SOUNDSCAPE COMPOSITION AND RELATIONSHIP BETWEEN SOUND OBJECTS AND SOUNDSCAPE DIMENSIONS OF AN URBAN AREA

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Abstract

Previous studies of soundscape have tried to understand the relationship between sound objects and soundscape rating, resulting in the categorisation of general sound objects according to positive or negative perceptions. This study tries to determine the relationship and interaction between specific sound objects in a soundscape and the soundscape dimensions.

This study is divided into four steps: testing the validity of soundscape study in the laboratory, the application of soundscape recording, the development of a soundscape environment simulator, and the determination of the relationship between specific sound objects and soundscape dimensions according to expectations and preferences regarding sound objects.

The first step confirms three reliable soundscape dimensions from in situ and laboratory experiments (measured using the same semantic scales for both): Relaxation, Dynamics and Communication. It also confirms the validity of laboratory experiments compared with in situ ones. Furthermore, the effect of sound level adjustment on soundscape reproduction in the laboratory is investigated.

The second step, using soundscape recording, confirms that the common method of analysing the relationship between sound objects and soundscape rating (in situ experiment and soundscape reproduction) is not adequate due to limitations in the selection of sound objects and control over their parameters. A different method is proposed to deal with these limitations: using a soundscape environment simulator.

A soundscape environment simulator is therefore developed to understand the relationship and interaction between sound objects in a soundscape and the perception of the soundscape.

The soundscape environment simulator can be used to compose complex soundscapes. Furthermore, semantic differential analysis confirms that soundscape composition can represent an actual soundscape.

Finally, two experiments are conducted using the soundscape environment simulator to study expectations and preferences of sound objects in a soundscape. The study succeeds in explaining the relationship and interaction between specific sound objects and the rating of soundscape. Furthermore, a perception model regarding the preference of sound objects used in the soundscape environment simulator and the soundscape dimensions is developed and implemented in the soundscape environment simulator. This implementation allows the simulator to predict perceptions of the soundscapes composed by the simulator.

1 Introduction

Nowadays, noise measurement methods are still widely used to rate the sound in urban areas. Noise measurement methods only rate sounds according to noise level, without consideration of discrete sound objects (Hall, Irwin, Edmondson-Jones, Phillips, & Poxon, 2013). The soundscape method attempts to understand the perception of a soundscape from the interaction of the sound objects inside it, hoping to create a better auditory environment by using positive sound objects and working more with people's perceptions rather than simply the overall sound level measurement (Davies et al., 2007). Using the noise measurement approach, as long as the sound level of a soundscape exceeds a certain level, it will be considered an unpleasant soundscape. With the soundscape approach, however, the focus is on how people who use the space feel about the soundscape and their interaction with sound objects in the soundscape. Researchers have therefore begun to investigate the factors affecting the perception of soundscapes, and one of the factors being investigated is the interaction between sound objects and the rating of the soundscape (Hall et al., 2013).

A soundscape environment is formed by the sound objects inside it. Sound object in here is taken as a source of sound in a soundscape including behaviours (movement and position in space), distribution in time (event sound or background sound), sound level, and interactions with the environment. Some studies have tried to find the relationship between these sound objects and the perception of the soundscape as a whole (Axelsson, Nilsson, & Berglund, 2010; Brambilla, Gallo, Asdrubali, & D'Alessandro, 2013; Dubois, Guastavino, & Raimbault, 2006; Hall et al., 2013). These studies have grouped sound objects according to how they are perceived, and not how they affect the overall perception of the soundscape. In addition, the previous studies have not clearly defined which specific sound objects significantly affect the perception of a soundscape, nor how specific sound objects affect the rating of soundscape compared to other sound objects.

This study tries to understand the perception of urban soundscapes, especially the relationship between sound objects and the perception of urban soundscapes. The main questions of this study are:

- **How is the interaction between the sound objects and the perception of urban soundscapes?**
- **Which is the best method to understand the relationship between sound objects and the perception of urban soundscapes?**

The perception of soundscapes has been explained by using soundscape dimensions (Axelsson et al., 2010; Cain, Jennings, & Poxon, 2013; Davies & Murphy, 2012; Jeon, Lee, You, & Kang, 2012; Kang, 2007), but most of the studies implement different semantic scales. The different semantic scales raise a question: **Which soundscape dimensions are reliable to rate the perception of urban soundscapes?**

This study is conducted using laboratory experiment due to the repeatability. The laboratory approach should represent the result from the actual soundscapes and this approach triggers a question: **Can the laboratory experiment represent the actual soundscapes?**

The main aim of this study is to determine the relationship and interaction between specific sound objects in a soundscape and the soundscape dimensions of an urban area and to develop a system to help urban planners design soundscapes. The first goal of the study is to confirm the validity of the laboratory experiment and to determine the effect of sound level adjustment on the perception of soundscape reproduction.

A soundscape is the acoustic situation perceived by people, and studies have been done to define the type of perceptions evoked by a soundscape using soundscape dimensions (Axelsson et al., 2010; Cain et al., 2013; Jeon et al., 2012; Kang, 2007). Studies of soundscape dimensions are usually conducted using either in situ experiments (Adams et al., 2008; Jeon, Hong, & Lee, 2013; Jeon, Lee, Hong, & Cabrera, 2011; Jeon, Lee, You, & Kang, 2010; Liu, Kang, Behm, & Luo, 2014; Semidor, 2006) or laboratory experiments (Axelsson et al., 2010; Cain et al., 2013; Davies, Bruce, & Murphy, 2014; Guillén & López Barrio, 2007; Hall et al., 2013).

Although these studies have managed to define semantic dimensions, each of them implements different semantic scales. The implementation of different semantic scales makes it difficult to compare the in situ and laboratory experiments. A study to compare soundscape dimensions in both the real conditions and in the laboratory conditions using the same semantic scales has not yet been done, and the work presented in this thesis represents the first step toward such a study. A study that used the same scale would have the consistency to validate laboratory experiments and be able to determine reliable dimensions for soundscape rating measurement. These reliable soundscape dimensions could then be implemented to understand the factors that affect the perceptions of soundscapes in the laboratory compared to the actual condition.

The validity of the laboratory experiments versus the in-situ perceptions of soundscape dimensions is tested first, and then a series of experiments are used to determine the relationships between sound object dimensions. Furthermore, the effect of sound level adjustments on soundscape reproduction is also investigated. After the validity of the laboratory experiment is confirmed, the next step is to understand the relationship between sound objects and soundscape dimensions with a series of laboratory experiments.

Previous studies have shown the relationship between sound objects by grouping general sound objects according to how people perceive them (i.e. positively or negatively), but not according to how specific sound objects affect the perception of and the interaction between sound objects in the soundscape. This may be because it is not possible to control the selection of sound objects or their parameters in an in-situ soundscape recording. Another problem with the application of soundscape recording is that the ability to vary the soundscape with the same sound objects at different sound levels is limited. Although the application of soundscape recording seems to have problems, the soundscape recordings (reproduced using ambisonic reproduction systems) are considered to represent the actual soundscapes well (Catherine Guastavino, Katz, Polack, & Levitin, 2005). A study is therefore conducted in order to find out whether soundscape recording can be used to determine the relationship between specific sound objects and soundscape dimensions. This is the second aim of the study.

A novel way to determine the relationship between sound objects and soundscape dimensions is introduced with the help of a soundscape environment simulator. Essentially, by using the simulator, experiments can be conducted in which sound objects and their parameters are selected and controlled in a soundscape. Furthermore, this selection and control of the sound objects allows us to create a large variation of soundscape samples. Two different stages were introduced: the composition of the soundscape in the laboratory, and the application of a simulated soundscape.

The composition of the soundscape is performed to understand people's expectations regarding sound objects in a soundscape according to soundscape dimensions. This experiment is conducted in a soundscape environment simulator. A soundscape environment simulator is a system that allows us to compose a soundscape by selecting different sound objects and controlling their parameters. The third aim of this study is to develop and validate a soundscape environment simulator system that would enable researchers to compose complex soundscapes. The composition of soundscapes in the soundscape environment simulator permits the relationship between sound objects, sound objects' parameters, and soundscape dimensions to be determined based on the expectations regarding sound objects in a soundscape.

The application of a simulated soundscape consists in reproducing the soundscape composition generated by the soundscape environment simulator; participants are then asked to rate the composed soundscape. This method allows us to understand participants' preferences regarding sound objects in a soundscape. Furthermore, a comparison between their expectations and preferences regarding sound objects in the soundscape can be made. Previous studies of soundscape have examined either soundscape expectations (using a simple soundscape environment simulator) or preferences (using soundwalk and reproduced soundscape recordings), but not both. The fourth aim of this study is to determine the relationship between specific sound objects in a soundscape with respect to expectations and preferences, compare the difference between expectations and preferences, and identify the factors that account for the difference.

The outcome of this study is a description of the relationship and interaction between specific sound objects and soundscape dimensions in an urban soundscape. In addition, the significant sound objects that affect soundscape dimensions, along with how they affect these dimensions, is outlined in a model. The fifth aim is to implement this perception model in the soundscape environment simulator, so that perception ratings of composed soundscapes can be obtained automatically according to soundscape dimensions. This system will significantly help soundscape designers and urban planners to test soundscape design or ameliorate negative soundscapes.

The result of this study shows several contributions and novelties. The reliable soundscape dimensions to rate the soundscape has been determined. The validity of laboratory experiment and the effect of sound level adjustment of reproduced soundscape has been analysed. The soundscape environment simulator has been developed and validated to compose complex soundscape. The implementation of soundscape composition approach using soundscape environment simulator has become a new method that successfully explains the relationship between sound objects and soundscape dimensions. This study has attempted to explain the relationship between specific sound objects and the perception according to the soundscape dimensions. Furthermore, mathematical models, regarding the interaction between sound objects and soundscape dimensions, have been developed. The mathematical model has been implemented into the soundscape environment simulator, allowing the simulator to predict the perception of composed soundscape.

This thesis consists of eight chapters. **Chapter 1** is the introduction of the thesis; **Chapter 2** explains the literature review**. Chapter 3** verifies the steps and methodology in this study. **Chapter 4** scrutinizes the process of identifying reliable soundscape dimensions, the validity of the laboratory experiments, also, in this chapter, the effect of sound level adjustments on soundscape reproduction are explained. In **Chapter 5**, soundscape recordings are used to investigate and determine the relationship between specific sound objects and soundscape dimensions. **Chapter 6** describes the development of the soundscape simulator and its validity in representing an actual soundscape. **Chapter 7** explains the application of the soundscape environment simulator in investigating the relationship between sound objects and soundscape dimensions from the perspectives of expectation and preference of sound objects, as well as the application of this relationship in the soundscape environment simulator (allowing the simulator to give predictions regarding perceptions of soundscape compositions). **Chapter 8** concludes the finding and recommends the further works of the study.

2 Literature Review

The literature review begins by explaining **The Perception of Soundscape Environment** to summarise and determine the gap in the study of the soundscape perception. This part also describes the background and the problem in this study.

Next is the review about the approach of analysing soundscape (**Soundscape Analysis**), both the in- situ approach and laboratory approach. This part reveals the limitation of the method utilised by other studies.

This study is conducted by using laboratory approach, and the sub-chapter on **Soundscape Reproduction System Validity** tries to explain the selection and validation of the of the reproduction system. This section also describes how the sound level reproduction might affect the validity of laboratory experiment.

The **Soundscape Environment Simulator** sub chapter explains the development of soundscape environment simulator. This study tries to use soundscape composition to understand the relationship between sound objects and the perception of soundscape and the compositions are made using soundscape environmental simulator.

The **Soundscape Analysis Using Soundscape Composition** gives the argument why the composition method might be used to explain the relationship between sound objects and the perception of soundscape better than the previous method.

2.1 The Perception of Soundscape Environment

"Soundscape" is a term derived from the word landscape. The soundscape concept attempts to understand the sonic environment surrounding us (Schafer, 1977). According to ISO/DIS 12913-1, the definition of a soundscape is the "acoustic environment as perceived or experienced and/or understood by people, in context." The acoustic environment is the sound produced by sound sources from every direction, reshaped by the environment (International Organization for Standardization, 2013).

The soundscape concept tries to understand the positive aspects of our environment as perceived by people (Brown, Kang, & Gjestland, 2011), and is one of the concepts introduced as an alternative to annoyance measurement. The soundscape concept tries to analyse environmental sound not only by how loud it is (SPL measurement), but also by understanding the relations between sound sources, the environment, and the people who use the space.

Perception plays an important role in the soundscape. One of the important aspects of the conceptual framework of soundscape in ISO/DIS 12913-1 is the interpretation of auditory sensation (International Organization for Standardization, 2013). The soundscape concept tries to combine sound measurement techniques with human perception. Jennings and Cain introduce the concept of soundscape intervention with a combination of objective measurement and emotional dimension (Jennings & Cain, 2013). Process maps of urban design planning using the concept of soundscape have also been developed by Adams, and perception evaluation has become an important aspect (Adams, Davies, & Bruce, 2009). This perception approach could be seen as an improvement over traditional annoyance measurement (Brown et al., 2011).

The rating of a soundscape can be measured by analysing the cognitive factor. The cognitive factor is the overall impression generated by various individual attributes and can be measured using affect measurement (Bech & Zacharov, 2006). The cognitive factor is affected by various aspects such as people’s expectations, emotional state, context, or previous experiments.

Expectations play an important role in soundscape, and have been examined by Bruce and Davies (N. S. Bruce & Davies, 2014) . The expectations regarding sound objects in a certain location, as well as the events taking place there, influence whether a soundscape will be perceived as positive or negative.

Perception of soundscapes environment has been investigated using various techniques by Davies et al. (Davies et al., 2013), whose results suggested that the explanation of a soundscape can be constructed from its sound objects, sound descriptions, and soundscape description.

Dubois applied the semantic categories technique to study the meaning of a soundscape (Dubois, 2000). This linguistic study of noise indicates that people explain sounds contained in noise as the effect of sounds on them and as the event related to the sound source.

Sound objects in a soundscape are considered to affect the ratings of the total soundscape; for example, natural sound is believed to increase the perception of pleasantness (Axelsson et al., 2010; Brambilla et al., 2013), whereas human sound is considered to increase perceptions of eventfulness. The insertion of natural sound objects in landscape planning is also crucial to creating better soundscape (Liu, Kang, Luo, Behm, & Coppack, 2013). The occurrence of natural sound is also preferred as ambient sound in a soundscape (Marry & Defrance, 2013).

In contrast, mechanical or artificial sounds correspond with unpleasant ratings of a soundscape (Hall et al., 2013). The experiment conducted by Dubois et al., using a linguistic approach, indicates that mechanical sound is judged as worse than both natural and human sound (Dubois et al., 2006). The experiment conducted by Guastavino using sound object judgment indicates a similar result (Catherine Guastavino, 2006). The research using tranquillity ratings by Pheasant et al. also reveals that mechanical sounds have a negative correlation with tranquillity ratings (Pheasant, Horoshenkov, Watts, & Barrett, 2008).

Many approaches to creating a better soundscape have been analysed, such as masking mechanical sound objects with natural sound, or adding natural sound to a soundscape. An experiment to understand the effect of masking traffic noise with water sounds was conducted by Jeon et al. (Jeon et al., 2012). The study indicates that water sounds improve the rating of an urban soundscape in which traffic noise is the dominant sound. Although the water sounds could lead to better ratings of the urban soundscape, their impact might be indirect, affecting only the audibility of traffic noise (Axelsson, Nilsson, Hellström, & Lundén, 2014). Jeon et al. furthermore analysed the type of water sounds which are most suitable to masking urban noise (Jeon et al., 2010). Stream and lake-waves seem to be the most effective water sounds when the level of water sound is at, or not less than 3 dB below, the noise level. The addition of water sounds is significantly related to the dimensions of Freshness and Calmness (Jeon et al., 2012). The dimension of Vibrancy seems not to be much affected by the addition of water sounds.

Another natural sound that has been investigated to mask urban sound is the sound of birds. Bird sounds are considered to be a more preferred natural sound compared with water sounds (Hong & Jeon, 2013). Another study shows that biological sound, especially bird sounds, can increase the quality of the environment even when the soundscape is dominated by human-produced sounds (Liu et al., 2013). In addition, the presence of bird sounds also seems to make people feel more relaxed compared to a soundscape without them (Viollon, Lavandier, & Drake, 2002).

Another categorization of sound objects from an urban soundscape in Sheffield was performed by Liu and Kang (Liu & Kang, 2016). They categorised the soundscape based on the soundscape sentiment, the preference of sound objects, and the emotions related to sound objects. The sound objects can be categorised based on participants’ preferences (favourite or annoying sounds) or based on related emotions (joy, anger, sadness, despair, and fear).

The soundscape approach tries to include these perceptions in order to understand the relationship between the sound objects and the people who use the space, so a better soundscape can be created. Several types of research have been conducted into how people judge a soundscape and its sound objects, but the relationship between specific sound objects, the overall impression of a soundscape, and how the sound objects affect the rating of the soundscape remains unclear.

2.2 Soundscape Analysis

Soundscape can be analysed according to the preference of the soundscape or the expectation of the soundscape. The preference is "A greater liking for one alternative over another or others" ("preference - definition of preference in English | Oxford Dictionaries," n.d.). The expectation is "A strong belief that something will happen or be the case" ("expectation - definition of expectation in English | Oxford Dictionaries," n.d.). The preference method works to understand the perception of soundscape by giving a different alternative of soundscape while the expectation method relies on what people believe the soundscape should be.

The preference of soundscape analysis in-situ is usually conducted by a soundwalk (Adams et al., 2008; Jeon et al., 2013, 2011, 2010; Liu et al., 2014; Semidor, 2006), and in the laboratory by reproducing the soundscape (Axelsson et al., 2010; Cain et al., 2013; Davies et al., 2014; Guillén & López Barrio, 2007; Hall et al., 2013).

The expectation of soundscape tries to understand the soundscape based on the probability of the occurrence of sound source and the perception that might emerge according to the sound source (regarding the soundscape context)(N. S. Bruce & Davies, 2014). The expectation has been analysed by using focus group and soundwalk (to validate the focus group result)(N. S.

Bruce & Davies, 2014). Soundscape composition using soundscape simulator also has been proposed to understand the expectation of soundscape (N. S. Bruce, Davies, & Adams, 2009).

The soundwalk is an empirical method used to identify a soundscape and its sound objects in situ (Schafer, 1977). Semidor suggested that a soundwalk should be conducted more than once, in order to minimise the temporal change effect (Semidor, 2006). Time effects are an important aspect of soundwalks due to the fact that soundscapes are always changing.

Time effects can be controlled in laboratory conditions, because it is possible for each participant to listen to an identical soundscape recording, even though the laboratory condition might not simulate the audiovisual relationships of a soundscape. The perception of soundscape environment has a strong relationship to the visual aspect (Hong & Jeon, 2013; Jeon et al., 2011; R. Pheasant et al., 2008; R. J. Pheasant, Fisher, Watts, Whitaker, & Horoshenkov, 2010; Viollon et al., 2002), but a study conducted by Davies and Murphy indicates that laboratory reproduction could reproduce a soundscape with similar perceptions to outdoor conditions by using semantic differential analysis (Davies & Murphy, 2012).

Semantic differential analysis is a method commonly used to characterise the perception of a soundscape environment, and can be used to analyse both outdoor soundscapes (Kang, 2007), or reproduced soundscapes (Axelsson et al., 2010; Cain et al., 2013; Davies & Murphy, 2012; Jeon et al., 2012). Semantic differential analysis is usually used to measure meaning and the way meaning changes in human or social behaviour, and attempts to define different judgements with semantic points by analysing their direction and distance from the origin (Osgood, Suci, & Tannenbaum, 1957).

Semantic differential analysis is examined using the results of Principal Component Analysis (PCA)(Kang & Zhang, 2010), which is a method used to discover similarities and patterns in data (Jolliffe, 2002). Furthermore, PCA is used to identify how variables correlate with one another. PCA is used in Semantic Differential Analysis to understand how people relate the semantic scales to semantic dimensions, how the dimensions relate each other, and how the dimensions explain variation in the data.

Semantic differential analysis has been applied to characterise soundscapes with differing scales. Kang used twenty-eight scales to analyse soundscape, resulting in four factors that explain soundscape in situ: Relaxation, Communication, Spatiality, and, Dynamics (Kang, 2007). Using laboratory reproduction, Axelsson, Nilsson, and Berglund used 116 scales, resulting in three factors: Pleasantness, Eventfulness, and Familiarity (Axelsson et al., 2010). Cain, Jennings, and Poxon identified two factors from five scales in laboratory conditions using headphones: Calmness, and Vibrancy (Cain et al., 2013). Jeon, Lee, and You introduced three semantic dimensions in their study: Freshness, Calmness, and Vibrancy (Jeon et al., 2012). The first factor in all these studies (Relaxation/Calmness) seems to be similar, and related to the pleasure of the soundscape. The second factor also seems similar and related with the feeling of vibrancy, dynamics, and eventfulness. The other factors are more varied, due to the differences in the scales used and soundscapes studied.

Although there have been many studies related to soundscape dimensions, there is no study that compares soundscape dimensions using the same semantic scale for in situ and laboratory experiments. As a result, the perception differences between in situ experiments and laboratory experiments have been compared using unreliable dimensions (due to the implementation of different semantic scales); therefore, a study to determine reliable soundscape dimensions using the same semantic scale is needed in order to validate not only the soundscape reproduction system but also the laboratory experiment as a method of analysing outdoor soundscapes.

Some studies have been conducted in an effort to understand the preference of soundscape environment based on in situ experiments and laboratory experiments using soundscape recording. Although in situ and laboratory experiments are widely used, they do not provide an opportunity to measure the parameters of each sound object, nor to control the sound objects that occur in the soundscape. Soundscape composition using a soundscape environment simulator was introduced as a way to address these problems. Composition using a soundscape environment simulator could reveal information about the expectations of sound objects in a soundscape (Davies et al., 2014). By using a soundscape environment simulator, data regarding sound objects' parameters, such as their sound level and selection, can be obtained. Furthermore, the preference of soundscape can be investigated by reproducing the soundscape composed in the soundscape environment simulator.

2.3 Soundscape Reproduction System Validity

A soundscape can be analysed by reproducing it under laboratory conditions. Several sound reproduction systems have been analysed to reproduce soundscape in the laboratory. The validity of various systems for reproducing soundscape has been analysed with several methods. For instance, Guastavino and Katz compared the ability of a stereo system, an pantophonic system, and an periphonic system to reproduce soundscape in an anechoic condition (Catherine Guastavino & Katz, 2004). Five scales were applied for the experiment: Readability, Presence, Distance, Localization, Coloration, and Stability. The experiment confirms that an pantophonic system can reproduce the proper spatial aspects of a soundscape on the sweet spot, and is suitable for outdoor soundscape reproduction. The periphonic system was considered to be better than the others when reproducing indoor soundscapes.

Semantic categorization according to verbal responses was also used to analyse the stereo system, the ambisonic system, and the field study (Catherine Guastavino et al., 2005). Three response categories were used here: Source, Object-Centered, and Subject-Centered. The experiment shows that ambisonic reproduction in anechoic conditions with the speakers concealed from the view enabled the subjects to feel that they were in real locations.

Some studies have been conducted to validate soundscape reproduction systems with semantic differential analysis, as shown in **Table 2.1.** Most studies of soundscape reproduction were conducted using binaural headphones. Two dimensions are consistent across all the studies: one associated with a general impression of calmness and pleasantness; and the other associated with a feeling of vibrancy, dynamism and activity.

The other two dimensions, originally from a field experiment, are Communication and Spatiality (Kang & Zhang, 2010). These two dimensions recur in the laboratory experiment using the periphonic system, which showed similar dimensions to Kang's in situ experiment: Relaxation, Communication, Spatiality, and Dynamics (Davies et al., 2014).

Table 2-1 Semantic Differential Analyses of Soundscape Reproduction

Contributor	Reproduction System	Room	Soundscape Dimensions
(Kang, 2007)	In Situ	-	Relaxation (26%), Communication (12%), Spatiality (8%), and Dynamics (7%)
(Axelsson et al., 2010)	Binaural headphones	-	Pleasantness (50%), Eventfulness (18%), and Familiarity (6%)
(Cain et al., 2013)	Binaural headphones	-	Calmness (60%) and Vibrancy(20%)
(Davies et al., 2014)	Periphonic system	Semi-anechoic	Relaxation/Calmness (41%), Dynamics/Vibrancy(10%), Communication (7%), and Spatiality (7%)
(Guillén & Barrio, 2007)	4 speakers	Acoustically treated	Emotional Assessment and Strength Factor (42%), Activity (14%), and Clarity (10%)
(Hall et al., 2013)	Binaural headphones	-	Pleasantness, Calmness and Intrusiveness (24%); and Vibrancy and Informational Content (24%)

An ambisonic reproduction system is considered to be a better way to reproduce outdoor soundscapes based on the analysis using verbal responses and semantic differential analysis. Verbal response analysis using semantic categorization indicates that the ambisonic system is suitable to reproduce outdoor soundscapes, and semantic differential analysis demonstrates similar soundscape dimensions to the experiment conducted in situ.

