiful.

Within the Clarity attribute, *clear* was often applied to explicit sound events that were foreground in the designs; examples include “the emission sounds of a television: a woman’s voice” from Simulation and “woman’s voice” from Radio Drama. *Unclear* was used for sound events that, whilst still audible, were difficult to discern, as in “female voice ‘Tomorrow’” from Games Sound Effects and “background ambience” in Composition. *Neutral* sound events were those which were regarded as neither *clear* nor *unclear*; examples comprise “rock bounce” from Soundscape Composition for the designers and “warning spearcon” from Auditory Display for the listeners.

In terms of the Emotions attributes, *positive* was applied when a sound event with obvious affirmative associations, such as “kiss” in Games Sound Effects or “success” in Auditory Display. *Neutral* was used when the

sound events were abstract; examples include “drive phase” from Sonification and “building transitional whoosh” in Film Sound Effects. *Negative* denoted sound events that were designed to have an unpleasant effect; these included “door” in Audio Logos and “Chetwood’s voice” in Radio Drama.

In general terms the designers’ responses were weighted towards the middle value in 5 of the attributes (Spectral, Dynamics, Aesthetics and Emotions) (see Table 17). Only one of the attributes (Material) had a value of under 10% (*liquid*, 7%) according to the designers. With regard to the listeners, 4 of the attributes had responses that fell below 10%: *music* (9%), *uninformative* (6%), *neutral clarity* (7%) and *unclear* (5%).<sup>[3]</sup> For 6 of the attributes, the internal ranking of responses was consistent between the designers and listeners, although the percentages differed. The 4 remaining attributes that did not have consistent ranking between the two groups were Type, Interaction, Aesthetics and Emotions, although the majority response was always the same. Listeners rarely rated any sound event as *music* unless it was exclusively musical; in contrast, the designers rated sounds that had musical elements as *music*. The contrast between the Material and Interaction interpretations could be a case of degrees of differentiation. Both *solid* and *impulsive* were interpreted reliably, but there was obvious variation in terms of *gas/liquid*. This could be an area where training is required to produce consistent differentiation. Some of the variation in responses for Clarity and Content may be due to listeners being asked to consider sound events in isolation, and being provided with descriptions rather than having to interpret what they were listening to without guidance. The differences in Emotions and Aesthetics might be due to the designers’ applying more subtlety in their sound designs than the listeners could interpret. The central weighting for Dynamics with listeners could be solely down to the reproduction apparatus, in that the designers had access to equipment with improved dynamic range. The consistency for Temporal and Spectral attributes may be down to an inherent familiarity, irrespective of training. In conclusion, all of the attributes were used by both the designers and the listeners, and as such appear to be suitable for describing soundscapes.

		Designers		Listeners	
		n	%	n	%
<b>Type</b>	Speech	26	12%	27	15%
	Music	41	19%	16	9%
	Sound effect	153	70%	140	77%
<b>Material</b>	Gas	81	42%	55	28%
	Liquid	13	7%	38	19%
	Solid	98	51%	103	53%
<b>Interaction</b>	Impulsive	74	39%	80	39%
	Intermittent	70	36%	51	23%
	Continuous	48	25%	75	36%
<b>Temporal</b>	Short	106	48%	89	46%
	Medium	77	35%	67	35%
	Long	37	17%	36	19%
<b>Spectral</b>	High	69	31%	61	31%
	Mid	121	55%	100	51%
	Low	30	14%	35	18%
<b>Dynamics</b>	Loud	55	25%	52	26%
	Medium	118	54%	123	62%
	Soft	47	21%	22	11%
<b>Content</b>	Informative	118	54%	132	69%
	Neutral	61	28%	47	25%
	Uninformative	41	19%	12	6%
<b>Aesthetics</b>	Pleasing	44	20%	46	24%
	Neutral	133	60%	115	61%
	Displeasing	43	20%	27	14%
<b>Clarity</b>	Clear	146	66%	165	88%
	Neutral	45	20%	13	7%
	Unclear	29	13%	9	5%
<b>Emotions</b>	Positive	51	23%	40	21%
	Neutral	118	54%	125	64%
	Negative	51	23%	29	15%

