# EVALUATING A VEHICLE AUDITORY DISPLAY: COMPARING A DESIGNER'S EXPECTATIONS WITH LISTENERS' EXPERIENCES

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## **ABSTRACT**

This paper illustrates a method for the early evaluation of auditory displays in context. A designer was questioned about his expectations of an auditory display for Heavy Goods Vehicles, and the results were compared to the experiences of 10 listeners. Sound design is essentially an isolated practice and by involving listeners the process can become collaborative. A review of the level of agreement allowed the identification of attributes that might be meaningful for the design of future auditory displays. Results suggest that traditional auditory display design guidelines that focus on the acoustical properties of sound might not be suitable.

## Keywords

Auditory Display, vehicle, evaluation, listeners' experiences, designer's expectations

## INTRODUCTION

Sound is one of the easiest ways to augment any environment and has always been used as a method of communicating information (Delage, 1998). Yet the use of sound in human-computer interaction remains problematic. Brewster (2008) raised this issue, despite successful research into the use of non-speech sounds going back to the early 1990s. Sound design is not an expertise easily conveyed (James, 1998). Robare and Forlizzi (2009) highlight the lack computing sound design guidelines, despite the number of sound enabled products having increased dramatically since 2000.

Auditory displays have been defined by Kramer (1994) as an interface between users and computer systems using sound. Displays differ from interfaces in that they are mono-directional (McGookin & Brewster, 2004). Sound has long been used to convey information in vehicles, and researchers have emphasized the suitability of auditory displays (Hirst & Johnson, 1992, Graham, 1999, McKeown, 2005, Fagerlönn & Alm, 2010). Barrass and Frauenberger (2009) argue that designers need to consider the context of use, particularly given that the conditions in vehicles can be 'complex and dynamic' (Cao at al., 2010 p. 109).

## SOUNDSCAPE MAPPING TOOL

Watson and Sanderson (2007) tell us that an auditory display's effectiveness at communicating information should be evaluated according to its *context of use*. By context we mean the ambient auditory environment or soundscape (Schafer, 1977). The *soundscape mapping tool* (SMT) is a way of abstracting and visualising sound events that allows designers to represent designs, and listeners to record experiences (McGregor *et al.*, 2010). The SMT was developed and validated with groups of audio professionals and listeners (McGregor *et al.* 2006, 2007).

The SMT has three distinct phases, identification, classification and visualisation. The sound designer identifies sound events within a sound design, and/or soundscape. Both the designer and listeners classify the sound events according to a list of attributes (see Table 1). The results are then visualised by the researcher for ease of comparison by the designer.

Awareness	Aware/Unaware	
Spatial cues	x/y axis	
Type	Speech/Music/Sound effect	
Material	Gas/Liquid/Solid	
Interaction	Impulsive/Intermittent/Continuous	
Temporal	Short/Medium/Long	
Spectral	High/Mid/Low	
Dynamics	Loud/Medium/Soft	
Content	Informative/Neutral/Uninformative	
Aesthetics	Pleasing/Neutral/Displeasing	
Clarity	Clear/Neutral/Unclear	
Emotions	Positive/Neutral/Negative	
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Table 1: Sound event classification

The visualisation takes the form of a "map", the key of which is shown in Figure 1. Each sound event is given a code and is represented by a combination of shapes, colours and symbols that are overlaid onto a grid that captures where the listener heard the sound. If a sound event is heard to move during the recording, then the start and end points are both marked and joined.