The ambisonic system is a comprehensive method of audio recording, transmission, and reproduction to reproduce sound from all directions with psychoacoustic optimisation (Rumsey & McCormick, 2009). The development of this system was begun by Gerzon around 1970 with a four-channel recording system and tetrahedral reproduction system (Gerzon, 1971). Ambisonic systems attempt to record and reproduce the sound field in order to give a true impression of three-dimensional sound from loudspeakers (Malham, 1995).

Ambisonic recording was developed from Blumlein recording technique, using a pair of figure-of-eight polar pattern microphones (Rumsey & McCormick, 2009). The addition of an omnidirectional microphone truly coincident with the pair of figure-of-eight microphones means that the whole sound field can be recorded at any point in the horizontal plane. Height information is captured using a third figure-of-eight microphone orthogonally and vertically (Malham, 1998). This system is called B-format recording.

B-format recording technique is not practical for a few reasons: the microphones must be truly coincident, must have good frequency response, and have a similar frequency response at all frequencies (Ferrar, 1979). A-format recording was developed as an alternative. A-format recording is created from four channel signals from subcardioid capsules with tetrahedron orientation, as seen in **Figure 2.1**. The four channels are Left Front Up, Right Back Up, Left Back Down, and Right Front Down.

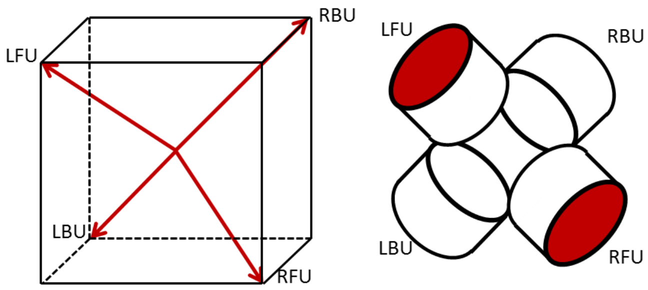


Figure 2-1 A-format Orientation

B-format recording consists of four channels (W, X, Y and Z signal), representing the pressure and velocity components of the sound field. B-format recording is made from three figure-of-eight components (X, Y, Z, components) and one omnidirectional component (W channel) as seen in **Figure 2.2.**

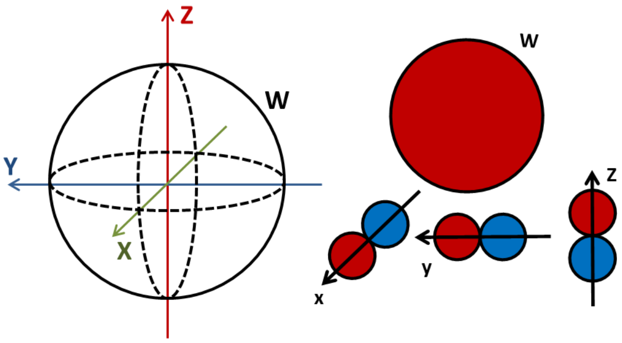


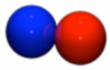
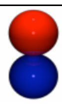
Figure 2-2 B-format Components

B-format signals can be recorded using three figure-of-eight microphones (facing the X, Y, and Z axes), and one omnidirectional microphone. B-format signal also can be derived from A-format signal (Benjamin & Chen, 2005) as shown in **Equation 2.1**.

$$
\begin{aligned}
W &= LFU + RFD + LBD + RBU \\
X &= LFU + RFD - LBD - RBU \\
Y &= LFU - RFD + LBD - RBU \\
Z &= LFU - RFD - LBD + RBU
\end{aligned}
\quad \textbf{Equation 2.1}
$$

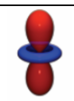
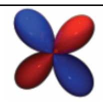
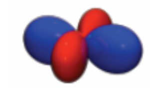
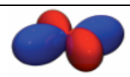
The ambisonic reproduction system was developed to accurately reproduce a sound field in a listening area from every direction (Branwell, 1983). Ambisonic reproduction is based on spherical harmonic decomposition with different orders (Gerzon, 1973). The simplest reproduction is first-order ambisonic, with sound-field sampling from three primary directions (X, Y, and Z) as seen in **Table 2.2**.

Table 2-2 0 and 1st Order Ambisonic Components (D. Malham, 1995)

Order	**Channel**	
0	W	
1	X	
	Y	
	Z	

The resolution of sound-field sampling can be increased with the addition of directional second order components, as shown in **Table 2.3**.

Table 2-3 2nd Order Ambisonic Components (D. Malham, 1995)

Order	Channel	
2	R	
	S	
	T	
	U	
	V	

The ambisonic reproduction system, especially in two dimensions, seems to be a better way to reproduce soundscape than the three-dimensional ambisonic or binaural systems (Catherine Guastavino & Katz, 2004). The binaural system is suitable for sound source identification, two-dimensional ambisonic (pantophonic) system is suitable for the reproduction of outdoor soundscape and the three-dimensional ambisonic (periphonic) system is suitable for the reproduction of indoor soundscape (Catherine Guastavino et al., 2005). Although comparisons between sound reproduction systems have been conducted, most of the research regarding soundscape reproduction does not consider the sound level adjustment of reproduction. Interestingly, it was found that participants tended to lower the sound level of sound objects in the simulation condition by -12.3 dB from actual levels (Davies et al., 2014). This sound level adjustment indicates that participants prefer the overall soundscape simulation to be reproduced at lower than actual levels. The effect of sound level adjustments on the perception of reproduced soundscapes should be analysed further, as this sound level adjustment may affect the validity of laboratory experiments.

2.4 Soundscape Environment Simulator

A soundscape environment simulator is a tool that allows people to create and manipulate the sound elements of a soundscape (N. S. Bruce et al., 2009). The simulator has the ability to include and exclude sound objects and to change the parameters of sound objects, allowing participants to compose a soundscape based on their expectations. The soundscape environment simulator developed by Bruce et al. (N. S. Bruce et al., 2009) uses the application Digital Audio Workstation (DAW) Controller and DAW software. There are three main components of this simulator: the DAW Controller, a computer running DAW software, and the audio interface and speakers.

Digital Audio Workstation is a system consisting of a computer with a soundcard/audio interface as well as audio software to manipulate and process multi-track digital audio (Leider, 2004). DAW software can implement an audio decoder to allow for variations in speaker set-up using Virtual Studio Technology (VST). VST is a system that enables integration between a digital audio processor and the signal in digital audio software (Steinberg, n.d.). A soundscape environment simulator uses an ambisonic decoder in VST format to reproduce soundscape in a room.

An ambisonic reproduction system is able to recreate the real acoustic conditions of the outdoor environment with neutral visual conditions (Catherine Guastavino et al., 2005). The neutral visual condition should be achieved by hiding the speakers from the subject’s view using a curtain.

The soundscape environment simulation, developed by Bruce et al., was created using the concepts of background and event sound objects which is grouped into cognitive categories

(N. S. Bruce et al., 2009). The categories were developed by Dubois, Guastavino, and Raimbault as part of their efforts to understand the meaning of soundscape by connecting perceptual categories and sociological representation (Dubois et al., 2006). There are two cognitive categories: Event Sequence and Amorphous Sequence. The event sequence is the sequence related to the specific event and the amorphous sequence which related with general event/background noise (Dubois, 2000; C. Guastavino & Dubois, 2006). The background sound object in the study, conducted by Bruce et al, is the sound objects representing the Amorphous Sequence while the event sound object is the sound objects representing the Event Sequence.

In this study, the background sound object is defined as the general sound object which occurs throughout the soundscape, for example, the sound of traffic noise, construction noise and hubbub. Also, the event sound object is defined as the specific sound event which might occur several times in the soundscape, for example, the sound of tram passing, trolley bag being pulled or footsteps.

Further development of the soundscape environment simulator could be done using the structured perspective in composing a soundscape. The perspective is divided into three parts: fixed perspective approach, moving perspective, and variable perspective (Truax, 2002). The fixed perspective approach considers a soundscape as a series of events in time; the moving perspective indicates the illusion of moving sound; and the variable perspective demonstrates several events that are present simultaneously. The structured perspective suggests the relationship between sound objects in a soundscape and the soundscape composer. This relationship and behaviour could be imitated using an object-oriented approach.

Object-oriented is a term used in programming that organises a program as several objects that include data structure and behaviour (Blaha & Rumbaugh, 2005). The object-oriented approach attempts to imitate situations in the world with a model (Cook & Daniels, 1994b). "A situation is a set of things and occurrences which describe some kind of activity in the world" (Cook & Daniels, 1994a).

The interaction between objects should be similar to the real-life condition. The identity of the data in the object-oriented approach is explained by the noticeable object. "An object is a concept, abstraction, or thing with an identity that has a meaning for an application" (Blaha & Rumbaugh, 2005).

In conclusion, the existing soundscape environment simulator was developed to enable the composition of simple soundscapes. The soundscape environment simulator could be developed further using background-event sound objects, the structured perspective in composing a soundscape, as well as the object-oriented concept to compose more complex soundscapes.

2.5 Soundscape Analysis Using Soundscape Composition

Most of the studies regarding soundscape use a preference-based approach. Two of the most common methods are soundwalk (Adams et al., 2008; Jeon et al., 2013, 2011, 2010; Liu et al., 2014; Semidor, 2006) and laboratory reproduction (Axelsson et al., 2010; Cain et al., 2013; Davies et al., 2014; Guillén & López Barrio, 2007; Hall et al., 2013). There are weaknesses in the application of the preference method: the selection of sound objects and parameters cannot be controlled, and the variability of the soundscape with the same sound objects is limited. A different approach to the analysis of soundscape based on participant expectations was therefore introduced, using a soundscape environment simulator that allowed participants to compose a soundscape themselves (Davies et al., 2014).

Soundscape composition may prove to be a major contribution to soundscape ecology (Truax & Barrett, 2011), by giving the audience a greater connection to environmental representation and improving understanding of the relationship between the listener and the environment. The soundscape composition method could be applied not only to representation of the acoustic environment but also to assimilating "abstracted sonic transformation" (Truax, 2002).

Soundscape composition could be an alternative to understanding perceptions of soundscape, based on participants' expectations and preferences. Expectations regarding sound objects in a soundscape could be analysed by allowing people to compose several soundscapes in the simulator, while preferences could be analysed by reproducing the soundscape composition in the laboratory.

Soundscape composition has advantages compared to both in situ experimentation and soundscape reproduction via recording, including the ability to control the selection and parameters of sound objects in the soundscape as well as the freedom to generate a great variety of soundscapes.

The soundscape composition approach can be implemented to understand the expectation of soundscape. Furthermore, by reproducing the soundscape composition, the preference of the soundscapes can also be determined.

2.6 Conclusion

The perception of soundscapes environment has been analysed using several methods to design a better soundscape. Many researchers have tried to understand soundscapes by judging them and categorising the sound objects in them as positive or negative. Despite these categorisations, the specific relationship between the sound objects in a soundscape and the overall impression made by a soundscape remains unclear. Furthermore, it is still not clear how certain sound objects affect the overall perception of a soundscape compared to the other sound objects present.

The overall impression of a soundscape can be derived based on soundscape dimensions measured by a semantic differential analysis. Semantic differential analysis is commonly used to categorise both outdoor and reproduced soundscapes. It can also be used to determine the type of impression that was made by the soundscape.

The relation between sound objects in a soundscape and the overall impression a soundscape makes can be analysed with in situ or laboratory experiments. Experiments in a laboratory can evoke different perceptions than experiments conducted at on-site locations, and as such, validation of laboratory experiments is needed. Some studies have validated soundscape reproduction in the laboratory by demonstrating that similar perceptions can be evoked by indoor and outdoor experiments. The problem is that the soundscape dimensions chosen for each of these studies were derived from different semantic scales, and there is no study that applies the same semantic scales to both its indoor and outdoor experiments. Therefore, there is a need for a study to determine reliable soundscape dimensions using the same semantic scale for indoor and outdoor experiment.

The pantophonic reproduction system seems to be a better approach to the reproduction of soundscape compared to the periphonic and binaural systems. Most of the studies regarding soundscape reproduction did not explore sound level adjustment, although one study in a soundscape environment simulator found that participants tend to lower sound levels to 12.3dB below the sound level measured in-situ. The effect of sound level adjustment should be analysed further to make sure that laboratory experiments can produce reactions that are similar to those produced by the actual condition.

Soundscape composition using a soundscape environment simulator may be an alternative way to understand the relationship between sound objects and the perception of overall soundscapes because it allows the selection and parameters of sound objects to be easily controlled.

Finally, the soundscape environment simulator can be used to compose a soundscape based on expectations, and this composition can be used to understand participants' preferences regarding sound objects in a soundscape. As the result, the relationship between specific sound objects in a soundscape as well as the dimensions of soundscape from the point of view of expectation and preference can be determined.

3 Methodology

There were three steps to this research, as shown in **Figure 3.1**: first, the investigation of a reproduced soundscape to determine the relationship between sound objects in a soundscape and the rating of the soundscape; second, the development of the soundscape environment simulator; and third, the development of a perception model of sound objects and soundscape dimensions.

In the first step, an investigation into soundscape reproduction in the laboratory and the implementation of reproduced soundscape was undertaken in order to understand the relationship between sound objects and soundscape dimensions. The second step aimed to develop a soundscape environment simulator that would enable the composition of soundscapes and the validation of the soundscapes composed with the simulator.

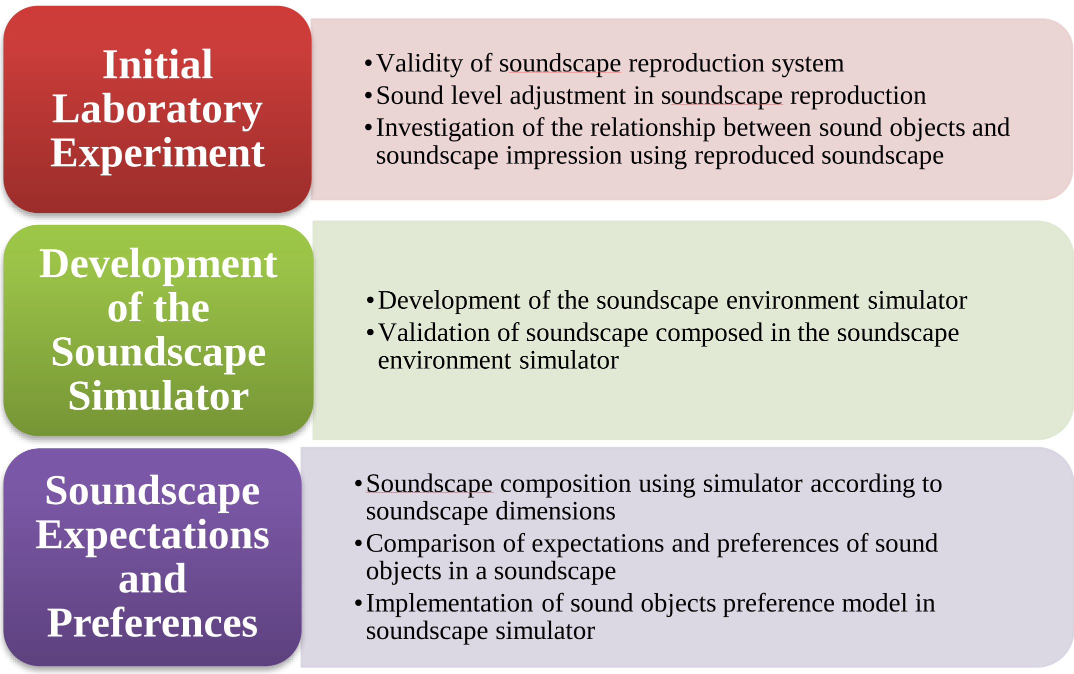


Figure 3-1 Research Steps

The final step aimed to understand the relationship between specific sound objects and soundscape dimensions by using the soundscape composition data. The relationship was evaluated from two points of view: that of the composer of the soundscapes, and that of the listener. The model that was developed based on this relationship was then integrated into the soundscape environment simulator so the simulator could predict perceptions (according to soundscape dimensions) of the soundscapes composed in the simulator.

3.1 Initial Laboratory Experiment

There were three aims in this step: first, to check the validity of the laboratory experiment; second, to determine reliable soundscape dimensions; and third, to use the reproduced soundscape to understand the relationship between specific sound objects in a soundscape and the soundscape dimensions.

The validity of the laboratory experiment was investigated by reproducing the soundscape with a pantophonic reproduction system and asking the participants to rate the soundscape using a semantic questionnaire. Ambisonic reproduction was selected based on the study by Guastavino that compared stereo, pantophonic, and periphonic systems (Catherine Guastavino et al., 2005) to reproduce soundscape in the laboratory. The sound level adjustment of the soundscape reproduction was also investigated in this step, because a previous study found that when using a soundscape environment simulator in the laboratory, participants tended to compose the soundscape at a lower level than that recorded in-situ (Davies et al., 2014).

Sound level adjustment was investigated by reproducing recordings of the soundscape in the laboratory and asking participants to adjust the sound to the level which represents the actual soundscapes. The sound level adjustment data were then used to reproduce the soundscape. Three experiments were then conducted: an in situ soundwalk, a listening test in the laboratory using a soundscape reproduced at the actual sound level, and a listening test in the laboratory using a soundscape reproduced at the adjusted sound level. All the experiments were carried out via a semantic questionnaire using the scales developed at the University of Salford (Davies et al., 2014). These scales are closely based on those of Kang (2007).

The analysis was conducted using the semantic differential analysis technique (N. S. Bruce & Davies, 2014; Jeon et al., 2012; Kang & Zhang, 2010, 2002). The soundscape dimensions from the in situ experiment, the laboratory experiment at the actual sound level, and the laboratory experiment with sound level adjustment were compared and analysed. The aim of the analysis was to understand the effect of the sound level adjustment on soundscape rating; to determine reliable soundscape dimensions for both the in situ and laboratory experiments; and to assess the validity of the laboratory experiment. This analysis is presented in **Chapter 4**.

After the validation of the laboratory experiment and the soundscape dimensions, the soundscape recording was used to understand the relationship between specific sound objects and soundscape dimensions. This relationship was measured by requesting that participants rate each of the sound objects in the recording as well as the overall soundscape according to the soundscape dimensions. This method was selected because measuring the sound level of each sound object in a soundscape recording is difficult. The results of this experiment are described in **Chapter 5**.

3.2 Development of the Soundscape Environment Simulator

The development and validation of the soundscape environment simulator is explained in **Chapter 6**. A soundscape environment simulator is a system that can design a soundscape in the laboratory by controlling the parameters of both background and event sound objects, allowing the user to compose a soundscape according to their expectations. Previous soundscape environment simulators were developed by simulate simple urban soundscapes

(Davies et al., 2014) and to imitate the sound of road and railway traffic (Lundén, Gustin, Nilsson, Forssén, & Hellström, 2010).

The soundscape environment simulator created for the present study was developed to incorporate the concepts of how people categorise sound objects in a soundscape as background-event sound objects (Dubois, 2000), the structured perspective in soundscape composition (Truax, 2002), and the object-oriented perspective. In addition, a pantophonic system was selected to reproduce the position and movement of sound objects.

The validation of the soundscape environment simulator was accomplished by reproducing the soundscape composed in the simulator and asking experiment participants to rate the composed soundscape using the same semantic scales as the experiments in step one. These results were then compared to the results from the in situ soundscapes.

3.3 Soundscape Expectations and Preferences

In the composition step, the interaction between sound objects and overall soundscape impression was investigated with respect to participants' expectations as expressed in their soundscape compositions. Participants could compose soundscapes using the simulator by selecting different sound objects and adjusting their position and sound levels to create particular impressions based on the soundscape dimensions. In addition, they were asked to rate their own soundscape based on the same soundscape dimensions used in the previous experiment.

Participants were asked to compose two different types of soundscape, one general and one urban, using the sound objects that had been recorded in various locations. They were also asked to compose soundscapes representing four perceptions: comfortable-simple, comfortable-varied, uncomfortable-simple, and uncomfortable-varied. An analysis was then undertaken to discover the relationship between the selection of sound objects, their sound levels, and participants' ratings of the soundscapes' dimensions.

Soundscape preferences were measured by asking participants to rate the soundscapes composed in the previous experiment. An analysis was then conducted to determine the difference between the ratings given to each soundscape by its composer and by participating listeners, as well as to develop a perception model that could explain the relationship between sound objects and soundscape dimensions.

The model developed in this step was then implemented in the soundscape environment simulator so that it could predict perceptions of soundscapes composed in the simulator. In other words, the simulator could then not only be used to compose a soundscape, but also to predict perceptions of soundscapes thus composed. The results of this step are presented in **Chapter 7**.

4 The Effect of Sound Level on Perception of Reproduced Soundscapes

4.1 Introduction

Audio reproduction systems are often used to recreate outdoor soundscapes in the laboratory for subjective testing. Several methods have been used to analyse the validity of various technologies in reproducing soundscape. For instance, Guastavino and Katz compared a stereo system, an ambisonic system on a horizontal plane (pantophonic system), and an ambisonic system with height (periphonic system) to reproduce soundscapes in an anechoic condition (Catherine Guastavino & Katz, 2004). Five scales were applied for the experiment: Readability, Presence, Distance, Localization, Coloration, and Stability. The experiment confirmed that a pantophonic system can reproduce proper spatial aspects of a soundscape when a listener is positioned in the sweet spot, and also that it is suitable for outdoor soundscape reproduction.

A different experimental method also validated the ambisonic sound system in reproducing outdoor soundscape in the laboratory (Catherine Guastavino et al., 2005). Semantic categorization based on verbal responses was adapted to compare soundscape reproductions by a stereo system and an ambisonic system with the actual condition. Responses were divided into three categories: source, object-centered, and subject-centered. The experiment showed that ambisonic reproduction in an anechoic condition with the speakers concealed from view enabled participants to feel that they were in real locations. Although the ambisonic reproduction system appears to offer better reproduction, many other experiments with soundscape reproduction were conducted using a binaural system (Axelsson et al., 2010; Cain et al., 2013; Hall et al., 2013).

Davies et al. conducted one of the studies of soundscape reproduction in the laboratory comparing an ambisonic system with the in situ condition, and obtained similar results according to semantic differential analysis (Davies et al., 2014). In their study, a periphonic system reproduced soundscape in a semi-anechoic chamber (Davies et al., 2014). Four perceptual dimensions were established from this experiment: Relaxation/Calmness, Dynamics/Vibrancy, Communication, and Spatiality. The perceptual similarity of their reproduction was confirmed by comparing their results with those of the field experiments in Sheffield (Kang, 2007). The dimensions gathered in the laboratory showed similar dimensions compared to the in situ experiment: relaxation, communication, spatiality, and dynamics. In other words, the periphonic playback system in the semi-anechoic chamber could evoke an impression much like the actual condition, even though information regarding the reproduction's sound level was not well defined.

Interestingly, in the previous work (Davies et al., 2014), it was found that participants tended to lower the sound level of event sound objects (not the overall sound level) in the soundscape environment simulator by -12.3 dB on average from the recording level. The soundscape environment simulator allowed participants to compose a soundscape by adjusting the sound level of each sound object in it. Although these sound level adjustments might indicate that participants prefer lower sound level reproduction, Davies's study did not analyse the overall reproduction sound level of a simulated soundscape or the effect of sound level adjustments on the perception of soundscapes reproduced in the laboratory.

As part of the present study, the validity of soundscape reproduction using a pantophonic system was analysed. Pantophonic reproduction obviously offers a much simpler set up than periphonic reproduction, while at the same time generating a better reproduction of outdoor soundscape (Catherine Guastavino & Katz, 2004). In addition, the overall sound level adjustment of soundscape reproductions, as well as how this adjustment affected the perception of soundscapes compared with actual conditions, will be analysed further.

4.2 Soundscape Recording

The soundscape was recorded using a soundfield microphone in Manchester city centre area. The Soundfield ST-250 microphone was used with a Roland R-44 digital recorder that recorded all four outputs (W, X, Y, and Z signal) from the microphone simultaneously. A wind shield was applied to the microphone to reduce wind noise. The recordings were taken over ten minutes at each location in a stationary position.