Table 18: Summary of designers’ and listeners’ application of attributes

In order to address the reliability of the attributes, we examined 120 conditions of which a small number (21) proved to be of interest (see Table 17).<sup>[4]</sup> When comparing designers’ and listeners’ responses, none of the attributes could be considered reliable for all of the sound designs, and interaction was not reliable for any design. However, for three of the sound designs there is a significant level of reliability for a limited number of attributes. There are two factors to consider. First, the method may not be reliable or valid: listeners and designers agree sometimes but not at other times, because the method is flawed in some way, the most obvious example being in describing interaction. Second, it is also possible that expert knowledge is very different from non-expert (Alves and Roque 2010; Cattell, Glascock and Washburn 1918; Kaufman, Baer, Cole and Saxton 2008), and we may be comparing apples with oranges – both fruit, but one is of the genus *Malus*, the other of the genus *Citrus*. What Table 18 shows is that in certain instances listeners’ and designers’ experiences can be compared with confidence, but that the scope is limited.

	Sonification	Radio drama	Audio logos
<b>Awareness</b>	x	x	x
<b>Spatial Type</b>	x	x	x
<b>Material Interaction</b>		x	
<b>Temporal</b>		x	x
<b>Spectral</b>		x	x
<b>Dynamics</b>	x		
<b>Content</b>	x	x	
<b>Aesthetics</b>		x	
<b>Clarity</b>	x		
<b>Emotions</b>	x	x	

Table 19: Attributes of interest<sup>[5]</sup>

Coleman (Coleman 2008) highlights the distrust that designers have for non-experts' descriptions of auditory environments. Audio professionals spend a considerable amount of time learning to shift between critical and natural listening. The visualisation allows a comparison to be made between designers' and listeners' listening experiences.

A simple comparison of the designer's soundscape map of the pre-existing environment with the listeners' illustrates where similarities and differences lie. Cross referencing what participants were aware of with all of the recorded sound events, highlights what was being attended to and what was ignored. The classification provides information about what the perceived events sound like, how relevant they are, whether they are pleasing, clear and what, if any, their emotional impact was. This informs the designer what is favourable and what is considered to be neutral or unfavourable.

### Expert Evaluation

A questionnaire was sent out to all ten designers with soundscape visualisations of their design. The questionnaire addressed classification, visualisation, and applications. Designers were asked to rate how important each attribute used in the soundscape visualisations was in order to compare sound designs with listeners' experiences. Designers were invited to choose the most appropriate way to display the audio attributes used in the classification. An adapted visual questionnaire approach was used, where each visualisation option was pictorially represented, using a check box to indicate choice. This was followed by their level of agreement with the statement that the "soundscape visualisation allowed me to compare a sound design with the experience of listeners". The questionnaire concluded with open-ended questions about what methods they currently employed to evaluate sound designs, how they could use this method, and suggestions for changes.

All ten designers completed the questionnaire; none of the questions were omitted. Seven out of the 12 audio attributes were considered to be either important or very important by 6 of the designers. A further 4 attributes were rated as important or very important by 5 of the designers, and only a single attribute (Interaction) was rated as being either important or very important by fewer than half of the designers. Awareness, Spatial Cues, Type, Dynamics, Content, Clarity and Emotions could be chosen as a reduced set of attributes for future visualisations.

The second part of the questionnaire asked designers for their preferred choice of displaying each audio attribute. Seven out of the 12 attributes had a single method of display chosen by the majority of the sound designers. Two of the methods of visualisation were chosen by all ten of the designers: the position on a grid for the Spatial Cues and symbols for the Type. A further 2 visualisation methods were chosen by nine out of ten designers: inclusion of object for Awareness and emoticons for Emotions. Opacity for Clarity, border dashes for Interaction and shape for Content were also chosen by more than half of the designers. There was no clear single choice of display for the remaining attributes Material, Temporal, Spectral, Dynamics, and Aesthetics.

A reduced set of 7 attributes has been suggested by the designers (Awareness, Spatial Cues, Type, Dynamics, Content, Clarity, Emotions), along with appropriate methods of display (see Figure 22). All but one of the

attributes (Interaction) were considered to be either “important” or “very important” by at least half of the designers, with 7 attributes being selected by the majority. All of the designers agreed that soundscape visualisation allowed them to compare a sound design with the experience of listeners.