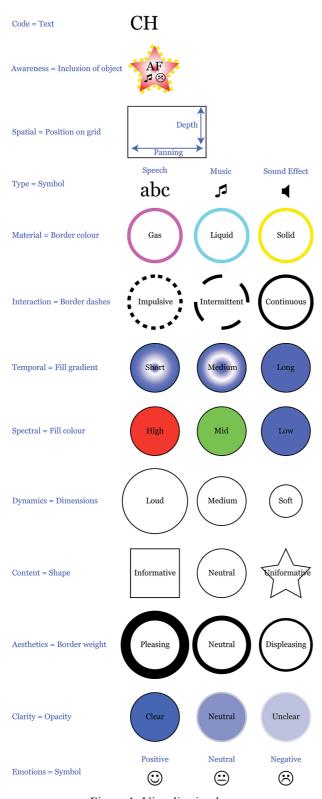


Figure 1: Visualisation key

# Method

## Participants

The designer (second author) and 10 listeners took part in this study. The 10 listeners were a sample of convenience made up from staff and students at Edinburgh Napier University.

## Materials

The designer made an 11 minute 41 second stereo recording of the auditory display within a moving Heavy Goods Vehicle (HGV). A professional driver was driving the truck with a co-driver, the designer was sitting in the centre on the back seat/bunk bed. The recording was made with a pair of electret microphones attached to the designers' spectacles. This near-ear microphone technique creates a partial binaural effect, improving distance perception and reducing *insidehead-locatedness* for listeners (Blauert, 1996).

#### Procedure

The designer supplied a list all of the sound events in the recording. The designer then classified what he had heard. Listener tests were conducted in a quiet office. The listeners were provided with fully enclosed stereo headphones. Listeners were asked to listen to an audio recording and answer questions about what they heard. The first author translated the tabulated information into soundscape maps.

#### Results

The designer identified 20 different sound events within the recording (see Table 2). Seven of the sound events were part of the auditory display (AD). The 13 remaining ambient sound events where either vehicle related (10) or people related (3).

Code	Description	
AA	windshield wiper	
AB	engine	
AC	tapping sound, "tick tick tick tick" (non- imminent message, e.g. new sms message)	
AD	warbling warning (p-brake)	
ΑE	Mech. of sound handbrake release or similar	
AF	Continuous ticking (tachograph)	
AG	Female speech (driver)	
AH	Male speech (co-driver 1)	
ΑI	Male speech (co-driver 2)(laughter)	
AJ	Four fast beeps (telling driver that they are not attending to the driving task appropriately)	
AK	windshield wiper loud scraping	
AL	"Beep beep Beep beep" (urgent warning, you need to go to the workshop within x km, or fix something with the vehicle)	
AM	Turn signal	
AN	Turn signal off	
AO	Car passing	
AP	Four sharp, fast beeps (lane keeping support, the vehicle is drifting out of lane)	
AQ	Fast turn signal sound 3x 2 ticks (is it broken?)	
AS	Beep beep-beep beep (driver is not attending to driving task appropriately)	
AT	Seatbelt fastening	

Table 2: Sound events

When the sound designer listened to the recording he did not identify four of the sound events but still classified them so that the results could be compared to the listeners experiences. The listeners were *aware* of

all of the sound events. The designer considered the sound events to be close and predominantly to his left (see Figure 2). A single sound event was heard to change locations (car passing). The listeners experienced the sound events as being farther away and predominantly to the left (see Figure 3). The listeners did not identify the movement of the car passing.

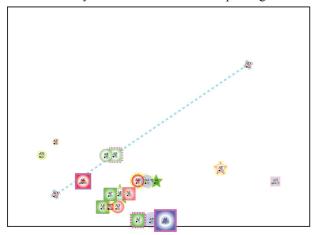


Figure 2: Designer's soundscape map

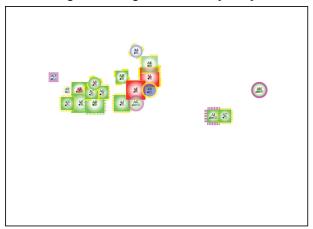


Figure 3: Listeners' soundscape map

Both the designer and the listeners classified all of the sound events except for three as *sound effects*. The vocalisations made by the driver, co-driver and designer were classified as *speech*. For the material attributes the designer considered all of the AD sound events to be *gas*. The listeners classified the AD sound events as predominantly *solid*. Mechanical vehicle sounds were mostly rated as *solid*. Within the interaction attribute, *impulsive* was applied to sound events such as the handbrake release, *intermittent* for the windscreen wiper and *continuous* for the engine. When listeners did not agree with the designer they tended to classify events as *intermittent* rather than *impulsive*.