The Manchester city centre soundscapes were recorded at several outdoor locations: the National Football Museum, Exchange Square, New Cathedral Street, St Ann Square, Market Street, and Piccadilly Gardens. All of the recordings were made in February 2014 at lunchtime. Four recordings were selected for the experiment: Market Street as a representation of urban area without traffic noise; St Ann Square as a representation of urban area with natural sound objects (water fountain and bird chirping), Piccadilly Gardens as representation of urban area with traffic noise; and the food market at Piccadilly Gardens as a representation of urban area with masked traffic noise. Detailed description of recording's locations is shown in **Table 4.1**. A snapshot of each location is shown in **Figure 4.1**. The snapshots are indicative of the typical sound in each place: people walking and talking on Market Street; the water fountain at St Ann Square; a combination of people and urban traffic at Piccadilly Garden; and the sound of food stalls at the food market at Piccadilly Garden. Audio samples, two minutes long, were selected from each of recordings. The samples were chosen to represent each soundscape based on the completeness of the sound objects and a minimum of wind noise.

Figure 4-1 Snapshots of the locations: (a) Market Street, (b) St Ann Square, (c) Piccadilly Garden, and (d) Food Market at Piccadilly Garden

Table 4-1 Description of Recording's Locations

Locations	Descriptions	Dominant Sound Objects
Market Street	Outdoor shopping lane surrounded by two floors shopping building; selected because the space represents urban soundscape without traffic noise.	Hubbub, and live music
St Ann Square	Pedestrianised square; away from traffic; mixed use building around the space; two natural sound objects appear: water fountain and bird chirping; selected because the space has natural sound objects	Water fountain
Piccadilly Garden	Open public space; main bus and tram stops; selected because the space represents urban soundscape with traffic noise;	Live music, hubbub, and traffic noise
Food Market at Piccadilly Garden	Open public space; main bus and tram stops; busy food market; selected because in this space, the traffic noise is masked by the sound of hubbub.	hubbub, live music, and traffic noise

Four soundscape recordings were used in these experiments, and the Sound Pressure Level (SPL) measurements at each location are shown in **Table 4.2**. The SPL data were calculated from the W channel of the calibrated soundfield microphone. The data of L_{10} (the SPL surpassed 10% of recording time), L_{50} (the SPL surpassed 50% of recording time), and L_{90} (the SPL surpassed 90% of recording time) were also calculated from each recording. The noisiest location was Market Street (73 dB L_{Aeq}), and the quietest was St Ann Square (62 dB L_{Aeq}). The two recordings made in Piccadilly Garden have similar conditions, with a noise level of 70 dB L_{Aeq}.

Table 4-2 Noise Measurement of Recordings

	Market Street	St Ann Square	Piccadilly Garden	Food Market at Piccadilly Garden
L_{A10} (dB)	74	65	73	72
L_{A50} (dB)	73	62	70	69
L_{A90} (dB)	71	60	68	67
L_{Aeq} (dB)	73	62	70	70

4.3 Pre-Experiment to Determine the Number of Participants for Listening Test

The study about soundscape perception in this study was conducted in laboratory. One of the important aspect in the listening test is the number of participants for the experiment. This experiment seeks to determine the adequate number of participant for soundscape experiment in laboratory.

The experiment was conducted by reproducing soundscape using pantophonic reproduction system in a listening room. Thirty-three participants joined the experiment voluntarily. The entire participants are students of University of Salford who come from different ethnics (Indonesian, Pakistani, British, Italian, Indian, Iraqi, Chinese, Nigerian, and American). The age of the participants is between 20-33 years old with the mean age of 25 years old.

In this experiment, the participants were requested to listen to one soundscape and to rate the soundscape according to the semantic scales developed by Davies et.al (Davies et al., 2014). After rating one soundscape, they continue to assess the next soundscapes. The listening test was conducted individually and last for about 30 minutes.

4.3.1 Results and Conclusion

The data from this study is analysed by comparing the result of Principal Component Analysis (PCA) from a different number of participants. The PCA is analysed by using the data from 5, 10, 15, 20, 25 and 33 participants. The validation is examined according to the factorability of the PCA model, the number of components gathered, and the reliable components collected from the PCA.

The factorability measures if there are some correlations between the variables (related with the identification of coherent component). Factorability is determined by the parameter of Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity. The KMO Measure of Sampling Adequacy is bigger than 0.5, and Bartlett’s Test of Sphericity must be significant (sig. <0.05).

The components of PCA are determined according to the Eigen value (Eigen value>1). The minimum number of participants is determined according to the consistent components of the PCA.

The other factor to determine the minimum number of participants in the laboratory experiment is the reliable components from the PCA. The minimum number of participants must also is also decided by the number of consistent reliable components. The reliability of the component is analysed using Cronbach’s Alpha (Cronbach’s Alpha > 0.7).

The result of the PCA using a different number of participants is shown in **Table 4.3**. The table shows that the good factorability is achieved with the minimum of ten participants. The PCA using five participants shows the value of KMO bellow 0.5 which indicates bad factorability.

Table 4-3 Principal Component Analysis with Different Number of Participants

No	Number of Participants	KMO	Sphericity	Components extracted	Reliable Components
1	5	0.181	0.000	4	3
2	10	0.678	0.000	6	2
3	15	0.731	0.000	5	2
4	20	0.807	0.000	5	2
5	25	0.829	0.000	5	2
6	33	0.863	0.000	5	2

The reliable components are consistent (two components) with the minimum data from ten participants. When the data from five participants are used in the PCA, three reliable components emerge while two reliable components appear when using the data from more than ten participants.

The component extracted from the PCA (eigen value >1) become consistent with the data from more than fifteen participants. Five components are extracted from the PCA with more than fifteen participants.

According to the factorability of the PCA model, the number of components extracted from the PCA and the number of reliable components, the minimum participants for laboratory experiment are fifteen participants. This result is used to decide the number of participants for the experiment in this study.

4.4 Experiment

Three experiments were conducted to verify the validity of soundscape reproduction in a room. The first was conducted in a listening room at the University of Salford, United

Kingdom. The second was performed in a recording room at *Institut Teknologi Bandung*, Indonesia. The third was carried out in Manchester's city centre, United Kingdom. The experiment in Bandung was conducted to explore how participants who had never visited the actual locations might adjust the sound level of the soundscape reproductions and how they would rate the soundscape of these places. An analysis, using semantic differential analysis with Principal Component Analysis (PCA), was also performed to understand the effects of the two different participant experiences: first, the participants in Salford who are familiar with the actual soundscape locations, and then the participants in Bandung, who have never visited the actual locations.

All the experiments were carried out with a semantic questionnaire using the scales developed by Davies et al.(Davies et al., 2014), which are closely based on those of Kang (2007). All were represented as eleven-point scales, with the descriptions shown in **Table 4.4** as anchor points.

Table 4-4 Semantic Differential Scales

Comfort 5 4 3 2 1 0 1 2 3 4 5 Discomfort	
Quiet-Noisy	Calming-Agitating
Pleasant-Unpleasant	Smooth-Rough
Natural-Artificial	Hard-Soft
Like-Dislike	Fast-Slow
Gentle-Harsh	Sharp-Flat
Boring-Interesting	Varied-Simple
Social-Unsocial	Reverberant-Anechoic
Communal-Private	Far-Near
Meaningful-Insignificant	Directional-Universal

4.4.1 Laboratory Experiment in Salford

4.4.1.1 Experiment Setup

The listening test employed two systems: an audio playback system and an audio control system. The audio playback system consisted of eight Genelec 1029A speakers connected with an RMA ADI-8DS and M-Audio Profire Lightbridge Audio Interface. A Behringer BCR 2000 Digital Audio Workstation (DAW) controller was used to control the sound level of the audio playback with Reaper DAW software. In this listening test, the soundscape recording was reproduced using the Wig Ware Ambisonic Decoder, developed by Bruce Wiggins (Wiggins, 2010). Near field compensation was applied in this system. The listening test was conducted in a listening room at the University of Salford that meets the requirements of BS 684013 / IEC 268-13. The layout of the system is shown in **Figure 4.2.**

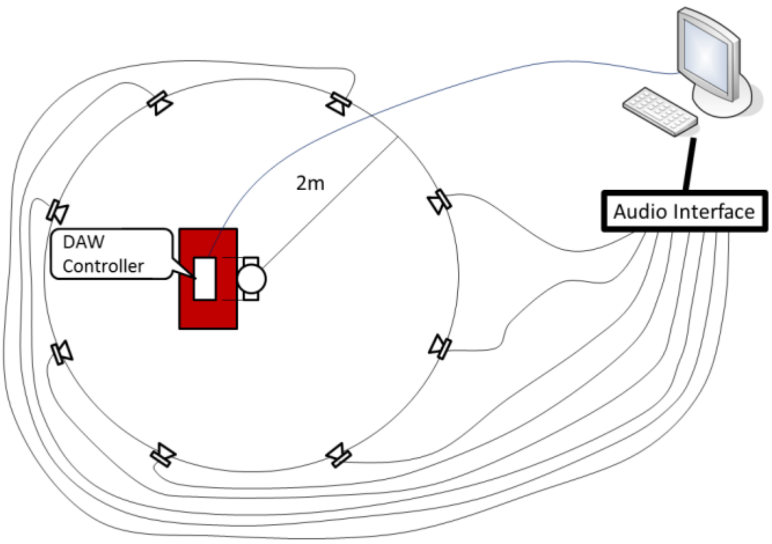


Figure 4-2 Listening Test Playback System

Calibration of the reproduction system was carried out using a reference signal recorded in the Reverberation Room at the University of Salford. The reference signal was white noise (played at 80 dB) recorded by an ambisonic recording system (ST-250 Soundfield microphone, and R-44 recorder). The level and gain were set at the same value as when the recording was made. Two calibrations were done in the experiment's setup phase: first, level calibration of individual speakers, so all the speakers played the same level of sound; and second, overall sound level calibration to confirm that the system reproduced sound at the same sound level as the actual condition.

One important aspect of soundscape reproduction is making the visual environment as neutral as possible. This should be done by making the speakers invisible to the subject (Catherine Guastavino et al., 2005). In this experiment, this was accomplished by using a white curtain that surrounded the subject, as shown in **Figure 4.3.**

Figure 4-3 Curtain Used in Listening Test

4.4.1.2 Experiment Methods and Participants

The experiment was carried out individually in four parts, and included a practice session before the experiment began. The experiment lasted for thirty minutes. Each participant was asked to listen to the soundscape and imagine themselves in the actual place. The soundscape recordings were reproduced in a random order in each session, without telling participants where they were made. Eighteen participants took part in this listening test. Most were Masters or PhD students at the University of Salford with various backgrounds (acoustics, audio engineering, engineering, and social science) and ethnicities (Indonesian, Chinese, Iraqi, Pakistani, Indian, British, Italian, and Nigerian). There were fourteen males and four females participants, whose ages ranged from 24-40 years old (mean age = 29). All of the participants volunteered for the experiment.

The 11-point semantic differential scale was used to rate the soundscapes based on participants' impressions of them. In each session, participants were asked to fill in the semantic questionnaire while listening to a soundscape, and then to adjust the reproduction to the sound level that they believed represented the actual sound level at the location.

4.4.2 Laboratory Experiment in Bandung

4.4.2.1 Experiment Setup

This listening test was conducted in a recording room at *Institut Teknologi Bandung*, Indonesia. Eight KRK Rockit 5 speakers were used in a pantophonic playback system. A laptop with Reaper DAW software was connected to an M-Audio Fast Track Ultra 8R audio interface. The Wig Ware Ambisonic Decoder, developed by Bruce Wiggins (Wiggins, 2010) with near field compensation, was used to decode a B-format recording of Manchester City Centre. A DAW controller, Korg Nanokontrol 2, was used to control the sound level of the reproduction.

The room used for this listening test was a recording room with absorbers on every wall as well as the ceiling, as shown in **Figure 4.4**. An air conditioning system was also installed in the room. The noise rating (NR) of this room during the experiment was NR 31, with the dominant noise source being the air conditioning system, as shown in **Figure 4.5**.

Figure 4-4 Speaker Setup for Listening Test

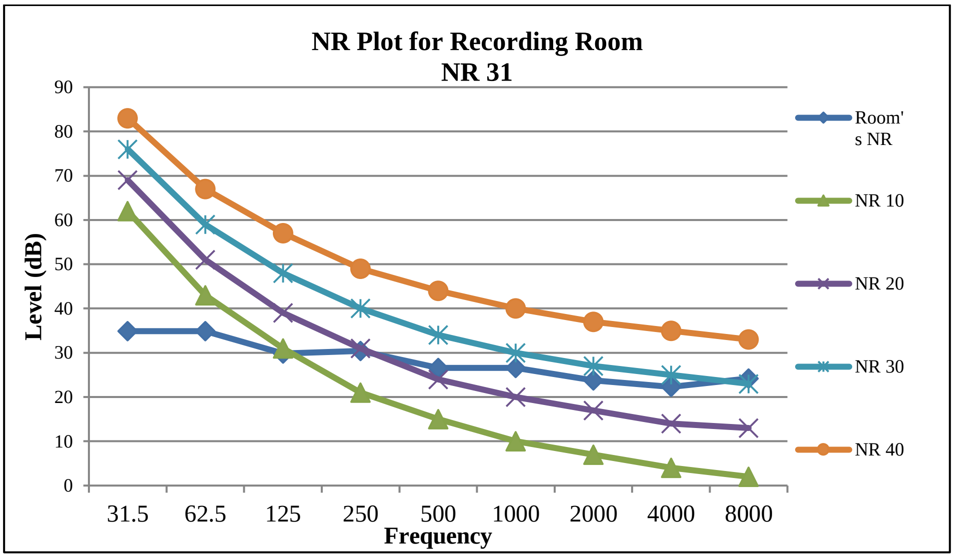


Figure 4-5 Noise Rating Plot of the Recording Room

4.4.2.2 Experiment Methods and Participants

Two experiments were conducted in Bandung. The first was carried out using the same method as the experiment in Salford (listening to the soundscapes at the actual sound level, rating the soundscapes, and adjusting the sound level of reproduction). For this first experiment, fifteen volunteers (eight males and seven females) participated. All of the participants were Bachelors and Masters students in engineering physics, with an age range between 17-34 years (mean age = 22). The experiment was done individually, and lasted for thirty minutes.

The second experiment was conducted by reproducing the soundscape at -9.5 dB below the actual sound level, a value chosen based on the results of the experiment in Salford. Sixteen new volunteers (nine males and seven females who had not been in the previous experiment) participated. All of the participants were Bachelors and Masters students in engineering physics, with an age range between 18-29 years (mean age = 21). The experiment was done individually, and lasted for thirty minutes.

The questionnaire used in this experiment deployed the same semantic scales utilised in the experiment in Salford. Participants, who were all English speakers, received a translation and explanation of the scale before the experiment to familiarise them with it.

4.4.3 In Situ Experiment

4.4.3.1 Experiment Methods and Participants

In situ experiments were conducted with a soundwalk, with participants filling in the semantic scales at the location where the recordings used in the laboratory tests were made. The soundwalk was commonly carried out in a group (Adams et al., 2008; Liu et al., 2014), and the participants were asked to listen to the soundscape in silence. The soundwalk was done at four locations in the city centre: Piccadilly Garden (1), the Food Market in Piccadilly Garden (2), Market Street (3), and St Ann Square (4). The locations are shown in **Figure 4.6**.

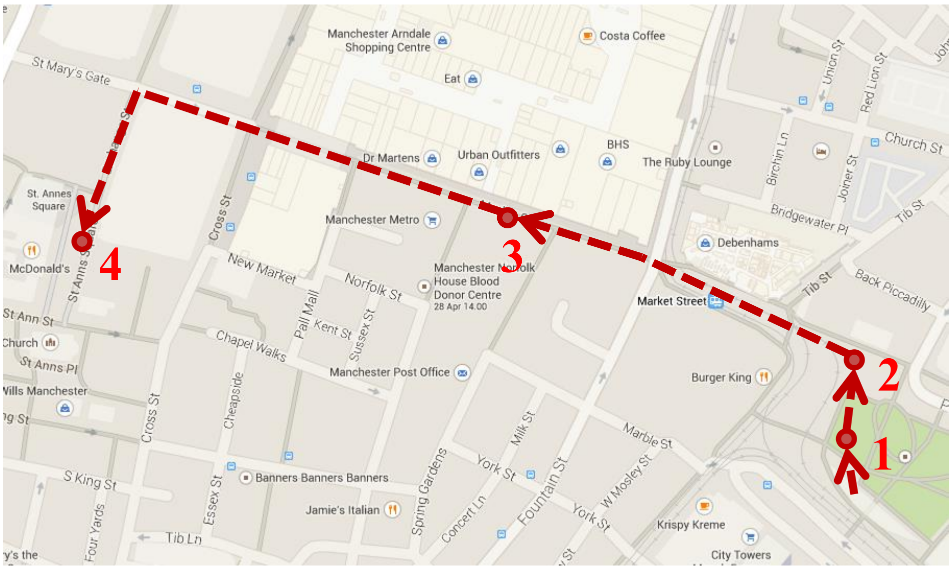


Figure 4-6 Locations and Soundwalk Route

The experiment was conducted in four sessions with 23 participants: 22 January 2015 (ten participants, five males and five females); 24 January 2015 (three participants, all males); 29 January 2015 (one participant, male); and 31 January 2015 (nine participants, five males and four females). The ages of the participants were between 23-50 years old (mean age 35), and they represented a variety of ethnicities (Indonesian, Chinese, British, and Italian). A photo of participants answering the questionnaires is shown in **Figure 4.7**.

Figure 4.7 Soundwalk in Manchester city centre

4.4.3.2 Consistency of In Situ Data

The in situ experiments were conducted in 4 different sessions (22 January 2015, 24 January 2015, 29 January 2015, and 31 January 2015). An Analysis of Variance (ANOVA) and effect size (using η^2) was done to check if significant differences appeared between experimental sessions. The results are shown in **Table 4.5.**

The results of the ANOVA and effect size analysis from Market Street show that perceptions of Hard-Soft and Sharp-Flat are significantly different between sessions. Both 45% of the total variance along the Hard-Soft scale and 57% of the total variance along the Sharp-Flat scale are due to the fact that the sessions were conducted at different times.

Table 4-5 ANOVA and Effect Size Calculation of Session Variation

Market Street

Semantic Scale	sig	η^2		Semantic Scale	sig	η^2
Comfort-Discomfort	.301	0.165		Calming-Agitating	.399	0.141
Quiet-Noisy	.320	0.153		Smooth-Rough	.095	0.279
Pleasant-Unpleasant	.357	0.102		Hard-Soft	.008	0.453
Natural-Artificial	.553	0.176		Fast-Slow	.223	0.202
Like-Dislike	.287	0.194		Sharp-Flat	.001	0.572
Gentle-Harsh	.241	0.059		Varied-Simple	.830	0.044
Boring-Interesting	.759	0.070		Reverberant-Anechoic	.098	0.277
Social-Unsocial	.700	0.084		Far-Near	.309	0.168
Communal-Private	.635	0.309		Directional-Universal	.742	0.062
Meaningful-Insignificant	.066	0.062				

St Ann Square

Semantic Scale	sig	η^2		Semantic Scale	sig	η^2
Comfort-Discomfort	.258	0.187		Calming-Agitating	.248	0.191
Quiet-Noisy	.326	0.163		Smooth-Rough	.597	0.092
Pleasant-Unpleasant	.442	0.129		Hard-Soft	.612	0.089
Natural-Artificial	.458	0.125		Fast-Slow	.314	0.167
Like-Dislike	.172	0.226		Sharp-Flat	.785	0.053
Gentle-Harsh	.613	0.089		Varied-Simple	.795	0.051
Boring-Interesting	.405	0.139		Reverberant-Anechoic	.554	0.102
Social-Unsocial	.560	0.100		Far-Near	.151	0.238
Communal-Private	.545	0.104		Directional-Universal	.090	0.283
Meaningful-Insignificant	.322	0.164				

Piccadilly Garden

Semantic Scale	sig	η^2		Semantic Scale	sig	η^2
Comfort-Discomfort	.384	0.145		Calming-Agitating	0.155	0.236
Quiet-Noisy	.161	0.233		Smooth-Rough	0.581	0.096
Pleasant-Unpleasant	.907	0.028		Hard-Soft	0.257	0.187
Natural-Artificial	.050	0.331		Fast-Slow	0.998	0.002
Like-Dislike	.980	0.009		Sharp-Flat	0.384	0.145
Gentle-Harsh	.993	0.005		Varied-Simple	0.794	0.051
Boring-Interesting	.963	0.014		Reverberant-Anechoic	0.137	0.247
Social-Unsocial	.429	0.132		Far-Near	0.141	0.244
Communal-Private	.457	0.125		Directional-Universal	0.870	0.036
Meaningful-Insignificant	.521	0.109				

Food Market at Piccadilly Garden

Semantic Scale	sig	η^2		Semantic Scale	sig	η^2
Comfort-Discomfort	.439	0.130		Calming-Agitating	.305	0.170
Quiet-Noisy	.462	0.124		Smooth-Rough	.872	0.036
Pleasant-Unpleasant	.484	0.118		Hard-Soft	.941	0.020
Natural-Artificial	.412	0.137		Fast-Slow	.907	0.028
Like-Dislike	.173	0.226		Sharp-Flat	.836	0.043
Gentle-Harsh	.437	0.130		Varied-Simple	.875	0.035
Boring-Interesting	.300	0.171		Reverberant-Anechoic	.675	0.076
Social-Unsocial	.518	0.110		Far-Near	.083	0.290
Communal-Private	.443	0.129		Directional-Universal	.803	0.050
Meaningful-Insignificant	.325	0.163				

Table 4.5 also shows that there was no significant difference in the semantic scales for other locations in the soundwalk that is attributable to the different times the soundwalk was conducted. An interesting thing happened at the Food Market at Piccadilly Garden. The food market was not open during the first, second and third sessions (it was only open during the fourth session), but it did not affect participants' perceptions. There was also an opera singer performing during the second session of the experiment, but perceptions of the space remained similar between that and the other sessions. It may be the case that some sound objects do not have a significant effect on the perception of a soundscape.

4.5 Results and discussion

4.5.1 Assessment of Soundscape Reproduction in the Laboratory

Two-dimensional soundscape reproduction using a first order ambisonic system with eight speakers in a Listening Room was analysed using semantic differential analysis to understand participants' impressions of the soundscape.

Principal Component Analysis (PCA) was used to analyse the semantic data. The significant components from the PCA were determined based on their eigenvalue (eigenvalue > 1), and further analysis was done using a reliability test.

4.5.2 In Situ Experiment

Factor analysis for the in-situ dataset was done by combining the results of the semantic scales from the four locations. The PCA from the in situ experiment, as shown in **Table 4.6**, revealed six components that explained 72% of the variance in the scale:

- **Component 1** (24%): **Calmness/Relaxation.** The scales of Comfort- Discomfort, Quiet-Noisy, Pleasant-Unpleasant, Like-Dislike, Gentle-Harsh, and Smooth-Rough load highly into this component.
- **Component 2** (14%): **Dynamics/Vibrancy.** The scales of Hard-Soft, Fast-Slow, Sharp-Flat, and Varied-Simple load highly into this component.
- **Component 3** (11%): **Communication**. The scales of Social-Unsocial and Communal-Private load highly into this component.
- **Component 4** (9%): **Naturalness and Meaningfulness.** The scales of Meaningful-Insignificant, and Natural-Artificial load highly into this component.
- **Component 5** (7%): **Spatiality.** The scale of Reverberant-Anechoic loads highly into this component.
- **Component 6** (7%): **Directionality.** The scale of Directional-Universal loads highly into this component.

Table 4-6 PCA of the In Situ Experiment

PCA In Situ
(N= 92, Kaiser-Mayer-Olkin index =0.647, Bartlett's test of sphericity sig. 0.000)

	Component					
	24%	14%	11%	9%	7%	7%
Comfort-Discomfort	.826	-.105	-.036	-.203	-.074	.052
Quiet-Noisy	.640	.016	-.375	-.132	.080	-.345
Pleasant-Unpleasant	.891	-.066	.057	.046	-.035	.195
Natural-Artificial	.519	.138	-.088	.538	-.228	-.183
Like-Dislike	.861	-.041	.144	.138	-.119	.218
Gentle-Harsh	.713	-.491	-.128	.031	.073	-.068
Boring-Interesting	-.475	-.292	.029	-.311	.075	-.412
Social-Unsocial	.096	.332	.790	.049	.039	-.017
Communal-Private	-.135	-.025	.872	.165	-.013	-.179
Meaningful-Insignificant	.457	.190	.315	.573	-.078	.170
Calming-Agitating	.458	-.180	-.309	.109	.464	-.069
Smooth-Rough	.515	-.622	-.054	.003	.294	-.093
Hard-Soft	-.354	.642	.233	-.123	.115	.189
Fast-Slow	-.073	.502	.231	.266	.408	.262
Sharp-Flat	.029	.851	-.055	.085	.203	-.084
Varied-Simple	.112	.621	.414	.067	-.207	-.169
Reverberant-Anechoic	-.138	.119	.019	-.021	.817	.066
Far-Near	.279	.065	-.160	-.829	-.168	-.013
Directional-Universal	.138	-.024	-.184	-.029	.096	.808

A reliability test (using Cronbach's Alpha) indicates that only three dimensions are reliable to measure the soundscapes: Calmness/Relaxation (Cronbach's Alpha = 0.872), Dynamics/Vibrancy (Cronbach's Alpha = 0.818), and Communication (Cronbach's Alpha = 0.706). The test demonstrates that although six dimensions can be gathered from the semantic differential analysis, only three are reliable. Further investigations are therefore focused on these three dimensions.