Figure 22: Possible reduced set of attributes

## 5. Further work

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Although the ten sound designers who took part in the final study agreed that visualisation of the soundscape allowed them to compare a sound design with the experiences of listeners, further work has been identified. Research needs to be conducted on the internal validity of each attribute; these attributes will be tested individually in order to establish the correct scale and be provided with easily understood descriptors. The attributes associated with the physical properties of sound events, such as Spatial, Temporal, Dynamics, and Spectral might be expected to be more consistent across listeners than the more subjective attributes of Interaction, Aesthetics, Emotions, or Content. However, this was not always the case, which can be seen in the significant level of reliability for Content and Emotions in Sonification and Radio Drama.

Of the 7 attributes that are retained, 6 had a single method of visualisation chosen by the majority of the designers. There was only a low level of agreement for the visualisation of the Dynamics attribute, and varying the dimensions of the shape was chosen by only four out of ten of the designers. Alternative methods of displaying this attribute will be researched and trialled with designers.

Individual visualisations of each of the listeners' responses vary from being almost identical to disparate, with the majority being similar. The designers' intentions are not always markedly different from the listeners' experiences, as in Radio Drama and Sonification, where two thirds of the attributes are rated identically. In contrast, there are obvious differences between designers' intentions and the listeners' experiences for both Soundscape Composition and Auditory Display, with only a third of the attributes being rated identically. In order to identify if it is the act of design or the expertise of the designer that introduces the differences in responses, each designer could analyse the sound designs that they did not create themselves, and the results could be compared to the listeners' experiences.

The low level of agreement for Simulation and Auditory Display might suggest that greater levels of agreement may be achieved if non-experts were to design for non-experts, and experts designed for experts. However, it could also be argued that the approach might be used as part of an iterative design process, where experts become more attuned at designing for non-experts and adapt their designs accordingly. The similarity between the designers' and listeners' responses for Radio Drama and Sonification illustrate that responses are not always disparate.

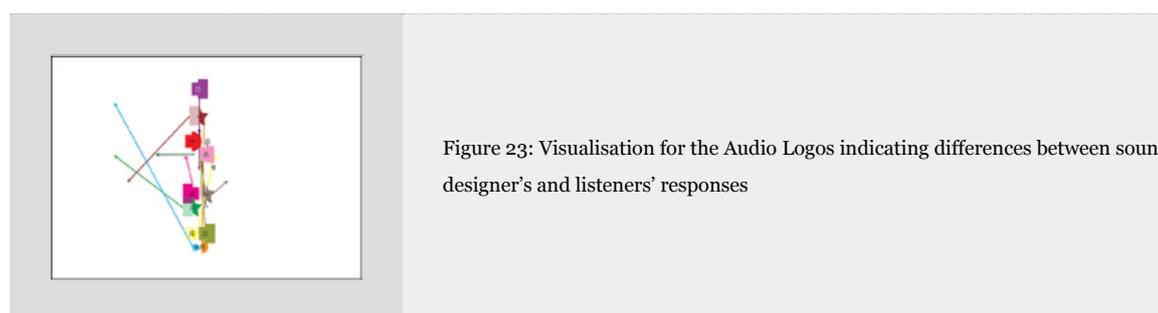
Studies will also be conducted to establish the most appropriate length and level of complexity for listeners to experience. There was not an easily identifiable relationship between length and complexity of a sound design

with regards to the level of awareness of sound events. A balance between reliance on listeners' memories and the level of awareness needs to be made.

A method of highlighting only the differences between a sound designer's intentions and the listeners' experiences within a single visualisation was suggested by one of the designers. A possible way of showing the differences on a single visualisation might be to overlay the listeners' responses onto the designer's, omitting all of the attributes that are identical, whilst still retaining the code in order to indicate the sound event's presence (see Table 19 and Figure 23). In this example, each sound event has been given a different colour in order to aid identification. The sound events are located on the grid according to the designer's responses, and the arrows indicate the positions according to the listeners. The designer's response is on the left hand side of each object, with the listeners' on the right.