There was a wider variation within the temporal attributes, only very short sounds were classified by both the designer and listeners as *short*. The turn signal was *medium* and the engine was *long*. There was little consistency within the spectral attributes. In general the

designer and listeners did not agree upon the classification of the dynamics attributes.

The listeners classified 15 out of 20 sound events as being *informative*, all of the remaining sound events were *neutral*. The designer's classifications were more evenly distributed: *informative* (9), *neutral* (7) and *uninformative* (4). The listeners classified all of the auditory display sound events as *informative*. For the aesthetics attribute none of the sound events were found to be *pleasing*. Only a single sound event (tachograph) was classified as *unclear* by both the designer and the listeners. All of the AD sound events were rated as *clear* by the listeners, with 14 out of the 20 total sound events being *clear*. The majority of the sound events were rated as having no affective content.

By looking at the level of agreement between the designer and the listeners' classification for the auditory display and the ambient sounds it is possible to identify attributes that might be of interest to designers. The attributes can be split into experience and physical properties. All of the experiential attributes (type, awareness, content, emotions and aesthetics) had a high level of agreement for the AD ( $\geq$ 71%), whereas the physical properties (temporal, spectral, interaction, clarity, material, dynamics and spatial) typically fell below 57%. Interestingly, the level of agreement over the content of a sound was low for ambient sounds at only 23% (see Table 3).

Attribute	AD	Ambient
Type	100%	100%
Awareness	86%	77%
Content	86%	23%
Emotions	71%	77%
Aesthetics	71%	77%
Temporal	71%	54%
Spectral	57%	31%
Interaction	43%	69%
Clarity	43%	38%
Material	14%	85%
Dynamics	14%	69%
Spatial	0%	0%

Table 3: levels of agreement

The type of sound had a 100% level of agreement for both the AD and ambient sounds. Agreement about awareness was high for both the AD and the ambience. The agreement between the designer and the listeners for the spatial attributes was 0%, which suggests that further work needs to be done on identifying an appropriate method for capturing spatial information. Responses were similar for the left and right orientation but there was a noticeable difference for the depth.

The level of agreement for the content was high at 86% for the AD but low for the ambient sound events (23%). Whilst this is an issue for describing sound events in general, the attribute is useful specifically for describing auditory displays. The inverse is true for the dynamics attribute where consistency is higher for ambient sound events (69%) than for the AD (14%).

#### Discussion

Fagerlönn & Liljedahl (2009) warn that end users may not feel confident enough to provide informed feedback about sound designs. Coleman (2008) highlighted the distrust that sound designers have for non-experts' descriptions. There are a number of issues to address. Accurate measurements of sound are difficult to achieve (Moore, 1997). Stopping and listening takes sound events out of context. Individual perceptions vary, making classification difficult (Porteous and Mastin, 1985). Perception includes 'stuff around the edges', context, background, history, common knowledge and social resources (Brown & Duguid, 2000)

Any method to capture the experience of inhabiting a soundscape will have issues with granularity. Balance must be achieved with gathering sufficient data, and overwhelming participants. Only limited time periods can be studied, as there are necessary time constraints for listeners' availability and fatigue.

The physical properties of sounds have been used for the stylised designs of sonifications and earcons. The finding of a low level of agreement of the physical properties of sound challenges the use of conventions in this area of sound design. Specifically, the wisdom of the use of guidelines to aid the design process of auditory displays should be investigated further.

This work demonstrated that the SMT was suitable for capturing the intentions of a sound designer and the experiences of 10 listeners. The trial also provided information about how the SMT could be developed further. This paper contributes evidence that auditory environments can be abstracted and visualised in a manner that allows designers to represent their designs, and listeners to record their experiences.

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