The in situ experiment results were similar to the field studies made at urban locations in Sheffield (Kang, 2007) that found four main dimensions: Relaxation (26%), Communication (12%), Spatiality (8%), and Dynamics (7%). All the dimensions found in Kang's experiment also appear in ours. The dimension of Calmness/Relaxation in our experiment seems to explain similar variance in Kang's (24% in our experiment, 26% in Kang's). The variance values are also similar in the dimension of Communication (11% in our experiment, 12% in

Kang's). The other dimensions found in Kang's experiment (Dynamics and Spatiality) also appear in our experiment, but with a higher percentage of variance.

The in situ experiment also revealed dimensions similar to a field study in France (Raimbault, Lavandier, & Bérengier, 2003). That study suggests that there are three dimensions of soundscape: Assessment and Strength (67%), Sound Dynamic (15%), and Spatial Dimension and Clarity (8%). The dimension of Calmness/Relaxation in our experiment resembles the dimension of Assessment and Strength. The dimension of Sound Dynamic also appears in our experiment, and explained a similar variance (14% in our experiment, 15 % in the experiment in France).

4.5.3 Laboratory Test at Actual Sound Level

An analysis of soundscape reproductions at actual sound levels was conducted using the data from the experiments in Salford and Bandung. Factor analysis of the laboratory experiment using the Salford dataset was done by combining the results of semantic scale responses from four experiment sessions. The PCA from the laboratory experiment in Salford, as shown in **Table 4.7**, showed five components that explain 69% of variance in the scales:

- **Component 1** (25%): **Calmness/Relaxation**. The scales of Comfort-Discomfort, Quiet-Noisy, Pleasant-Unpleasant, Like-Dislike, Gentle-Harsh, Calming-Agitating, and Smooth-Rough load highly into this component.
- **Component 2** (14%): **Communication and Dynamics**. The scales of Social-Unsocial, Hard-Soft, Fast-Slow, Sharp-Flat, and Varied-Simple load highly into this component.
- **Component 3** (12%): **Spatiality**. The scales of Reverberant-Anechoic and Far-Near load highly into this component.

- **Component 4** (9%): **Naturalness and Meaningfulness.** The scales of Meaningful-Insignificant and Natural-Artificial load highly into this component.
- **Component 5** (6%): **Directionality**. The scale of Directional-Universal loads highly into this component.

Table 4-7 PCA of the Laboratory Test in Salford at Actual Sound Level Reproduction

PCA Laboratory Salford Actual Level
(N=54, Kaiser-Mayer-Olkin index 0.754, Bartlett's test of sphericity sig. 0.000)

	Component				
	25%	17%	12%	9%	6%
Comfort-Discomfort	.828	.053	.092	.147	.137
Quiet-Noisy	.688	-.305	.068	.136	.033
Pleasant-Unpleasant	.754	.057	-.178	.389	.194
Natural-Artificial	.215	-.182	-.156	.735	-.027
Like-Dislike	.715	.146	-.202	.490	.154
Gentle-Harsh	.841	-.083	.186	.265	-.112
Boring-Interesting	-.386	-.490	.423	-.090	-.177
Social-Unsocial	.017	.521	-.469	-.019	-.157
Communal-Private	-.011	.404	-.606	-.039	-.295
Meaningful-Insignificant	.172	.405	-.085	.728	-.031
Calming-Agitating	.778	-.221	.073	-.237	.006
Smooth-Rough	.760	-.374	-.040	.023	-.071
Hard-Soft	-.582	.562	.068	.041	.294
Fast-Slow	-.209	.787	-.146	.014	.046
Sharp-Flat	-.272	.689	.147	.194	-.102
Varied-Simple	-.118	.712	-.236	-.067	-.276
Reverberant-Anechoic	.101	.051	.739	-.232	.052
Far-Near	.026	-.079	.827	-.063	-.042
Directional-Universal	.070	-.146	.106	-.031	.898

The PCA from the laboratory experiment in Salford shows different results than the experiment conducted outdoors at Manchester city centre. The four dimensions of space proposed by Kang (2007) exist in the laboratory experiment, but here, the dimensions of Communication and Dynamics combine into one. The components related to Calmness/Relaxation, Naturalness and Meaningfulness, and Directionality show the same outcomes as the in situ experiment. Those components were formed from the same semantic scales in both experiments, and also showed a matching amount of variance explanation in the PCA.

The differences appear in the second and third components. The second component in the laboratory experiment (Communication and Dynamics) appears to be a combination of the second component (Dynamics) and the third component (Communication) from the in situ experiment. This combination shows that participants responded to the soundscape reproduction differently than to the real condition. In the experiment using periphonic systems (Davies et al., 2014), the dimensions of Dynamics and Communication were separate even though the soundscape was reproduced in the laboratory. Unfortunately, information about the reproduction sound level of the soundscape in the study is not available.

The experiment in Bandung was conducted to explore how people who are not familiar with a certain place perceive a soundscape reproduction of that space. The analysis was done using factor analysis. The results of a PCA are shown in **Table 4.8**, and the analysis indicates four main dimensions that explain 74% of all variations:

- **Component 1** (32%): **Calmness/Relaxation.** The scales of Comfort-Discomfort, Pleasant-Unpleasant, Like-Dislike, Gentle-Harsh, Meaningful-Significant, Calming-Agitating, and Smooth-Rough load highly into this component.
- **Component 2** (26%): **Communication and Dynamics.** The scales of Social-Unsocial, Communal-Private, Fast-Slow, Sharp-Flat, and Varied-Simple load highly into this component.
- **Component 3** (9%): **Spatiality**. The scales of Natural-Artificial and Far-Near load highly into this component.
- **Component 4** (7%): **Directionality.** The scale of Directional-Universal loads highly into this component.

The first, second and fourth components seem consistent with the results of the experiment in Salford. The combination of Communication and Dynamics in this experiment indicates the difference between participants' perceptions in the laboratory and those at the actual location.

Table 4-8 PCA of the Laboratory Test in Bandung at Actual Sound Level Reproduction

PCA Laboratory Bandung Actual Sound Level
(N=60, Kaiser-Mayer-Olkin index 0.810, Bartlett's test of sphericity sig. 0.000)

	Component			
	32%	26%	9%	7%
Comfort-Discomfort	.917	-.067	.022	.068
Quiet-Noisy	.450	-.636	.263	.073
Pleasant-Unpleasant	.850	-.124	.039	.151
Natural-Artificial	-.045	.082	.775	.166
Like-Dislike	.932	-.013	.045	-.003
Gentle-Harsh	.761	-.294	.188	.013
Boring-Interesting	-.722	-.345	.141	.052
Social-Unsocial	.040	.850	.133	.115
Communal-Private	.000	.864	.123	.052
Meaningful-Insignificant	.660	.072	-.289	-.151
Calming-Agitating	.771	-.419	-.034	-.089
Smooth-Rough	.788	-.296	-.038	-.033
Hard-Soft	-.654	.499	.047	.117
Fast-Slow	-.475	.624	-.104	.147
Sharp-Flat	-.205	.677	-.316	-.044
Varied-Simple	-.083	.848	-.158	.024
Reverberant-Anechoic	.030	-.050	-.148	-.862
Far-Near	-.072	-.300	.669	-.330
Directional-Universal	-.012	.076	-.427	.561

Reliability tests from the two laboratory experiments at actual sound level reproduction in Salford and Bandung indicate that only two dimensions are reliable in measuring the soundscapes: Calmness/Relaxation (Cronbach's Alpha = 0. 906 and 0.930), and the combined dimension of Communication and Dynamics (Cronbach's Alpha = 0. 791 and 0.747). Furthermore, it indicates that personal experience of a space does not affect judgement of its soundscape.

The results of the laboratory experiments without sound level adjustment appear to be similar to the results of other studies in the laboratory. The study conducted by Axelsson et al. using headphones shows three significant soundscape dimensions: Pleasantness (50%), Eventfulness (18%), and Familiarity (6%) (Axelsson et al., 2010). Another study by Cain et al. using headphones shows two significant soundscape dimensions: Calmness (60%) and Vibrancy (20%) (Cain et al., 2013). Two significant soundscape dimensions, Pleasantness, Calmness and Intrusiveness (24%) and Vibrancy and Informational Content (24%), emerge from the study by Hall et al. using headphones (Hall et al., 2013). Another study, conducted using a 4-speaker system, indicates three soundscape dimensions: Emotional Assessment and Strength Factor (42%), Activity (14%), and Clarity (10%) (Guillén & López Barrio, 2007). Two dimensions are consistent across all these studies, including our own: a dimension associated with a general assessment, such as calmness or pleasantness, and a dimension associated with a feeling of vibrancy, dynamism and activity.

Our experiment shows that soundscape reproduction using a pantophonic playback system at actual sound levels causes a perceptual difference between laboratory and in situ conditions (the dimensions of Communication and Dynamics combine into one scale in the laboratory condition, while the in situ experiment shows that the two dimensions diverge). This may suggest that the pantophonic system without sound level adjustment might not reproduce the outdoor soundscape accurately enough.

4.6 The Effect of Sound Level Adjustment on Perception of Soundscape Reproduction

The effect of sound level adjustment on perception was analysed in two steps: first, by determining the sound level adjustments made to reproduced soundscapes by participants in the laboratory (experiments in Salford and Bandung); and second, by comparing the perception of soundscapes reproduced in the laboratory (with and without sound level adjustments) to perception of the in situ soundwalk.

4.6.1 Sound Level Adjustment

The analysis of sound level adjustment was based on the experiment by Davies et al. that used a soundscape environment simulator (Davies et al., 2014). The participants in their study tended to lower sound objects by -12.3 dB from the recorded sound level in the soundscape environment simulator. The sound level adjustment seems to indicate that the overall soundscape simulated in the laboratory should be reproduced at a lower sound level than the actual level in situ.

The laboratory experiments were conducted (using four soundscape recordings) in Salford and Bandung. Participants were asked to adjust the sound to the level that represented the actual condition. The experiment confirmed that if participants have an opportunity to adjust the sound level of a soundscape reproduction, they tend to choose a lower reproduction level than the actual level in situ.

The sound level adjustment of each location was analysed with Analysis of Variance (ANOVA) with 95% significance level. The ANOVA shows that there is no significant difference in sound level adjustment between the four recordings used. This result indicates that the amount of sound level adjustment is unrelated to the loudness of the reproduced soundscape. In brief, participants adjusted the reproduced soundscapes by a similar value, as shown in **Figure 4.7,** even when the soundscapes had different loudness.

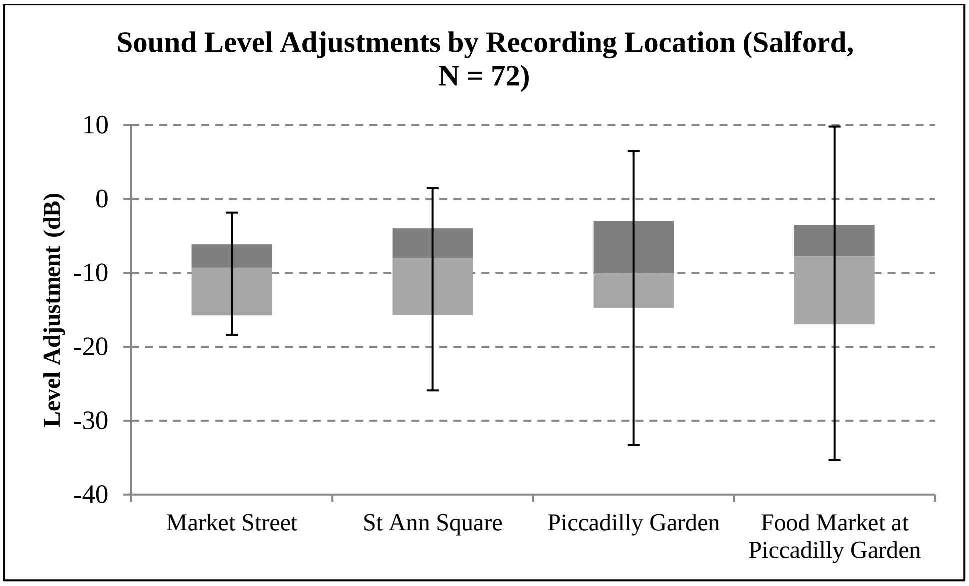


Figure 4-7 Sound Level Adjustments to Soundscape Reproduction by Recording Location, Salford

Data from both experts and non-experts was sought to determine if there are any differences in the ways expert and non-expert participants adjust sound levels. Expert participants were considered to be those with at least five years' experience in acoustic or audio engineering, and who had participated in at least five listening tests before the present experiment. There were eight participants who were considered experts based on these criteria. The analysis was done using a Mann-Whitney test, and shows that the difference between the groups is not significant; however, the expert group demonstrated lower variance than the non-experts, as shown in **Figure 4.8.**

The lower variance of expert participants might happen because they are already familiar with the listening test condition. Usually, the stimulus in the listening test are reproduced at the certain sound level, and the participants cannot adjust the sound level. The expert participants, who are familiar with the listening test condition, might have developed a similar expectation of sound level in the listening room. This similar expectation of sound level reproduction might affect how they adjust the sound level in this experiment.

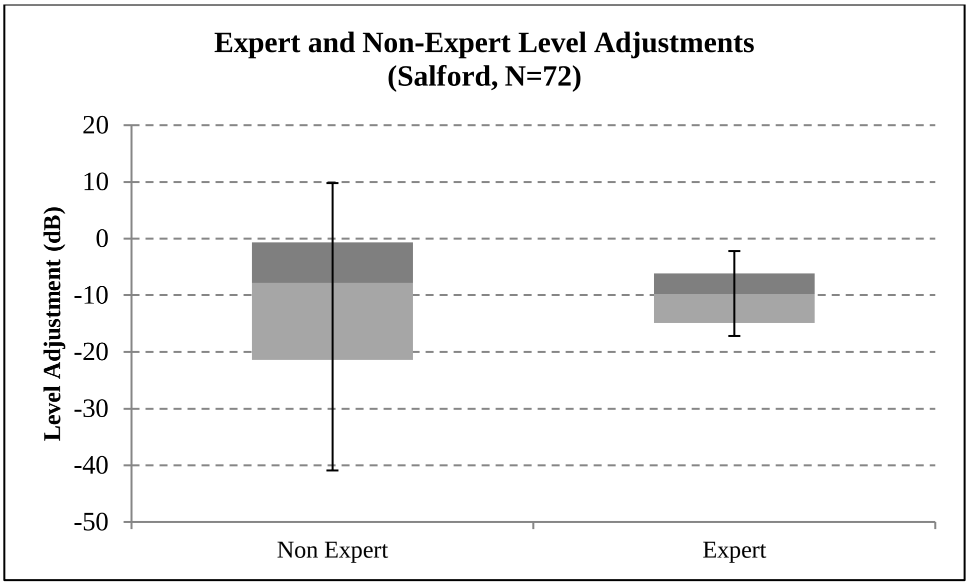


Figure 4-8 Expert and Non-Expert Level Adjustments

Some non-expert participants adjusted the sound to a level that felt comfortable to them, in some cases very low (one participant adjusted the sound level to -49 dB), but in general the adjustments of non-experts were consistent with those of the experts. The overall sound level adjustment of soundscape reproduction in the laboratory is -9.5 dB (based on median calculation), as shown in **Figure 4.9.**

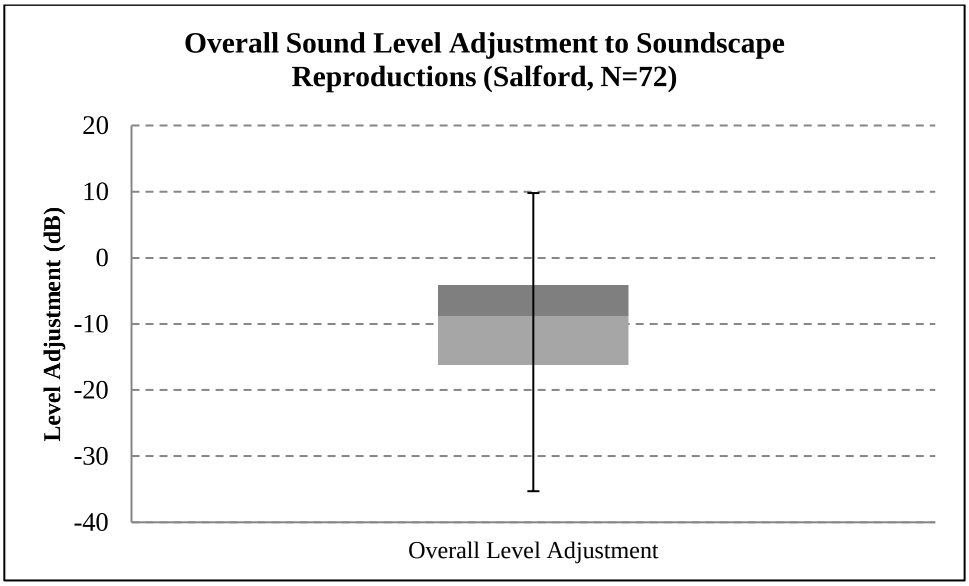


Figure 4-9 Overall Sound Level Adjustment to Soundscape Reproductions, Salford

4.6.2 Difference in Adjustment Level Between Salford and Bandung

The experiment in Bandung was conducted to verify the level of sound level adjustment by participants, and to better understand the impression made by soundscape reproduction when it is reproduced at -9.5 dB below the actual sound level (based on the previous experiment in Salford).

Sound level adjustment of the soundscape reproduction was conducted by asking participants to adjust the sound to the level that represented the actual condition. The results are shown in **Figure 4.10.** An ANOVA test was used to analyse the effect of the different recordings in the sound level adjustment experiment and showed that there is no significant difference ($p>0.05$) attributable to the variation in soundscape recording. The participants had a tendency to adjust the sound level to about -9.5 dB compared to the real outdoor level. This result is consistent with the previous study conducted in Salford.

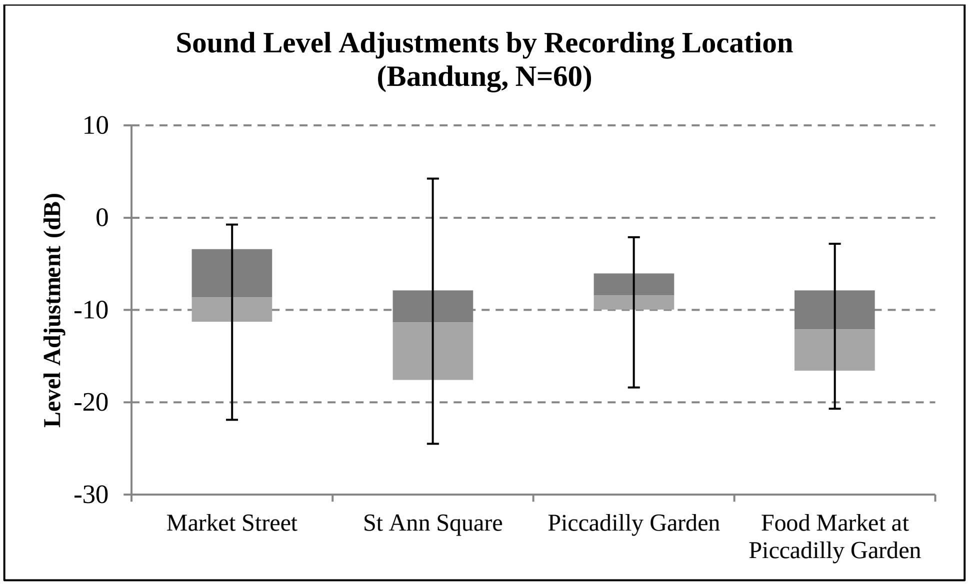


Figure 4-10 Sound Level Adjustments to Soundscape Reproduction by Recording Location, Bandung

The data from this experiment were also compared to the experiment conducted in Salford to analyse the effect of participants' backgrounds and room conditions with the sound level adjustment. The experiment in Salford was carried out in a listening room with participants who lived in Manchester. The experiment in Bandung was conducted in a normal recording room with Indonesian participants. The experiment showed that there is no significant difference ($p > 0.05$) in sound level adjustment between the laboratory experiments in Salford and Bandung, as illustrated in **Figure 4.11**. The adjustment average was at -9.5 dB in both the places.

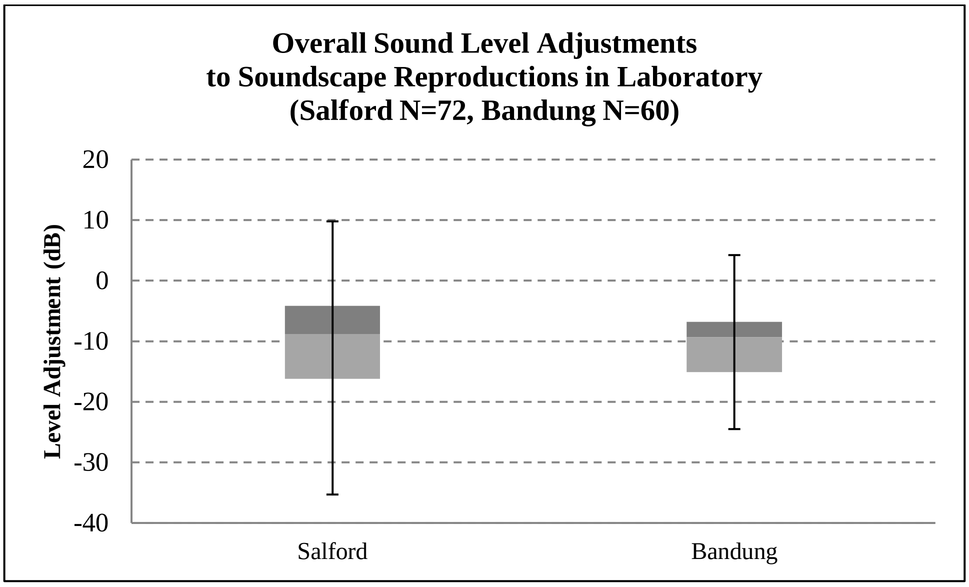


Figure 4-11 Overall Sound Level Adjustments in Salford and Bandung Experiments

4.6.3 Semantic Differential Analysis Comparison Between In Situ Experiment and Laboratory Experiment with Sound Level Adjustment

A factor analysis of the experimental data set was done by combining the results of semantic scale ratings from the four locations. The PCA of the laboratory experiment with the -9.5 dB sound level adjustment, as shown in **Table 4.9**, showed that five components explain 76% of variance in the scales:

- **Component 1** (32%): **Calmness/Relaxation.** The scales of Comfort-Discomfort, Quiet-Noisy, Pleasant-Unpleasant, Like-Dislike, Gentle-Harsh, Meaningful-Insignificant, and Smooth-Rough load highly into this component.
- **Component 2** (18%): **Dynamics/Vibrancy.** The scales of Fast-Slow, Sharp-Flat, and Varied-Simple load highly into this component.
- **Component 3** (12%): **Communication.** The scales of Social-Unsocial and Communal-Private load highly into this component.
- **Component 4** (7%): **Spatiality.** The scales of Reverberant-Anechoic and Far-Near load highly into this component.
- **Component 5** (7%): **Directionality.** The scale of Directional-Universal loads highly into this component.