Code	Description	Code	Description	Code	Description
AA	Acoustic country	AF	Leather bass drum	AK	Vocal "xxxxx" (Piano)
AB	Old jazz (Classical)	AG	Vocal "xxxxx"	AL	Wood blocks (Piano)
AC	Plucked strings (Classical)	AH	Piano (Piano)	AM	Leather bass drum (Piano2)
AD	Voice (Classical)	AI	Vocal "xxxxx" (Piano)	AN	Piano (Piano 2)
AE	Birds (Pikares)	AJ	Classical guitar (Pikares)		

Table 20: Key for figure 23



An alternative approach might be to convey the results through sound, either through a sonification or a sound design. A sonification that conveys agreement for each attribute could be running concurrently. If there is agreement, then there is no additional sound. If there is a differing response between designer and listeners, then an appropriate tone or alert could be played, according to the attribute. Another solution could be to alter the sound design according to the listeners' experiences. Attributes that represent physical properties of sound, such as Spatial, Temporal, Spectral, and Dynamics would be relatively easy to alter so that the design that more closely matches the listeners' experiences could be made available for the designer to experience. Awareness would be the easiest to convey, as it would only require the removal of a sound event. Attributes such as Emotion and Content would be more difficult to convey, however, through analysis of successful matches, it might prove possible to alter the sound design so that the designer can experience the listeners' perspective. Although the study contributes in general to the design of sound for any application, there are specialist applications which might benefit as well. These applications include those for the visually impaired, or mainly out of the user's view, without a screen, or in high performance environments in which the misinterpretation of audio cues might have serious repercussions.

The aim of this work is to enable sound designers to evaluate their designs' intended meaning with their listeners. In this paper we have reported on an evaluation of the soundscape visualisations, involving ten designers and 100 listeners. The study provided examples of how the visualisations could be used by designers to compare their intentions for a sound design with the experiences of listeners. The need to visualise sound designs has not been established in this paper, a method has merely been presented, and has not been compared to other forms of comparison. The ten designers who took part in the study all agreed that soundscape visualisation is an effective way of evaluating soundscapes for their sound designs. They proposed a number of modifications, the most important being the reduction in the number of attributes needed to describe the salient features of a sound event. Before any assessment about the suitability of visualisation for sound design in general is made, it is important to develop the method further and test it in a more systematic manner, as there is little evidence that the approach could describe a general range of sound design practices. Revisiting the work of authors such as Barrass (Barrass 1996), should help provide descriptors more robustly suited for the design of sonifications and auditory displays in general.

Research continues to refine the visualisations, based on the 7 attributes favoured by the designers. The reduction in the number of attributes should reduce the cognitive demand on those interpreting the maps, as the number of symbols has been reduced from 13 to 7. We hope that with a smaller set of attributes and clearer notation for the visualisations we can produce a method for the evaluation of soundscapes that could become a standard part of interaction design. At present, a sound design expert needs to draw the visualisations, but with the more focused set of attributes, tool support, and a database of sound design patterns, we are confident that the benefits of soundscape visualisation would be easily available to designers. We are of the opinion that using a visual form to represent soundscapes could make an interaction designer's job easier and more efficient.

## Notes

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1. "Awareness" and "spatial" were not recorded as the listeners were asked to listen until they were aware of each sound event prior to questioning. Listeners were also not questioned about the spatial aspects, as each sound event was presented in isolation, normally they are part of an appliance. Whenever awareness or spatialisation is missing from a table it is due to listeners not being questioned about the two attributes.
2. A full statistical analysis was not carried out at this stage as it was clear there were significant differences in responses and that the attributes should be tested individually in further studies. This point is mentioned as part of further work. A brief statistical analysis is reported below, and highlights where the results are significant.
3. As the Spatial attribute had more than three options it has been excluded from table 17.
4. For this we used the Fischer's exact test which is a measure of statistical significance used when the numbers involved are small. Designers' and listeners' responses for 12 of the attributes (excluding Spatial) were compared for each of the 10 sound designs, which resulted in 120 conditions.
5. It was expected that there would be a wide range of responses, and the surprise was that in certain conditions the results were so similar. The main purpose of the tool is to highlight differences so that designs can be improved, rather than confirming that a design is successful. Familiarity with content has been shown to alter what listeners attend to. The designs mentioned in this section were not discussed in depth as the focus of the paper is on highlighting differences in perception.

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