Table 4-9 PCA of the Experiment in Bandung with -9.5 dB Sound Level Adjustment

PCA Laboratory in Bandung with -9.5 dB Sound Level Adjustment
(N= 64, Kaiser-Mayer-Olkin index 0.790, Bartlett's test of sphericity sig. 0.000)

	Component				
	32%	18%	12%	7%	7%
Comfort-Discomfort	.873	.143	.006	-.066	-.017
Quiet-Noisy	.619	-.387	-.437	.005	-.045
Pleasant-Unpleasant	.907	.078	-.006	-.087	.090
Natural-Artificial	.138	-.608	.427	-.284	.271
Like-Dislike	.843	.167	.223	-.087	.052
Gentle-Harsh	.799	-.252	-.096	.184	.101
Boring-Interesting	-.357	-.694	-.330	.071	.155
Social-Unsocial	-.102	.045	.872	-.065	-.084
Communal-Private	-.198	.356	.719	.168	-.367
Meaningful-Insignificant	.546	.473	.307	.018	.190
Calming-Agitating	.819	-.159	-.194	.003	.166
Smooth-Rough	.794	-.197	-.094	.160	-.067
Hard-Soft	-.821	.022	.206	-.206	.162
Fast-Slow	-.577	.583	.136	-.049	.219
Sharp-Flat	-.093	.794	-.029	-.038	.117
Varied-Simple	-.098	.775	.367	.078	.183
Reverberant-Anechoic	.099	.197	-.027	.835	-.129
Far-Near	.060	-.476	.058	.653	.294
Directional-Universal	.041	.161	-.190	-.001	.873

The soundscape reproduction with -9.5 dB sound level adjustment shows a result similar to those of the field study conducted by Kang (2007), the laboratory experiment using periphonic system by Davies et al. (2014), and the in situ experiment. The first three dimensions are the same as in the in situ experiment. The dimensions of Dynamics and Communication, which combined into one dimension when participants rated the reproduction at the actual sound level, are once again separated at the lower sound level into two dimensions, as in the field experiment. Furthermore, based on a reliability test using Cronbach's Alpha, the dimensions determined to be reliable in the field test are also reliable in this experiment (Calmness/Relaxation = 0.918, Dynamics = 0.738, and Communication = 0.756). In conclusion, when reproduced with a -9.5 dB sound level adjustment, the soundscape makes a similar impression to the in situ experiment, but it does not do so when reproduced at the actual sound level. The finding also suggests a reason for the sound level adjustment: participants might feel that the reproduction at actual sound level is not ecologically realistic.

4.7 Conclusion

The soundscape reproduction using a pantophonic reproduction system at the actual sound level was not able to produce an impression similar to that of the soundscape under actual conditions, according to a Semantic Differential Analysis. When participants are given the opportunity to adjust the sound level of a soundscape reproduction in the laboratory, they tend to adjust the sound level to -9.5 dB below the actual level. The adjustment was consistent even when the experiments were conducted with participants possessing different experiences of the actual locations, and when different types of rooms were used to conduct the experiments (listening room in Salford, and recording room in Bandung). Furthermore, soundscape reproduction using a pantophonic system with -9.5 dB sound level adjustment seems to be a better approach for soundscape reproduction in a room because it was able to evoke perceptions that were more similar to perceptions of the actual soundscape in situ. This study also confirms three reliable soundscape dimensions in the evaluation of urban soundscape: Relaxation, Dynamics, and Communication.

The contributions of this study include how sound level adjustment can be used to deliver perceptions of soundscape reproduction that are more like those in actual locations; the validity of a pantophonic reproduction system in reproducing soundscapes; and the confirmation of the soundscape dimensions that were used to rate soundscapes in the next set of experiments.

The next chapter will discuss the application of soundscape reproduction in the laboratory to understand the relationship between the perception of sound objects in a soundscape and the overall rating of the soundscape.

5 The Application of Soundscape Recording to Find the Relationship between Sound Objects and Soundscape Dimensions

5.1 Introduction

A soundscape is the “acoustic environment as perceived or experienced and/or understood by people, in context” (International Organization for Standardization, 2013). There are three important contexts in soundscape: auditory sensation, interpretation of audio sensation, and response to the acoustic environment. The interpretation of audio sensation indicates the relationship between the listener and the sound objects in a soundscape.

The study conducted by Axelsson et al. (Axelsson et al., 2010) indicates that soundscapes dominated by natural sound objects have a positive correlation with the dimension of pleasantness, and soundscapes dominated by human sounds have a positive correlation with the dimension of eventfulness. These results indicate that soundscape dimensions might also be related to opinions held about of sound objects. Another study by Yang and Kang showed that the experience of acoustic relaxation was affected significantly by the type of sound objects present (Yang & Kang, 2005).

Recorded soundscape reproduction is a common way to analyse the perception of soundscape as an alternative to in situ soundwalk. Following confirmation in the previous chapter that soundscape reproduction is able to imitate an actual soundscape, soundscape recordings were used to understand the relationship between sound objects and soundscape dimensions. This study tried to find the correlation between the perception of sound objects in a soundscape with the impressions made by the soundscape according to three soundscape dimensions (Relaxation, Dynamics, and Communication) when the soundscape recording was reproduced

9.5 dB under the actual sound level. Furthermore, the study analysed the application of recorded soundscape in order to find the relationship between sound objects and soundscape dimensions.

5.2 Experiment

5.2.1 Experiment Setup and Soundscape Recording

The experiment was conducted in a listening room at the University of Salford that meets BS 684013 / IEC 268-13 requirements. A pantophonic playback system with eight speakers (hidden from participant view using a curtain) was applied to reproduce soundscape recordings made in Manchester city centre. Audio playback systems consisted of eight Genelec 1029A speakers connected with RMA ADI-8DS and M-Audio Profire Lightbridge Audio Interface. All the recordings were reproduced at -9.5 dB below the in situ level.

The recordings were made using a stationary soundfield microphone with B-Format output in five locations: Market Street (representing a busy shopping area), St Ann Square (a quiet place), Piccadilly Garden (an urban garden), Deansgate (a location with traffic noise), and Exchange Square (a location with construction noise), as shown with red dots in **Figure 5.1**.

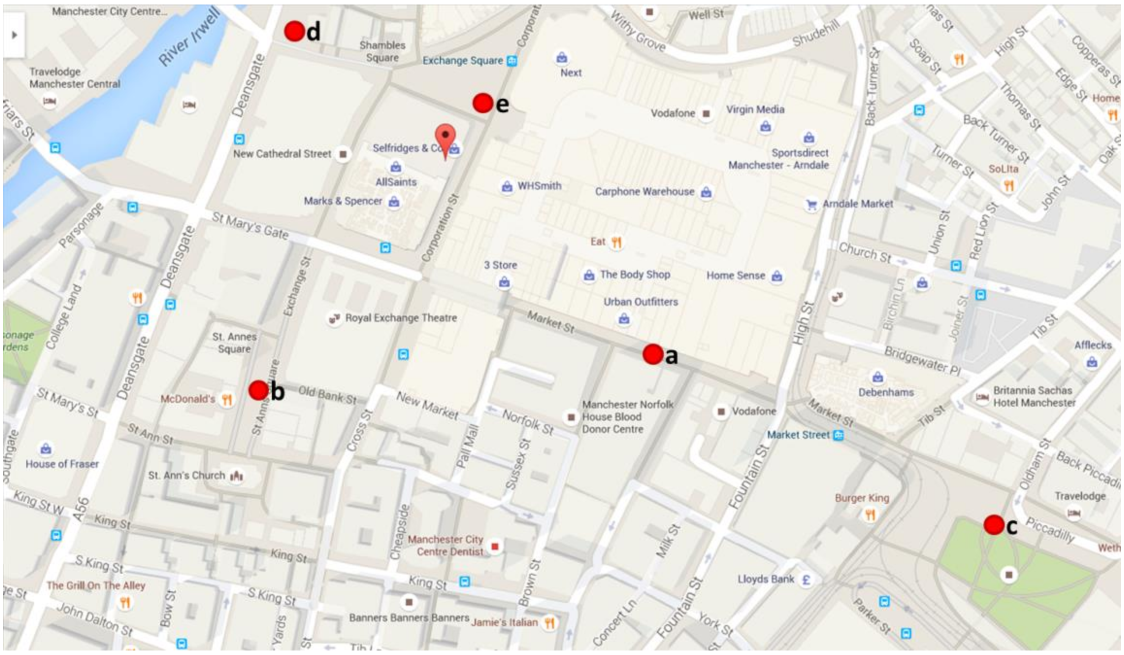


Figure 5-1 Recording Locations: (a) Market Street, (b) St Ann Square, (c) Piccadilly Garden, (d) Deansgate, (e) Exchange Square

5.2.2 Experiment Method

Twenty-one volunteers (16 males and 5 females) participated in the experiment with an age range between 25-40 years old (mean age = 23). Most of them were Masters or PhD students at the University of Salford, with a variety of backgrounds (acoustics, audio engineering, engineering, and social science) and ethnicities (Indonesian, Chinese, Pakistani, Iraqi, British, and Italian). The experiment was conducted individually and lasted for approximately 40 minutes.

There were two experiments conducted at the University of Salford. The first session was conducted to understand expectations regarding sound objects in Manchester city centre. In this session, participants were asked to fill in a questionnaire consisting of an open question about their expectations of sound objects in an urban area. The question was “**What sound sources would you expect to hear in the urban area**?”

The second session was conducted to understand the correlation between the perception of sound objects and the overall impression of the soundscape. In this session, participants were asked to rate the overall soundscape and its sound objects on the basis of three soundscape dimension scales (Relaxation, Dynamics, and Communication). This type of question was designed to understand the relationship between participants' ratings of the sound objects in a soundscape and their overall rating of the soundscape. In addition, this approach was used because it is difficult to determine the exact sound level of each sound object in the recording. The participants were asked to listen to each soundscape and imagine themselves in the actual place when rating the soundscape and sound objects. The soundscape recordings were reproduced in random order without informing participants of the locations where the recordings were made.

The questionnaire was designed to examine the ratings of sound objects in a soundscape as well as the overall impression of the soundscape based on three dimensions: relaxation/calmness, dynamics, and communication (the three dimensions that were developed based on reliability analysis of soundscape dimensions in the first step of the research).

The dimensions were related to semantic scales as shown in **Figure 5.2.** The first dimension (Relaxation) was related to perceptions of comfort-discomfort, quiet-noisy, pleasant-unpleasant, like-dislike, gentle-harsh, calming-agitating, and smooth-rough. The second dimension (Dynamics) was related to the perception of hard-soft, fast-slow, sharp-flat, and varied-simple. The third dimension (Communication) was related to the perception of social-unsocial, and communal-private.

In this experiment, participants were asked to rate each sound object along subjective scales, because it is quite difficult to measure their objective parameters. The relationship between the sound objects and the overall rating was analysed by comparing the rating of each sound object to the overall rating.

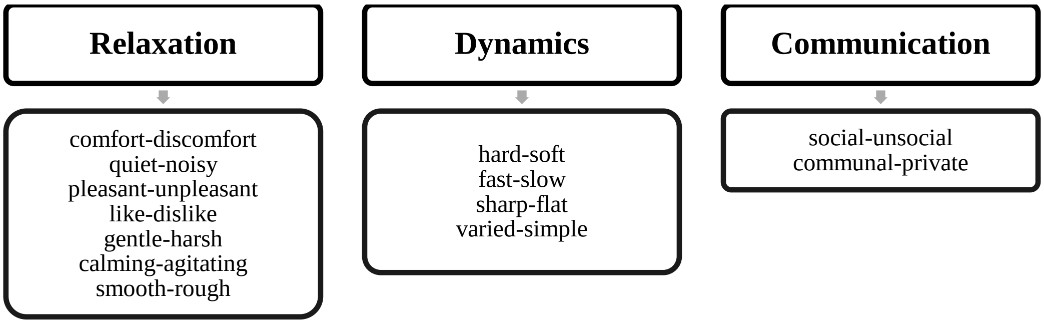


Figure 5-2 Soundscape Dimensions

The questionnaire was developed using Microsoft Excel, as shown in **Figure 5.3**. The participants were asked to rate the overall soundscape as well as the individual sound objects by ticking the selected circles while listening to the recording. An eleven-point continuous rating scale was applied to the anchor of semantic perception.

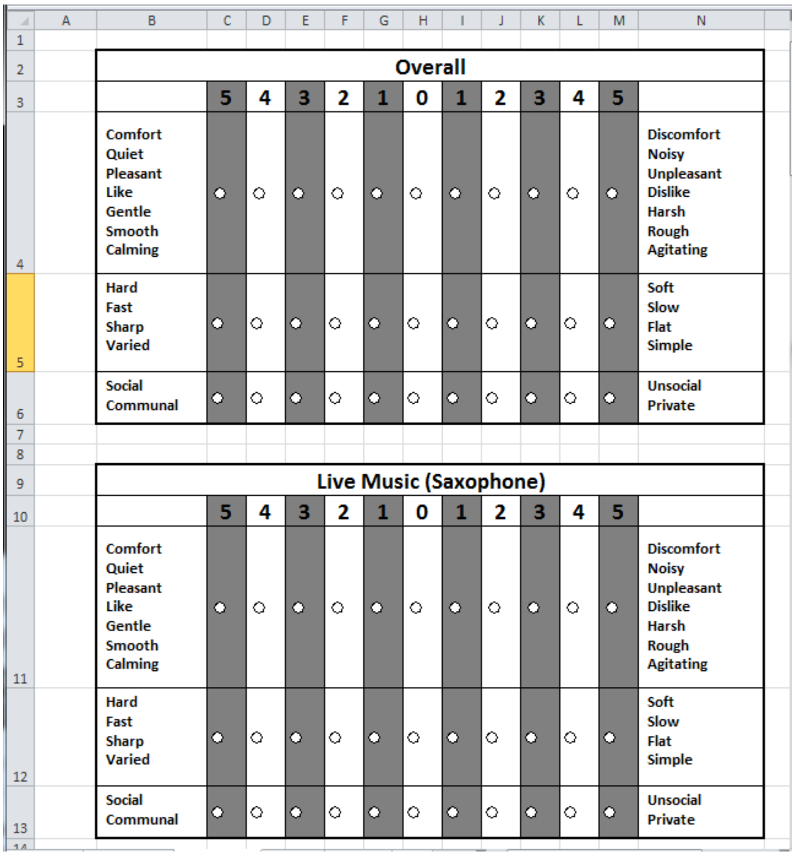


Figure 5-3 Microsoft Excel Interface for Experiment

Before the experiment started, a discussion session was held to explain the scale used in the experiment. Each dimension used in the experiment consisted of several semantic scales, as shown in **Figure 5.3.** The semantic scales were grouped in the questionnaire as they related to the soundscape dimensions, rather than using the dimensions' titles, in order to make it easier for participants to correlate the scales with the dimensions.

5.2.3 Sound Objects

Sound objects in a soundscape can be categorised based on cognitive categories: event sounds and background sounds (Dubois, 2000). Event sounds are the sound of specific events and occur within a short time, while background sounds are the sounds of unspecific events that happen all the time. The categorization of soundscape components from three recordings is shown in **Figure 5.4.** Each soundscape has different dominant background sound: the sound of people talking on Market Street, the sound of a water fountain at St Ann Square, the sound of live music at Piccadilly Garden, the sound of traffic noise at Deansgate, and the sound of construction noise at Exchange Square.

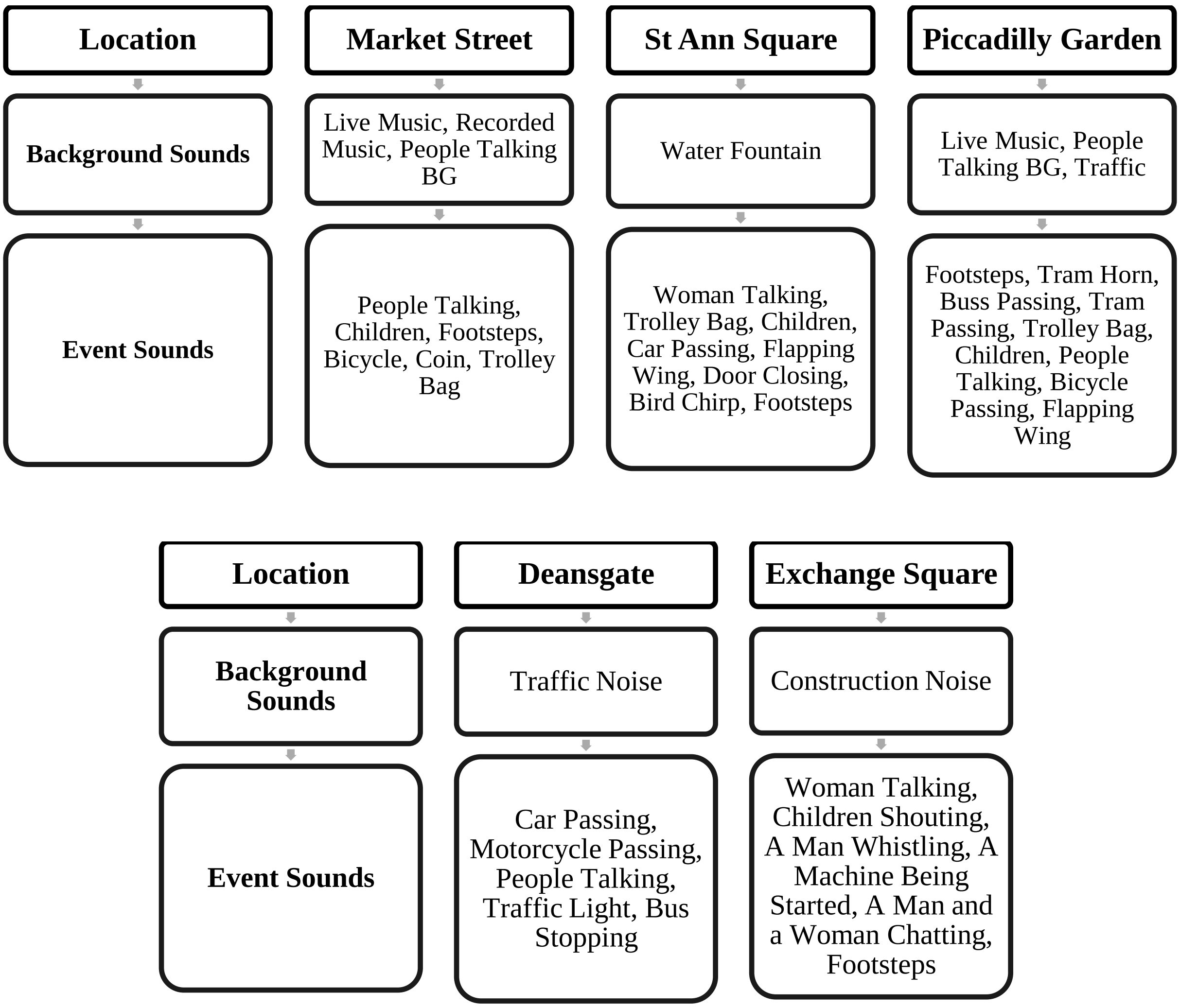


Figure 5-4 Background and Event Sounds in Each Soundscape

The explanation of the sound objects is shown in **Table 5.1.**

Table 5-1 Description of Sound Objects

Market Street

Sound Object	Description
Live music	Someone playing the saxophone
Recorded music	Pop music from a music store
People talking BG	People talking in the background (unclear)
Children	Children shouting
People talking	People talking in the foreground (clear)
Footsteps	Someone walking
Bicycle	Bicycle passing through
Coin	A coin being thrown into a bucket
Trolley bag	A wheeled suitcase being pulled

St Ann Square

Sound Object	Description
Water fountain	Water fountain
Woman talking	Woman talking in the foreground (clear)
Trolley bag	A wheeled suitcase being pulled
Children	A child shouting
Car passing	A car passing through
Flapping wing	A pigeon flapping its wings in flight
Door closing	A car door being closed
Bird chirp	Bird chirping
Footsteps	Someone walking

Piccadilly Garden

Sound Object	Description
Live music	A string instrument being played
People talking BG	People talking in the background (unclear)
Traffic	Vehicle traffic in the street
Footsteps	Someone walking
Tram horn	A tram’s horn
Bus passing	A bus passing through
Tram passing	A tram passing through
Trolley bag	A wheeled suitcase being pulled
Children	Children talking
People talking	People talking in the foreground (clear)
Bicycle passing	A bicycle passing through
Flapping wing	A pigeon flapping its wings in flight

Deansgate

Sound Object	Description
Traffic noise	General urban background noise
Car passing	A car passing close to the microphone
Motorcycle passing	A motorcycle passing at high speed
People talking	Two men passing the microphone in conversation
Traffic light	The ‘beep beep’ sound of a traffic light
Bus stopping	A bus stopping and opening its door

Exchange Square

Sound Object	Description
Construction noise	Sounds of construction machines
Woman talking	A woman talking on her mobile phone while walking
Children shouting	Children shouting to their mother
A man whistling	A man whistling while walking
A machine being started	A compressor machine is started
A man and a woman chatting	A man and woman walking in conversation
Footsteps	Footsteps made by high-heeled shoes

Each of the five soundscapes reproduced in the laboratory featured a different dominant background sound. The Market Street soundscape had people talking in the background as the dominant sound; St Ann Square had a water fountain; Piccadilly Garden had live music; Deansgate had traffic noise; and Exchange Square had construction noise.

5.3 Results and Discussion

5.3.1 Expectations of Sound Objects in a City Centre

Participants' expectations regarding sound objects in the city centre are shown in **Figure 5.5.** Traffic noise, people talking, and music seem to be the most expected sound objects in the city centre (more than 50% of participants selected these sound objects). This result is similar to a study of soundscape expectations conducted by Bruce and Davies (2014), which showed that the most expected sound objects in an urban area are the sounds of traffic and of people. Furthermore, our study indicates that the most expected sound objects in a city centre seem to belong to the category of background sound objects.

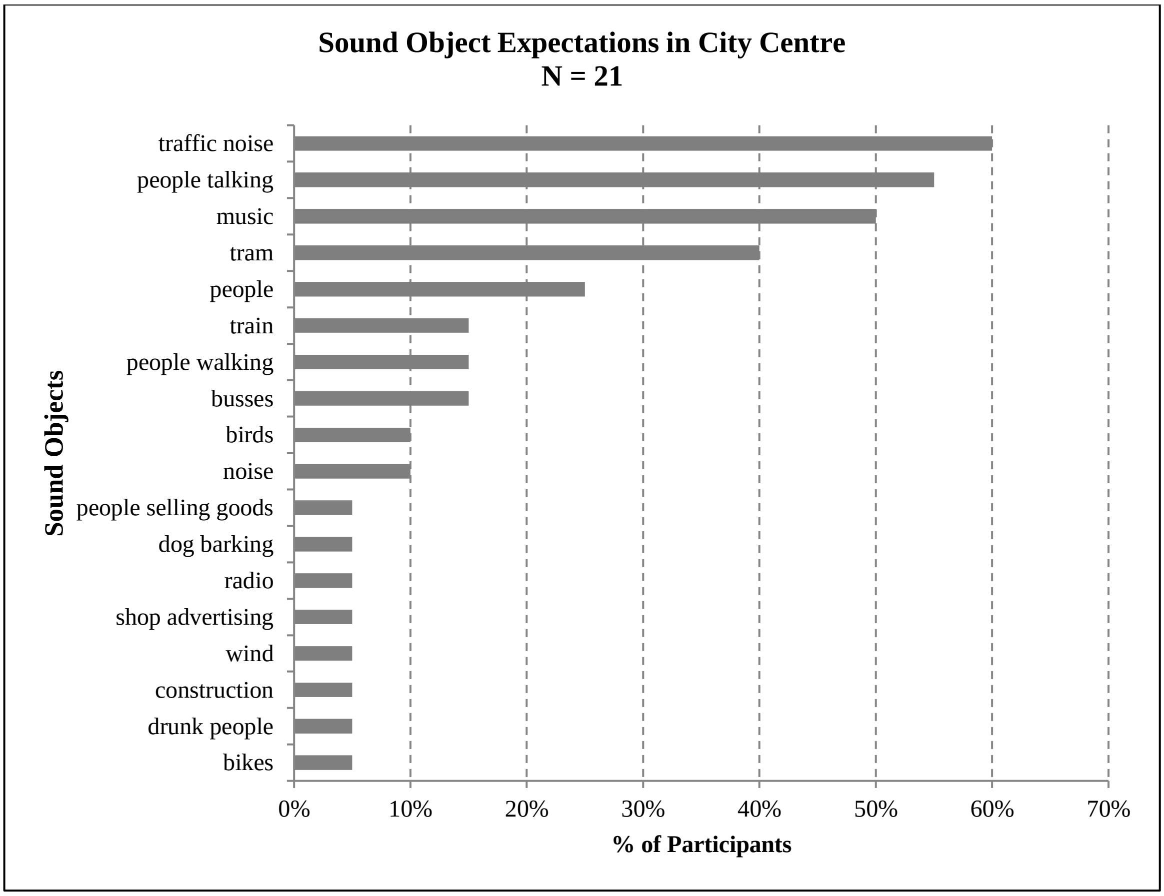


Figure 5-5 Sound Object Expectations in City Centre

5.3.2 Overall Impressions of Soundscape Recordings

The overall impressions of the soundscape recordings according to the scale of relaxation are shown in **Figure 5.6.** The most relaxing recording was the soundscape of St Ann Square, followed by the soundscape of Piccadilly Garden. The dominant sound object in the recording of St Ann Square was the sound of a water fountain, while in the Piccadilly Garden recording, the dominant sound object was the sound of string instrument music. The soundscapes of Market Street (dominated by the sound of people talking in background), Deansgate (dominated by traffic noise), and Exchange Square (dominated by construction noise) are considered neutral on this dimension, as the mean value of the ratings are almost 0 (neutral).

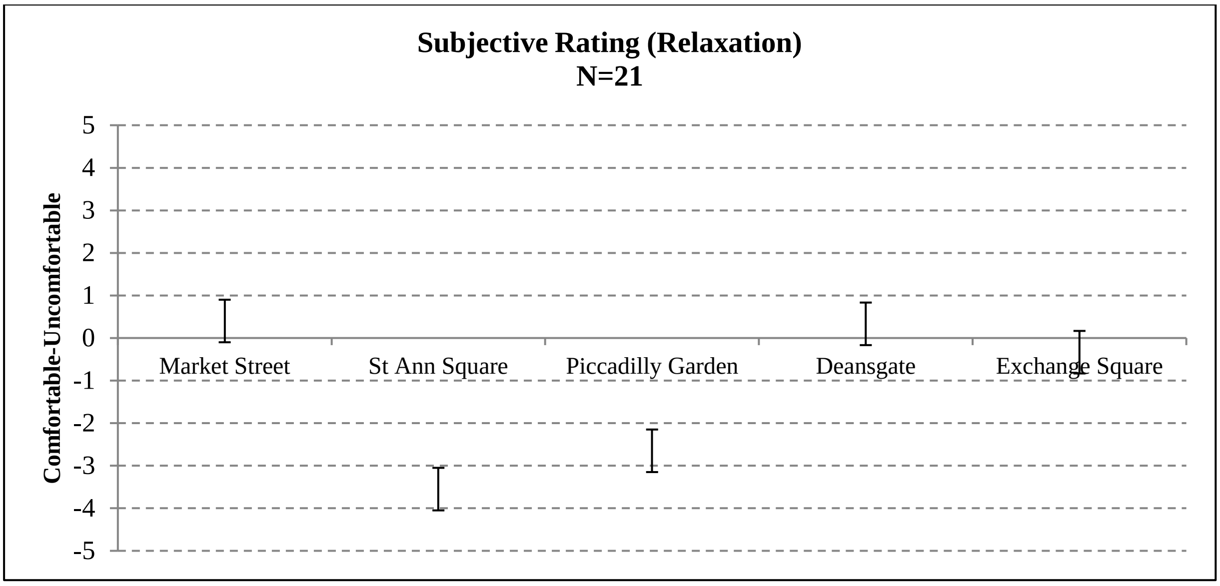


Figure 5-6 Overall Score According to the Dimension of Relaxation

The soundscapes of St Ann Square and Piccadilly Garden may be affected by the sound of a relaxing dominant background sound object (water fountain at St Ann Square, and string music at Piccadilly Garden). A water fountain is typically considered a relaxing sound object. Some participants rated the soundscapes of Market Street, Deansgate, and Exchange Square as uncomfortable soundscapes, although the rating was not high (not more than 1). The ratings indicate that the participants were not feeling too bothered (the ratings were not more than 1) by the soundscapes, even though they were dominated by urban noises.

The overall perception according to the dynamics dimension is shown in **Figure 5.7**. The most varied soundscape was that of Market Street, while the most sparse was that of St Ann Square. The others soundscapes (Piccadilly Garden, Deansgate, and Exchange Square) were considered neutral with respect to this dimension.

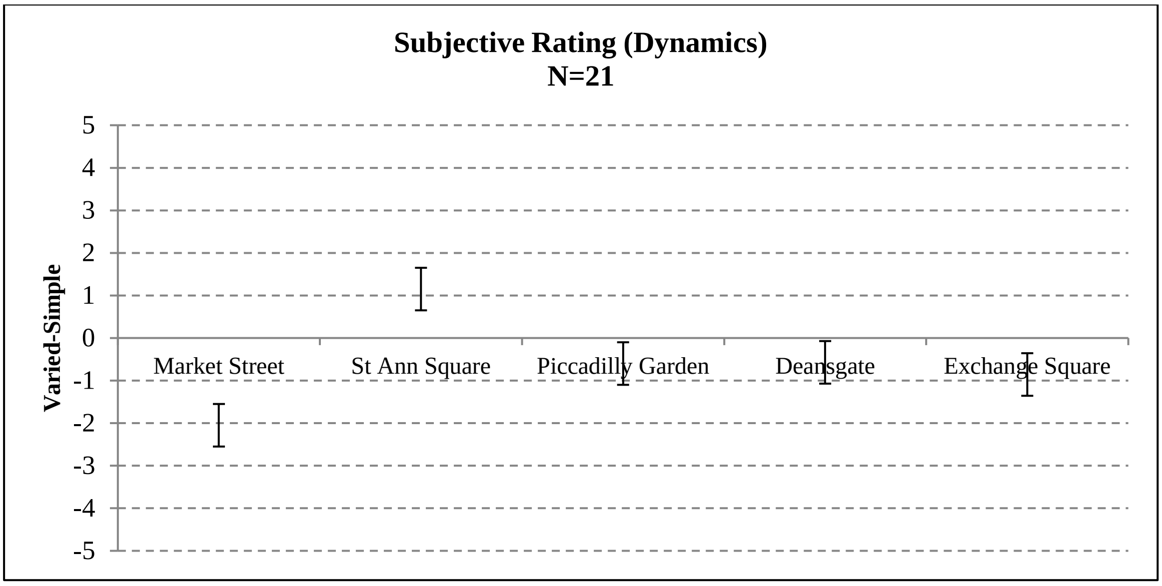


Figure 5-7 Overall Score According to the Dimension of Dynamics

The dynamics dimension may be affected by the number of background sound objects in the soundscape. The soundscape of Market Street, which had the highest number of background sound objects, was the most varied soundscape among the recordings. In the soundscape of St Ann Square, the dominant background sound was that of a water fountain, and this constant sound might have caused the participants to experience it as a simple soundscape.

The overall impression according to the dimension of communication is shown in **Figure 5.8**. The soundscape of Market Street imparts the most communal feeling. The soundscapes of Piccadilly Garden, Deansgate, and Exchange Square are also considered communal soundscapes, although their ratings were not as high as Market Street. The soundscape of St Ann Square was considered neutral on this dimension, with a mean value of 0.1.

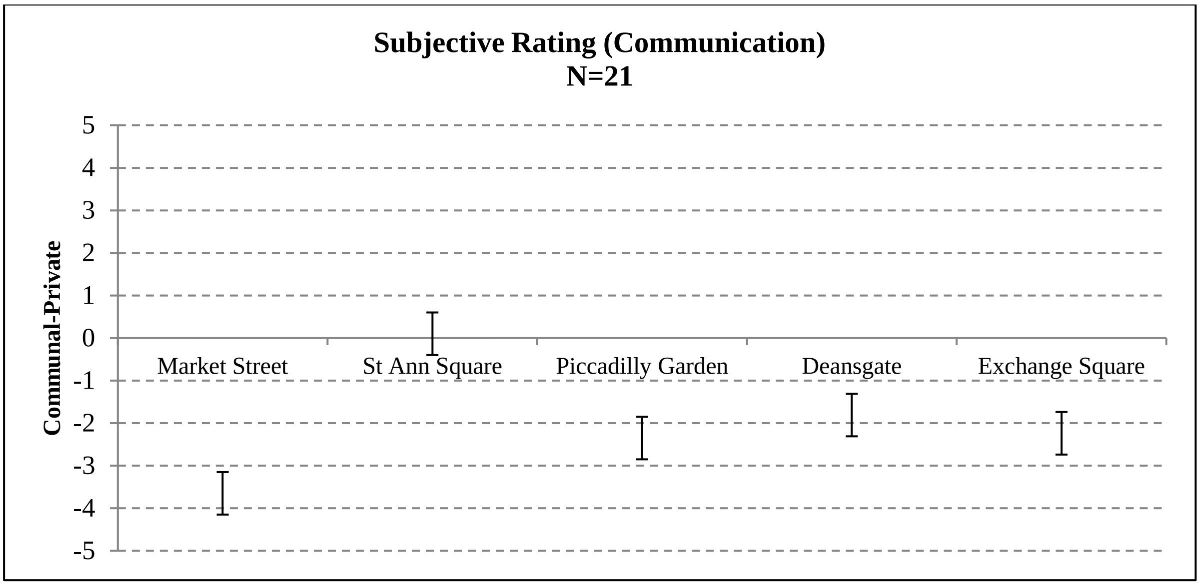


Figure 5-8 Overall Score According to the Dimension of Communication

The communal soundscapes might be affected by the amount of human activity in the locations, especially in the background sound. The soundscape of St Ann Square was dominated by a natural sound (running water in a fountain), while the other soundscapes were dominated by the sounds of human activity (people talking, music, traffic noise, and construction noise).

5.3.3 The Perception of Sound Objects

The perception of sound objects in Market Street based on soundscape dimensions is shown in **Figure 5.9.** The sounds of children, live music, footsteps, and a bicycle – in other words, sounds related to human activity – are considered to be slightly relaxing here. The scores along the dynamics dimension show that participants tend to rate the sounds of children, live music, and recorded music as slightly varied sound objects. On the other hand, the bicycle sound is considered to be slightly simple. The sounds of people talking, children, and people in the background are identified as communicative sound objects. The sound of live music is perceived to be a slightly communicative sound object. In addition, sound objects related to human speech are recognised as communicative.

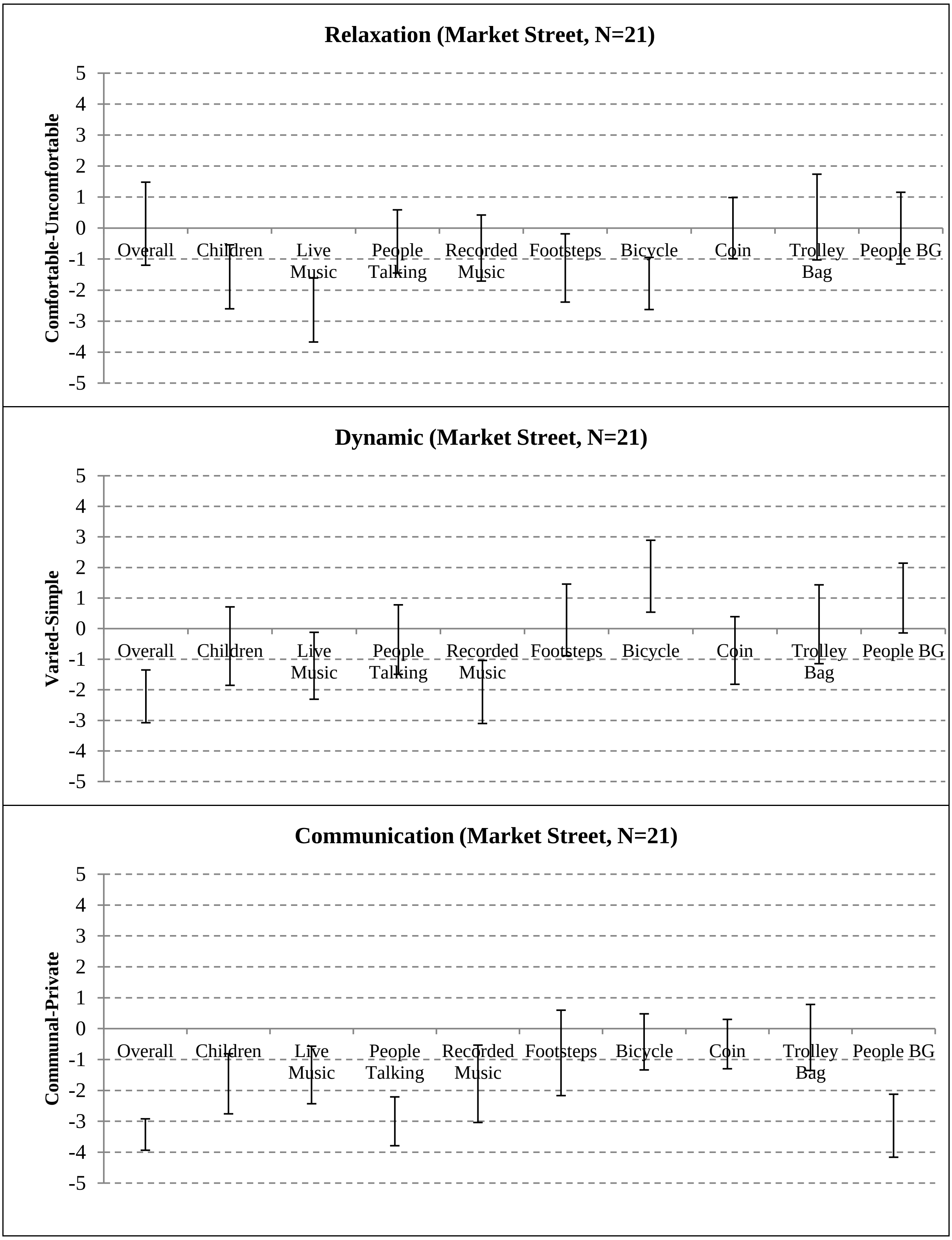
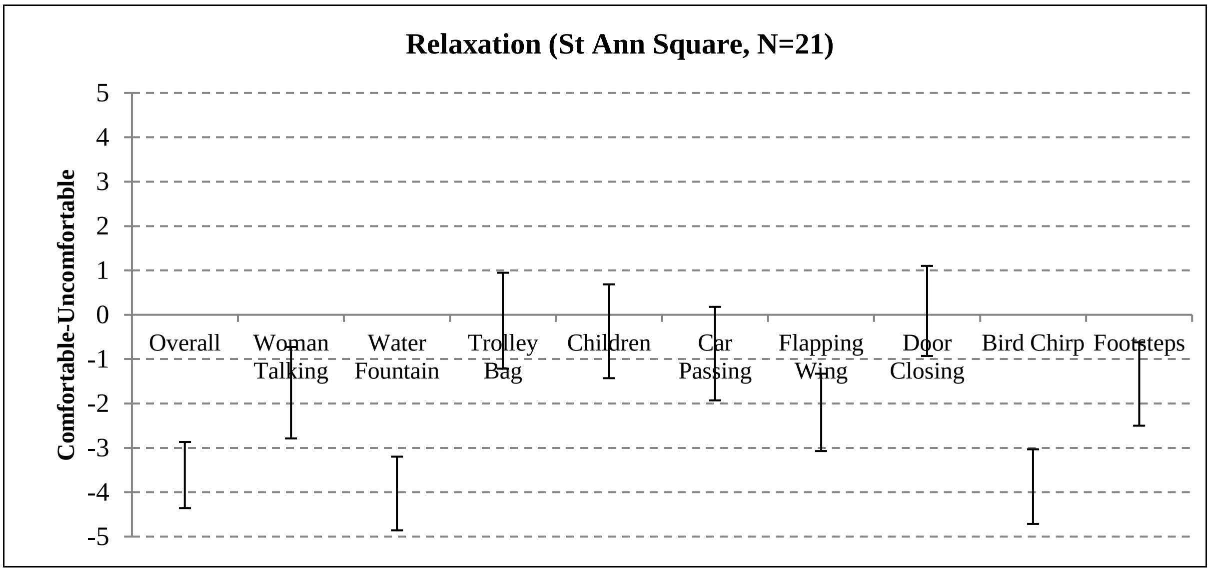


Figure 5-9 Scores of Sound Objects in Market Street

The perception of sound objects in St Ann Square is shown in **Figure 5.10.** The soundscape of St Ann Square was considered the most relaxing soundscape of the five, as it includes two sounds that are considered relaxing: the sounds of the water fountain and of birds chirping.

The result demonstrates results similar to the study by Jeon et al. regarding perception of water sounds (Jeon et al., 2012), and to the study of Hong & Jeon regarding perception of bird sounds (Hong & Jeon, 2013). Other sounds related to human activity, such as a woman talking and footsteps, are also considered slightly relaxing sounds. The sound of bird wings flapping was also judged to be slightly relaxing, which is consistent with previous findings that natural sound is perceived to be relaxing (Brambilla et al., 2013), (Axelsson et al., 2010).

Most of the sound objects in St Ann Square were judged to be neither varied nor simple. The sound of water fountain seems to be judged as a simple sound, while the sound of children is considered varied. The judgements of sound objects that associate with the communication dimension here are consistent with those from Market Street. The sound of a woman talking and the sound of children are perceived as slightly communal sounds.



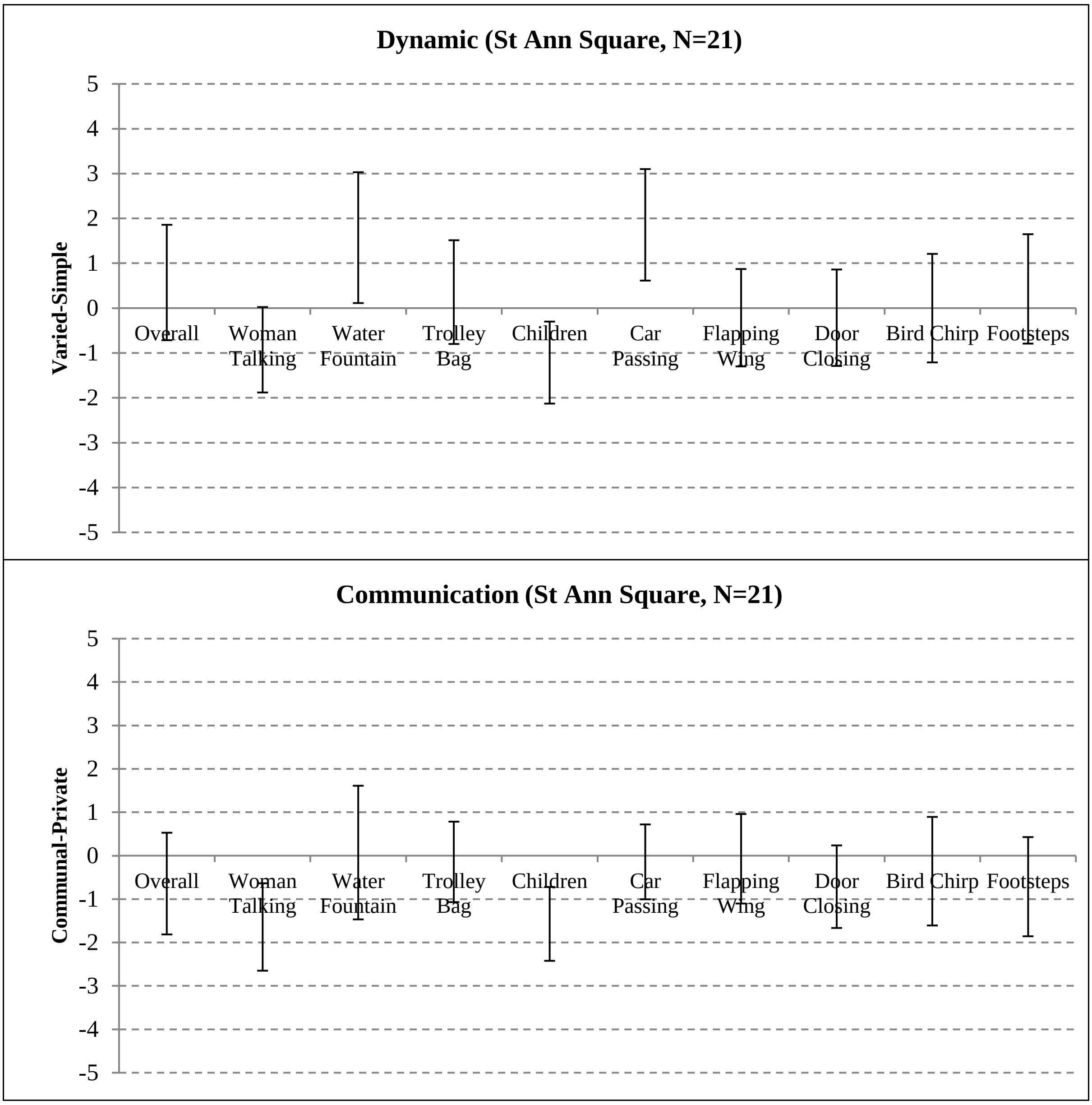
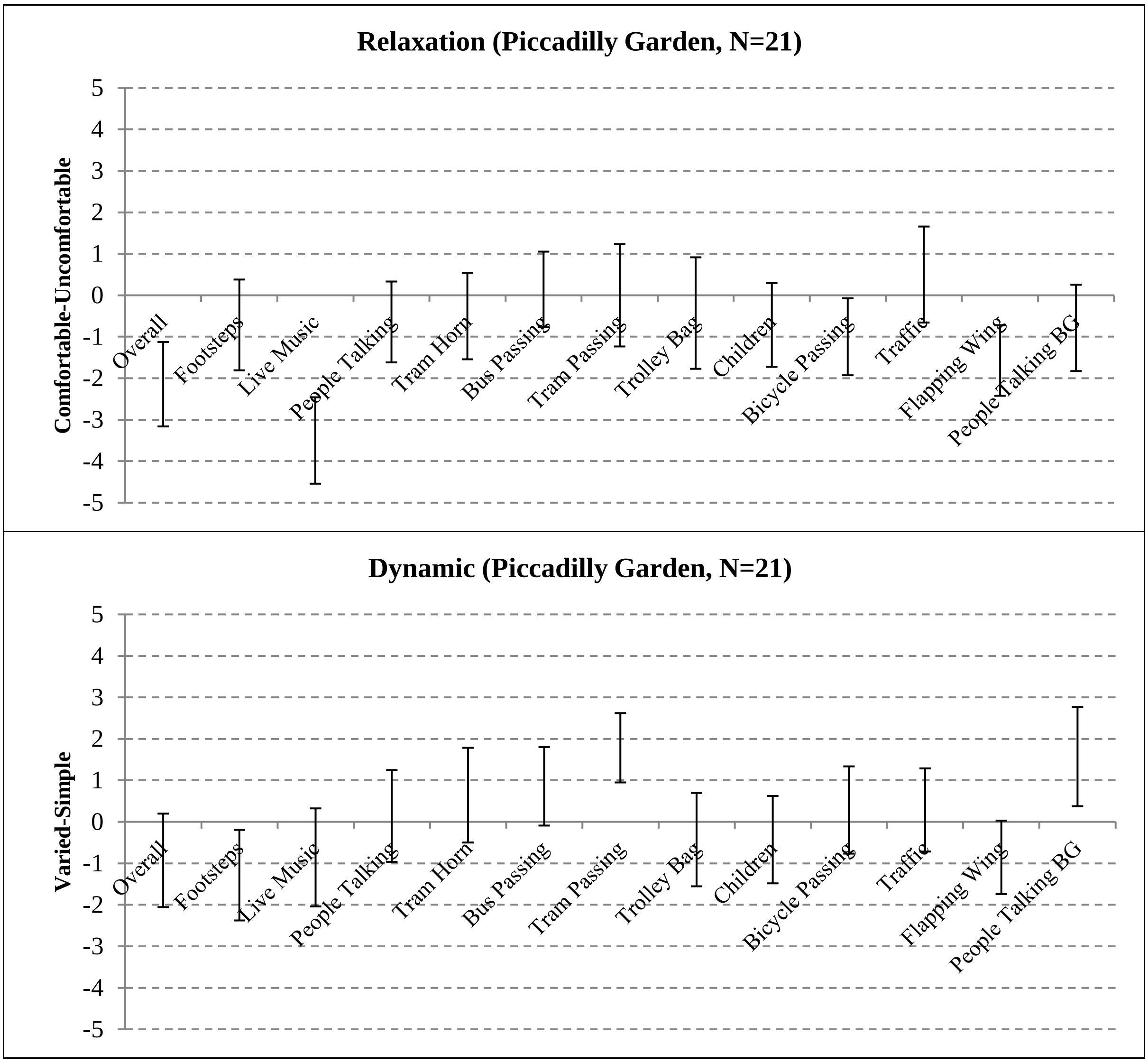


Figure 5-10 Scores of Sound Objects in St Ann Square

The perception of sound objects in Piccadilly Garden is shown in **Figure 5.11.** The live music – a string instrument being played – is considered to be the most relaxing sound in this location. The sounds related to human speech, such as people talking in the background, children, and people talking in the foreground are considered to be slightly relaxing sounds. The sound of flapping bird wings is also perceived as slightly relaxing.

Event sounds related to traffic (the sound of a tram horn, a bus passing, and a tram passing) are perceived to be less dynamic. The same was true of the sound of people talking in the background. In contrast, the sound of foreground speech (such as the sound of children, and of people talking) is considered to be a slightly more dynamic sound object.

The data from Piccadilly Garden indicates that all soundscape components related to human activity and traffic are considered to be communal sounds. The natural sound object (the sound of flapping wings) is considered to be a less communal sound object. The highest communal sound rating was given to the sound object most associated with human speech.



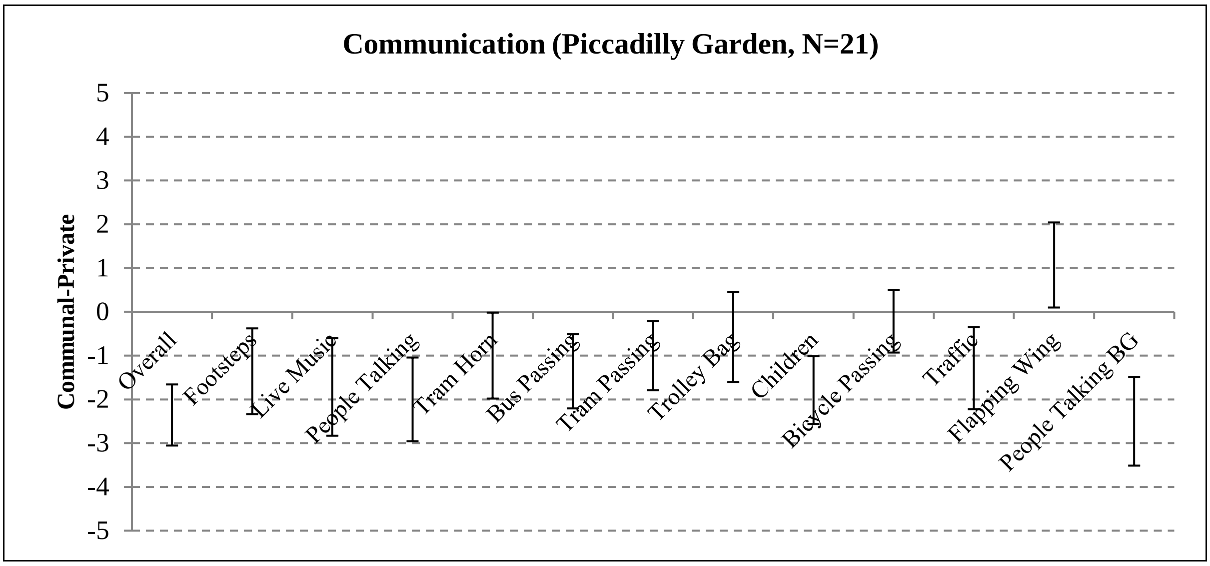


Figure 5-11 Scores of Sound Objects in Piccadilly Garden

The soundscape at Deansgate was dominated by traffic noise. The rating of the sound objects in the recording is shown in **Figure 5.12.** Most of the sound objects in the recording were rated as uncomfortable sound objects. The sounds of people talking, a car passing, and the traffic light were judged as comfortable sound objects, while the others, which were considered to be part of the traffic noise, were rated as uncomfortable. Deansgate was rated as a varied soundscape. The sound of a motorcycle passing was rated as the most varied sound object in the recording. The other sound object that was rated as varied was the sound of people talking, although the rating was not as high as that of the motorcycle. The simplest sound object in the Deansgate soundscape was the sound of the traffic light. All of the sound objects in the Deansgate soundscape were rated as communal, possibly because they were related to human activities.

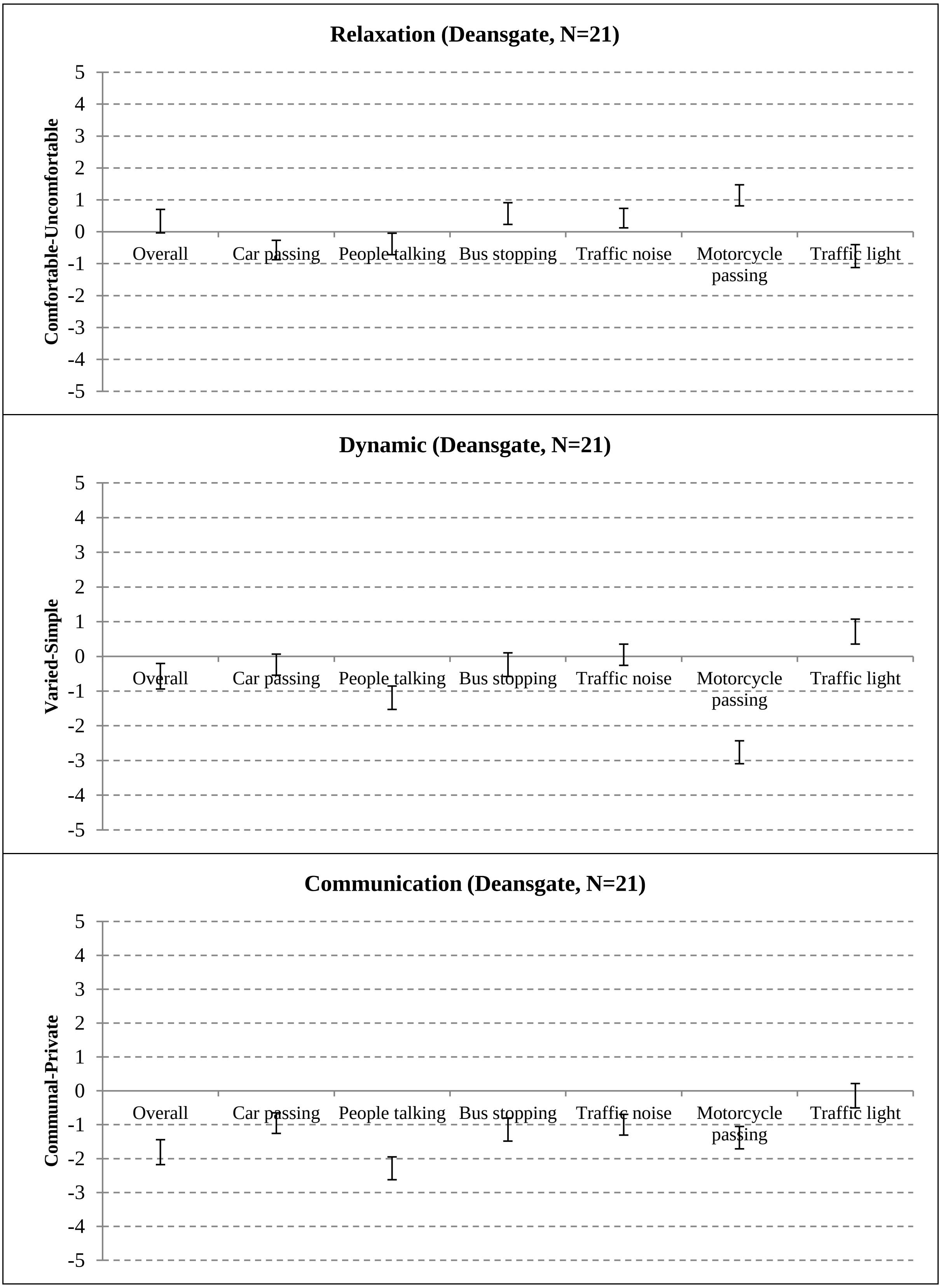
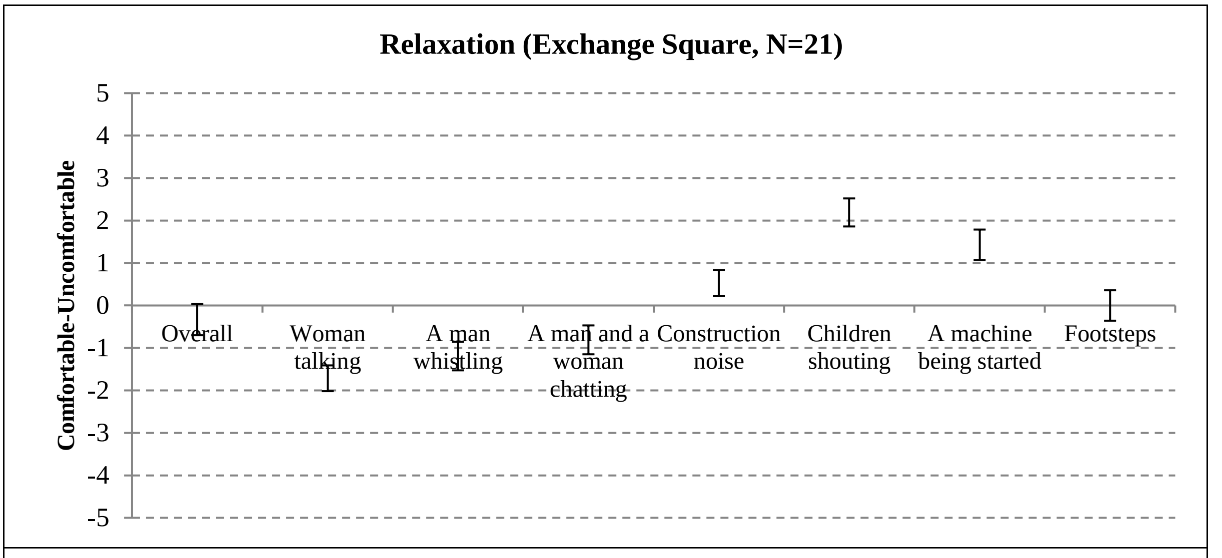
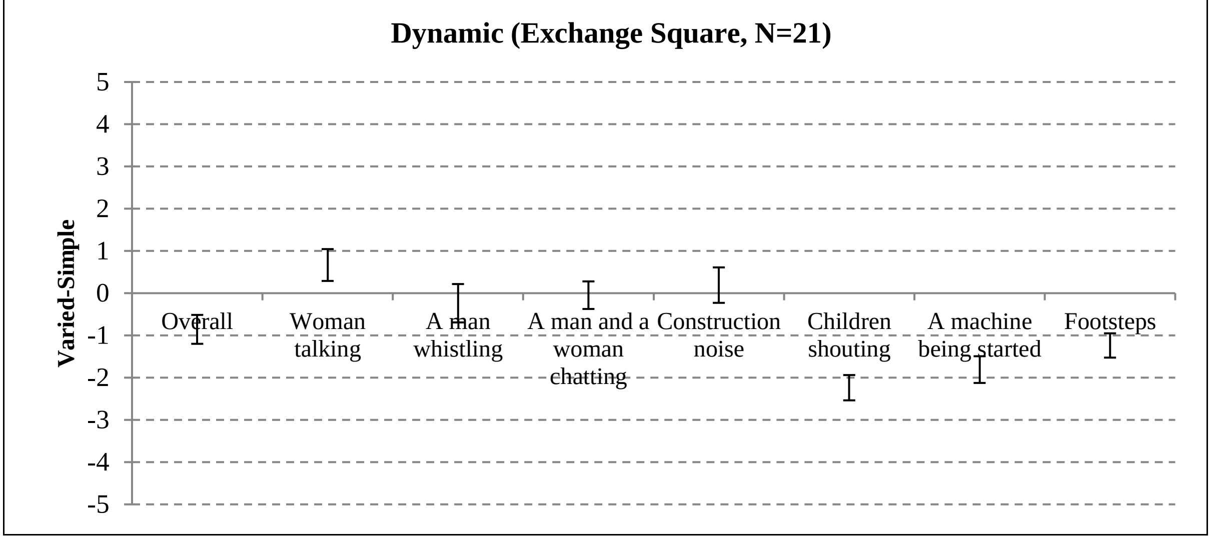


Figure 5-12 Scores of Sound Objects in Deansgate

The rating of sound objects in Exchange Square is shown in **Figure 5.13.** The sound objects in Exchange Square that related to the sounds of human activity, such as the sound of a woman talking, the sound of a man whistling, and a man and woman chatting, were rated as comfortable sound objects. The sound of children shouting was the only sound object related to human activity that was considered uncomfortable. The sounds of a woman talking and of construction noise were considered simple sound objects, while the other sound objects were rated as varied. All of the sound objects in Exchange Square were rated as communal, perhaps because all were related to human activity.





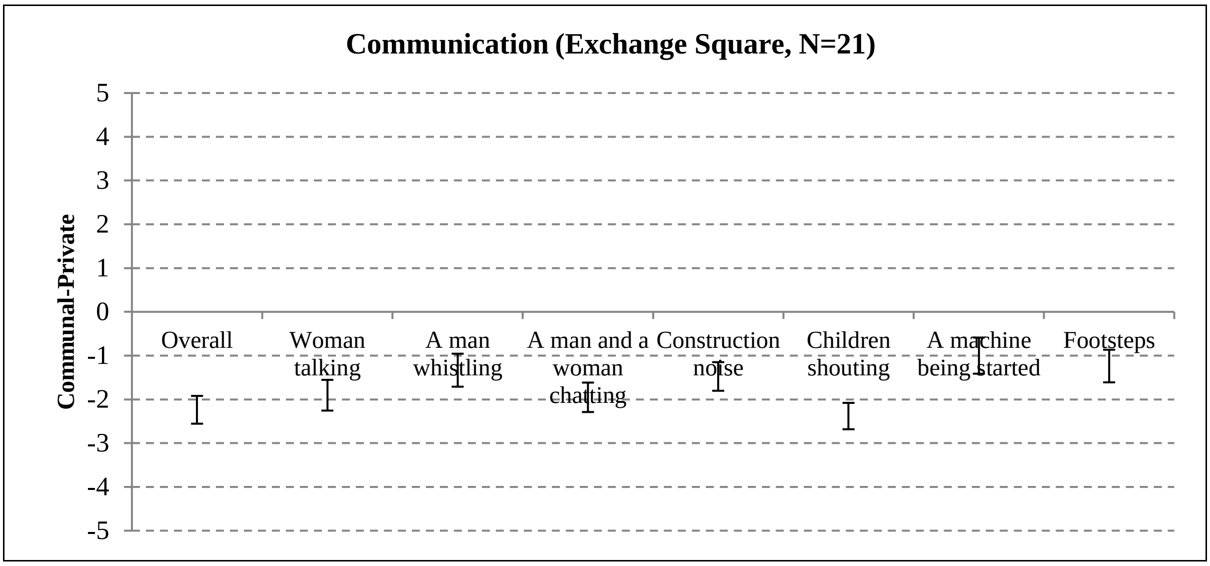


Figure 5-13 Scores of Sound Objects in Exchange Square

In general, the sound objects that related to human activity, as well as the natural sound objects, were rated as comfortable. This result is consistent with previous findings about the categorization of sound objects, which showed that natural sounds are considered to be relaxing (Axelsson et al., 2010; Brambilla et al., 2013). The sounds of machinery, traffic, and construction were rated as uncomfortable sound objects, just as was found in previous studies (Dubois, 2000; Dubois et al., 2006; Catherine Guastavino, 2006; Hall et al., 2013; R. Pheasant et al., 2008).

Sound objects representing human activity, such as speech and music, were rated as varied. This is consistent with a study conducted by Axelsson, which found that sounds related to human beings would be considered eventful (Axelsson et al., 2010).

The sound objects related to human activity also seem to be judged as communal. Furthermore, sound objects that are associated with human speech are considered more communal than other sound objects that represent human activity.

5.3.4 Correlations between the Perception of Sound Objects and Overall Impression

An analysis to determine the relationship between the ratings of sound objects and overall perceptions was done using Forward Linear Regression. Forward Linear Regression is a stepwise linear regression which adding one variable on each iteration. The prediction models show moderate Pearson's Correlation Coefficient (0.5-0.8) and, interestingly, that soundscape dimension ratings are significantly affected by the perception of a few soundscape components.

In general, the dimension of relaxation is affected by the perception of natural sound (flowing water), human activity (people talking and the sound of live music), and urban noise (traffic noise and construction noise). The dimension of dynamics is affected by the perception of human activity (people talking, people in the background, and live music) and urban noise (traffic noise and construction noise). The dimension of communication is affected by the sound of human activity, especially the sound of people talking.

Table 5-2 Prediction Model of Sound Objects and Soundscape Dimension Ratings

Relaxation

No	Location	Model	Pearson's Correlation
1	Market Street	0.749*People BG + 0.363	0.647
2	St Ann Square	0.474*Water Fountain - 1.655	0.638
3	Piccadilly Garden	0.504* Live Music - 0.936	0.516
4	Deansgate	0.824*Traffic Noise - 0.20	0.872
5	Exchange Square	0.621*Construction Noise - 0.658	0.516

Dynamic

No	Location	Model	Pearson's Correlation
1	Market Street	0.448*People Talking - 1.871	0.585
2	St Ann Square	0.971*People BG +0.130	0.835
3	Piccadilly Garden	0.519*Live Music -0.133	0.544
4	Deansgate	0.755*Traffic Noise -0.607	0.764
5	Exchange Square	0.512*Construction Noise – 0.955	0.627

Communication

No	Location	Model	Pearson's Correlation
1	Market Street	0.303*People Talking+0.187*Footsteps - 2.518	0.722
2	St Ann Square	0.682*Woman Talking + 0.986	0.611
3	Piccadilly Garden	0.460*People BG - 1.316	0.668
4	Deansgate	0.939*Bus Stopping - 0.737	0.806
5	Exchange Square	0.688*Construction Noise + 0.315*Woman Talking - 0.622	0.819

Although the model generated shows the relationship between the perception of sound objects in the simulator and the rating of soundscape dimensions, the relationship is limited to only one soundscape.

In this study, soundscape recordings were used and the participants are requested to rate both the individual sound objects and the overall perception. The general perception of several soundscape can be determined if there is an overlap of sound objects between the recordings. This study (using five recordings) shows limited overlap of the sound objects. Also, even if there is overlap sound objects, the sound objects have different sound level. The different sound level might affect how the participants rate the sound objects in a soundscape.

The comparison between soundscapes in this study is challenging due to two factors: the different sound level of sound objects, and the overlapping of sound objects between soundscape. It seems that the application of soundscape recording cannot be used to understand the relationship between specific sound objects and the perception of the soundscape.

5.4 Conclusion

The overall judgement of soundscape in this study indicates results similar to the study conducted by Axelsson et al. (Axelsson et al., 2010). Axelsson et al. discovered that a soundscape dominated by natural sound has a positive relationship to the dimension of pleasantness (similar to the relaxation dimension in this study), while a soundscape dominated by human sound has a positive relationship to the dimension of eventfulness (similar to the dimension of dynamics in this study).

This study of soundscape rating and sound objects using reproduced soundscape has demonstrated the relationship of sound object ratings to overall ratings for individual soundscapes, but not for a general urban soundscape. The linear model gathered in the experiment applies only to the specific samples, and the relationship between specific sound objects and soundscape dimensions in an urban soundscape remains unclear. This is because the sound level of each sound object in the soundscape can be neither measured nor controlled in the soundscape. Also, the sound objects in a soundscape are not overlapped in the different soundscape, so the general interpretation is hard to determined.

Based on these results, it was concluded that further study using simulated soundscape should be conducted such that the sound level and selection of sound objects in the soundscape could be controlled. The next chapter will discuss the development of a soundscape environment simulator in order to create this kind of composed soundscape.

6 Soundscape Environment Simulator as a Tool to Investigate Expectations and Preferences of Sound Objects in a Soundscape

6.1 Introduction

A soundscape environment simulator is a system that facilitates soundscape environment design by controlling the parameters of sound objects (both background and event sounds), allowing participants to compose a soundscape according to their expectations. A soundscape environment simulator was developed by Davies et al. based on the concept of background and foreground sound (Davies et al., 2014). The background sound consisted of a soundscape recording made using a soundfield microphone, and the foreground sounds were recorded individually in mono. This simulator was able to successfully replicate a simple soundscape in the laboratory. Another soundscape environment simulator was developed to imitate the sounds of road and railway traffic (Lundén et al., 2010), and was able to imitate the movement of vehicles and trains in the laboratory.

Despite these early developments, these soundscape environment simulators were not able to compose a complex soundscape, and the validity of the simulated soundscapes was not analysed. In this study, a soundscape environment simulator was designed that would simulate complex soundscapes, and the validity of the simulated soundscapes was investigated.

6.2 Development of the Soundscape Environment Simulator

A soundscape environment simulator was developed in this study for the purpose of composing complex soundscapes. A complex soundscape is one that consists of both background sound objects and event sound objects, and that can stand in for an actual soundscape. Furthermore, the behaviour of each of the sound objects, such as its position, sound level, and movement, should be imitated in the simulator.

The soundscape environment simulator was developed using three concepts: background-event sound objects, the structured perspective in soundscape composition, and the object-oriented concept.

The background-event sound objects concept was implemented in the soundscape environment simulator developed by Davies et.al (Davies et al., 2014), where it was based on the general categorisation of sound objects in a soundscape (Dubois, 2000). Background sound objects are sounds in the background that appear throughout a soundscape, whereas event sound objects are sounds that define a specific event.

The structured perspective in soundscape composition was introduced by Truax (Truax, 2002). It includes three perspectives that should be implemented in order to compose a soundscape: the fixed spatial perspective, the moving spatial perspective, and the variable spatial perspective. The fixed spatial perspective states that a soundscape is formed by sound objects in time; the moving spatial perspective relates to the imitation of moving sound objects in the composition; and the variable spatial perspective relates to the presence of several simultaneous sound objects. The fixed spatial perspective was implemented in the present soundscape environment simulator by using a long recording of background sound, not a short-repeated sample, because listeners need to perceive the flow of the sound objects in time. The spatial movement of the sound objects was imitated using an automated ambisonic panner. The presence of simultaneous sound objects was implemented using multi-track playback in the simulator.

The object-oriented concept was implemented in this simulator by considering three sound object behaviours: the position of sound objects (for static sound objects), the sound level of sound objects, and the movement of sound objects. The position of sound objects was imitated using an ambisonic panner by controlling the azimuth parameter; the sound level of sound objects was controlled by adjusting sound level parameters; and their movement was imitated by automating the azimuth parameter in the ambisonic panner.

The context in a soundscape indicates the interaction in space and time between individuals, his/her activity, and the location (International Organization for Standarization, 2013). The context affects the soundscape via the factors: auditory sensation, the interpretation of the auditory sensation, and the response of the soundscape. The auditory sensation represents the hearing process that starts with the sound coming from the ear up to the neurological response. The interpretation of the auditory sensation represents the process of interpreting the audio signal which creates the understanding the soundscape. The response of the soundscape represents the effect of the soundscape and the feeling that arises from the acoustic environment.

The soundscape environment simulator is created to measure the interaction between the interpretation of auditory sensation of and the response to the acoustic environment composed in the simulator specifically in the urban area. The context of urban environment is considered in this experiment by choosing the sound objects which represent urban area. The selection is base on the data from literature (the sound of people and traffic noise)(N. S. Bruce & Davies, 2014), from the result of **Chapter 5** about the expectation of sound objects in urban area, and from the sound objects identified in the soundscape recording used in **Chapter 5**. The context of urban soundscape is emphasised by requesting the participant to compose soundscape that represents the urban area. The definition of the urban area is also explained prior to the experiment as “the area that represents a town or a city”.

This simulator is designed by considering the factors that related with the soundscape context. The periphonic reproduction system (to reproduce the movement and position of the sound object) is implemented to imitate the auditory sensation from the actual sound environment. The interpretation of auditory sensation is considered by including sound object recording that isolated from the other sounds and by allowing the participants to adjust the level of the sound objects. Also, since the simulator is built to measure the relationship between the interpretation of auditory sensation and the response of the soundscape, the participants are requested to rate the soundscape composition according to the soundscape dimensions.

Although the development of soundscape environment simulator put emphasis on the context of the soundscapes, the simulator still has some limitations. The simulator can only be used to compose one minute of the soundscape, and the composition is looped. This system might only be used to understand the response of general perception but not the specific perception such as the recognition of certain space. The recording of sound objects in this simulator includes reverberation since all the recordings are made outdoor or in a normal room. The soundscape environment simulator is still not able to simulate the interaction between the sound objects and the environment. This simulator can only simulate the acoustic environment and not the visual environment.

The soundscape environment simulator was designed using Digital Audio Workstation (DAW) software because DAW software has suitable functionality for the task of building such a simulator: a multi-track system, implementation of the Virtual Studio Technology (VST) plug-in in every track, implementation of multi-channel output, parameter automation, multi-channel routing in every track, real-time signal processing, and MIDI controller input.

The multi-track system allows several sound objects to be played at the same time, and could be used to expand the system to include more sound objects. The implementation of the VST plug-in in every track allows different effects or behaviours to be implemented in each sound object. The implementation of multi-channel output offers flexibility in reproducing the output, permitting the use not only of stereo systems, but also multi-channel ambisonic or surround systems. Parameters automation is used to imitate the movement of sound objects. The multi-channel routing is very useful, since we apply B-format signals (four channels) in the simulator. Real-time signal processing allows the user to compose and listen to the soundscape composition in real time. The MIDI controller input allows the DAW software to be controlled by a MIDI controller or a custom interface.

The soundscape environment simulator developed for this study has several advantages compared to the previous simulator developed at Salford by Bruce et al. in 2009 (N. S. Bruce et al., 2009). First, the interface is simpler and more intuitive compared to the previous simulator, which used a DAW controller. Second, this simulator can be designed to use up to 90 sound objects, because Reaper (the DAW software used in this study) can handle 90 tracks and the interface can be customised. Third, this simulator has the flexibility to use different reproduction systems because it uses B-format signals, which can be decoded into systems as varied as stereo, pantophonic, periphonic, or surround system. Fourth, it reproduces in real-time, so the user can listen to their soundscape composition while manipulating its constituent sound object parameters. Fifth, it enables the result of the composition to be recorded for later reproduction.

6.2.1 System Setup

The soundscape environment simulator system consists of three main devices as shown in **Figure 6.1**: a personal computer (PC), an audio interface, and speakers. It was developed using a pantophonic reproduction system, since the validity of this reproduction system was tested and confirmed earlier in the study. The reproduction system consisted of eight Genelec 1029A speakers connected to an RMA ADI-8DS and an M-Audio Profire Lightbridge Audio Interface.

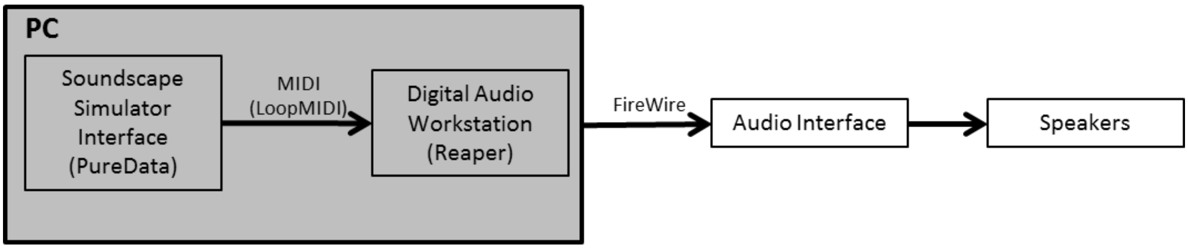


Figure 6-1 The Soundscape Environment Simulator System

Three programs are applied in this simulator: PureData, LoopMIDI, and Reaper. PureData was utilised to create the simulator interface and the Digital Audio Workstation (DAW) controller. The interface made in PureData is connected to DAW software (Reaper) using LoopMIDI. In Reaper, the parameters connected to PureData objects must be assigned manually. The simulator is built up in Reaper DAW software using the Wigware VST ambisonic plugin developed by Bruce Wiggins (Wiggins, 2010): a Wigware ambiPan x-y 1-3D ambisonic panner and Regular Shape 1st order ambisonic decoder.

6.2.2 The Soundscape Environment Simulator Interface

The interface for the soundscape environment simulator was developed using PureData, and it is basically a custom Digital Audio Workstation (DAW) controller that controls selected parameters in the DAW software. There are three areas in the simulator, as shown in **Figure 6.2**: the rating area (light grey background), the background sound objects (blue background), and the event sound objects (dark grey background).

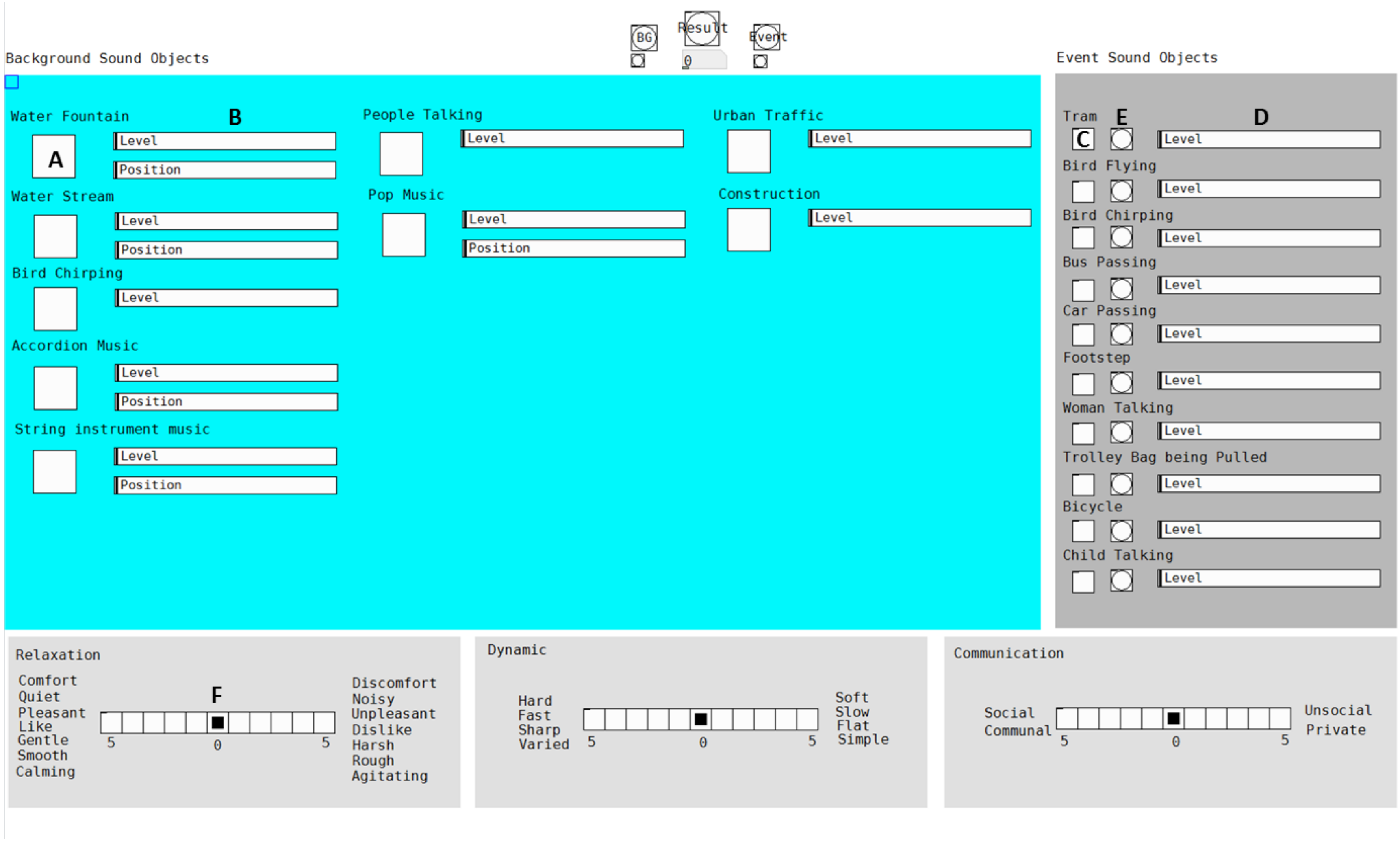


Figure 6-2 The Soundscape Environment Simulator Interface (A and C=toggle object, B and D=hslider object, E=bang object, and F=hradio object)

The rating area is for the composer to rate the soundscape composition. The composer rates the soundscape by clicking the appropriate box on the hradio object (marked as '**F**' in **Figure 6.2**). The simulator saves the rating as a value between 1 and 11, and that value is later translated into a rating between -5 and 5.

There are two types of sound objects in this soundscape environment simulator: background sound objects and event sound objects. Background sound objects are those that appear throughout a soundscape, while event sound objects are those that appear just once in a soundscape. There are two tabs in the DAW software, as shown in **Figure 6.3**: one for background sound objects tab and one for event sound objects.

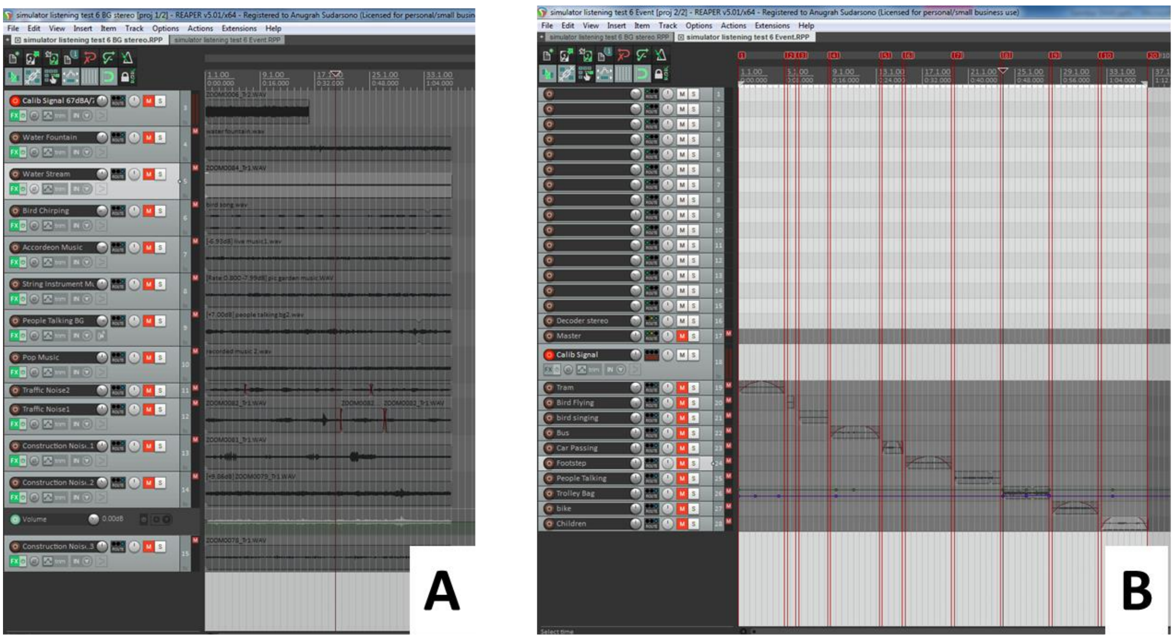


Figure 6-3 The Tabs in DAW Software
(A=background sound objects tab, B=event sound objects tab)

The background sound objects are controlled using toggle objects (marked as '**A**' in **Figure 6.2**), and hslider objects (marked as '**B**' in **Figure 6.2**). The code for these objects is shown in **Figure 6.4.** When the toggle object is clicked, it sends a message to the DAW software to go to the background sound objects tab and send another message to the mute button (shown by code started with "r mute1"). The hslider object works similarly to the toggle objects, by sending a message to go to the background sound objects tab and then control a certain button in the DAW software, but instead of sending a "1" or "0" message (i.e. "on" or "off"), it sends a value between 1 and 127. The first hslider object controls the sound level parameter, where the output value (1 to 127) represents a level of between -∞ to +12. The second hslider object controls the azimuth of ambisonic panning, where the output value (1 to 127) represents an azimuth of between 0˚ and 360˚.

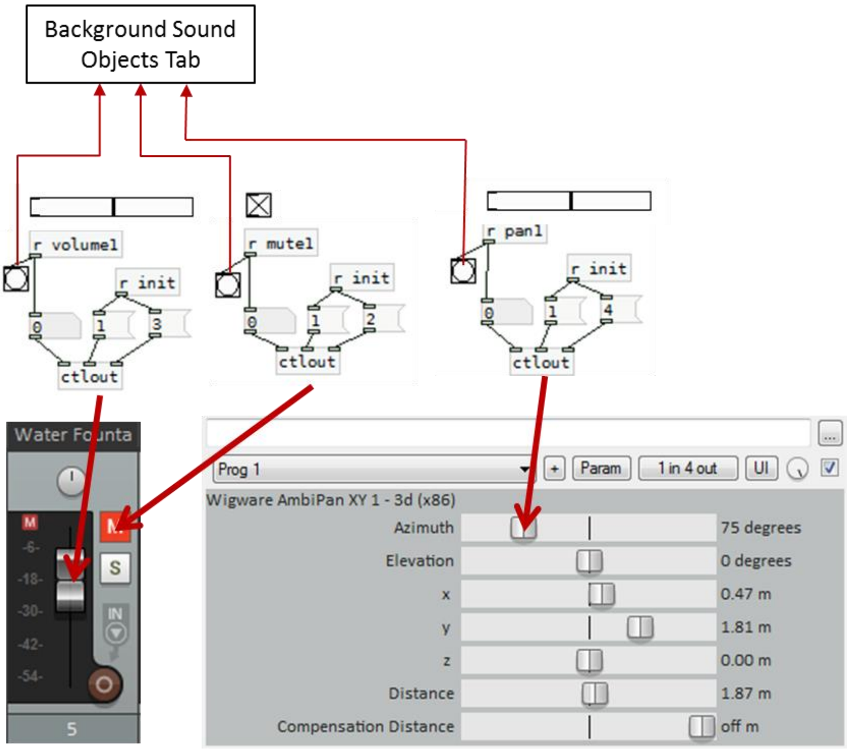


Figure 6-4 PureData Code for Background Sound Objects

The event sound objects are also controlled using a toggle object (marked as '**C**' in **Figure 6.2**), hslider object (marked as '**D**' in **Figure 6.2**), and bang object (marked as '**E**' in **Figure 6.2**). The code for the event sound objects controller is shown in **Figure 6.5**. The toggle object is used to control the mute button, and the hslider object is used to control the sound level button, both on the DAW software. The hslider and toggle object in the event sound object controller work just like the background sound objects controller, but instead these objects send the message to go to the event sound objects tab.

Another element added to control the event sound objects is called a bang object. This object allows the user to play the event sound objects while the background sound objects are still playing. The code is shown in **Figure 6.5** on the left side. When the bang object is clicked, it sends a message to the DAW software to go to the event sound objects tab, send another message to go to a certain marker, and play the sound objects beginning at the marker. The sound automatically stops on the next marker.

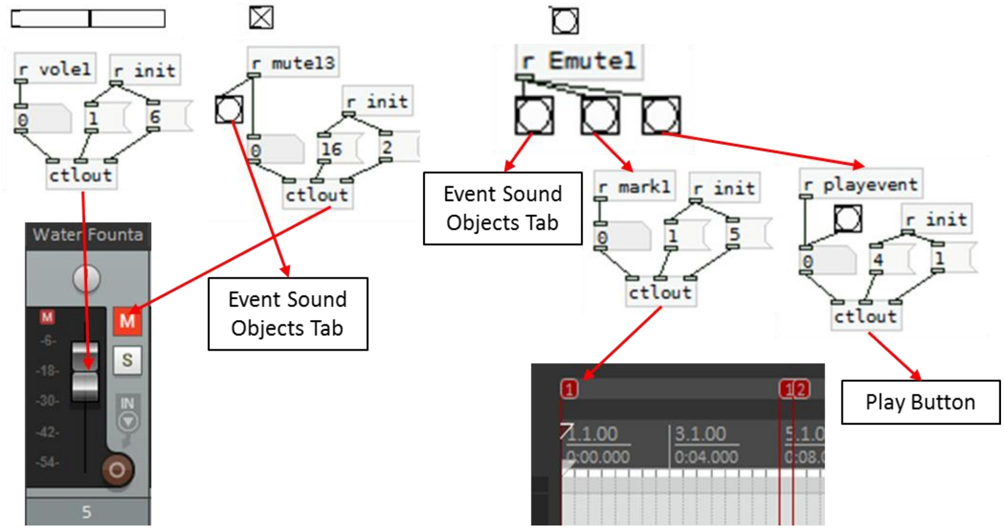


Figure 6-5 PureData Code for Event Sound Objects

6.2.3 Implementation of Digital Audio Workstation Software to Imitate the Behaviour of Sound Objects

The soundscape environment simulator was designed with Reaper DAW software using the Wigware VST plug-in developed by Bruce Wiggins (Wiggins, 2010). Two Wigware VST plug-ins are implemented in the simulator: first, Wigware ambiPan X-Y 1-3D, and second, Wigware Regular Shape 1st order Ambisonic Decoder. The signal processing of the sound objects is shown in **Figure 6.6**.

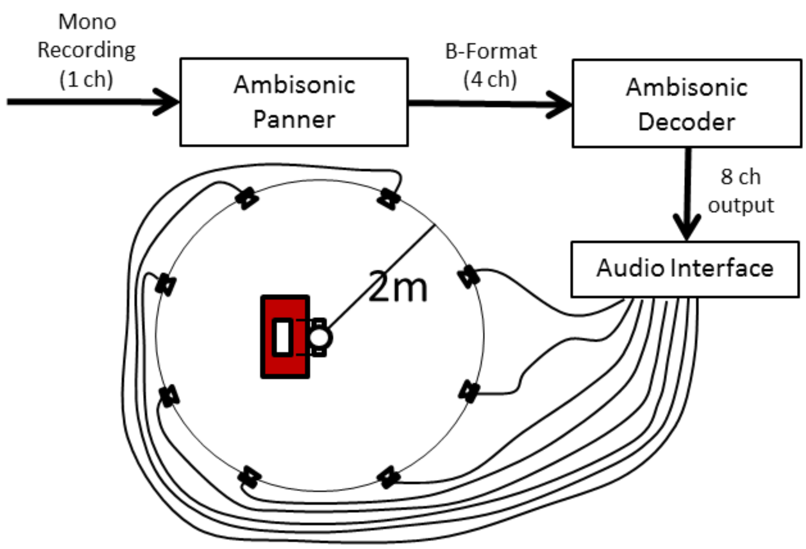


Figure 6-6 The Signal Processing of Sound Objects in the Soundscape Environment Simulator

All recordings used in the simulator were recorded in mono. The position and movement of sound objects were performed using the ambisonic panner VST plug-in. The output of the plug-in is a four-channel B-format output. The ambisonic panner is shown in **Figure 6.7.**

The ambisonic panner is able to manipulate several parameters, such as azimuth, elevation, X, Y, Z, Distance, and Compensation Distance. The position of sound objects is controlled by changing the azimuth parameter while keeping the other parameters constant.

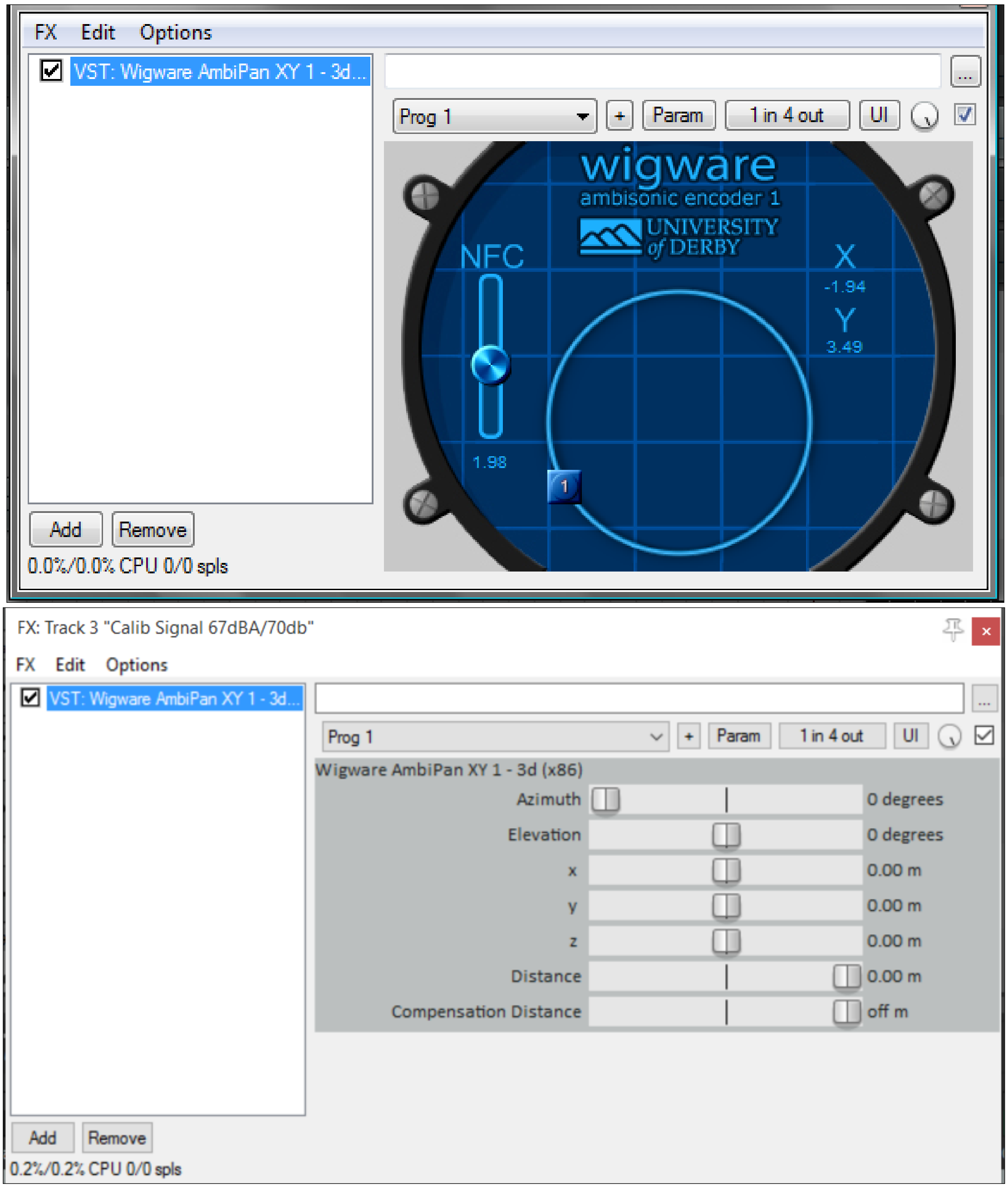


Figure 6-7 WigWare Ambisonic Panner

The movement of sound objects is also replicated in this simulator. There are two kinds of movement made possible in the simulator: the movement of people talking in the background, and the movement of sound objects in a line (left to right, right to left, front to back, or back to front).

The movement of the people talking in the background is mimicked by automating the azimuth parameter with the ambisonic panner, as shown in **Figure 6.8**. The azimuth is changed randomly, as shown with the purple graph in **Figure 6.8** and the distance of the sound is set to 0.25 m. This adjustment is made so the composer feels that the sound of people is coming from many directions, as though they are surrounding the composer. The same concept is implemented with the background sound of a bird chirping, but the distance between the composer and the sound object is set at a greater value than that of the sound of people talking in the background (2.5 m).

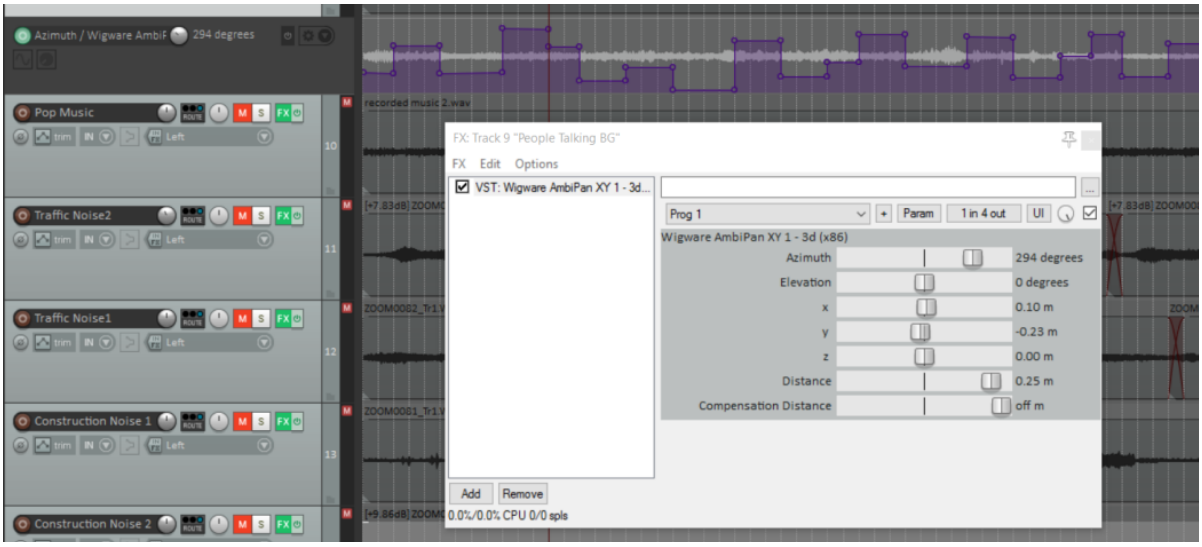


Figure 6-8 Movement Imitation of the Sound of People Talking in Background (Azimuth automation shown in purple)

The movement of sound objects in a straight line is imitated in two scenarios. The first scenario is the imitation of a sound object's movement using a moving recorded object, and the second scenario is the imitation of sound object's movement using a static recorded object.

Recordings of moving objects already include sound level variation, since they are louder as they get nearer to the microphone. With this type of recording, automation is only applied to the azimuth parameters of the ambisonic panner, as in **Figure 6.9**, which shows the automation of the azimuth parameter in the ambisonic panner to imitate the movement of traffic noise. The azimuth automatically changes, as seen in the purple graph in **Figure 6.9.** The automation can be set to make the object move from left to right and vice versa, or from front to back and vice versa, depending on the simulated condition desired. The azimuth is set to change 90˚ from the initial position, with the distance set at a constant 1 m.

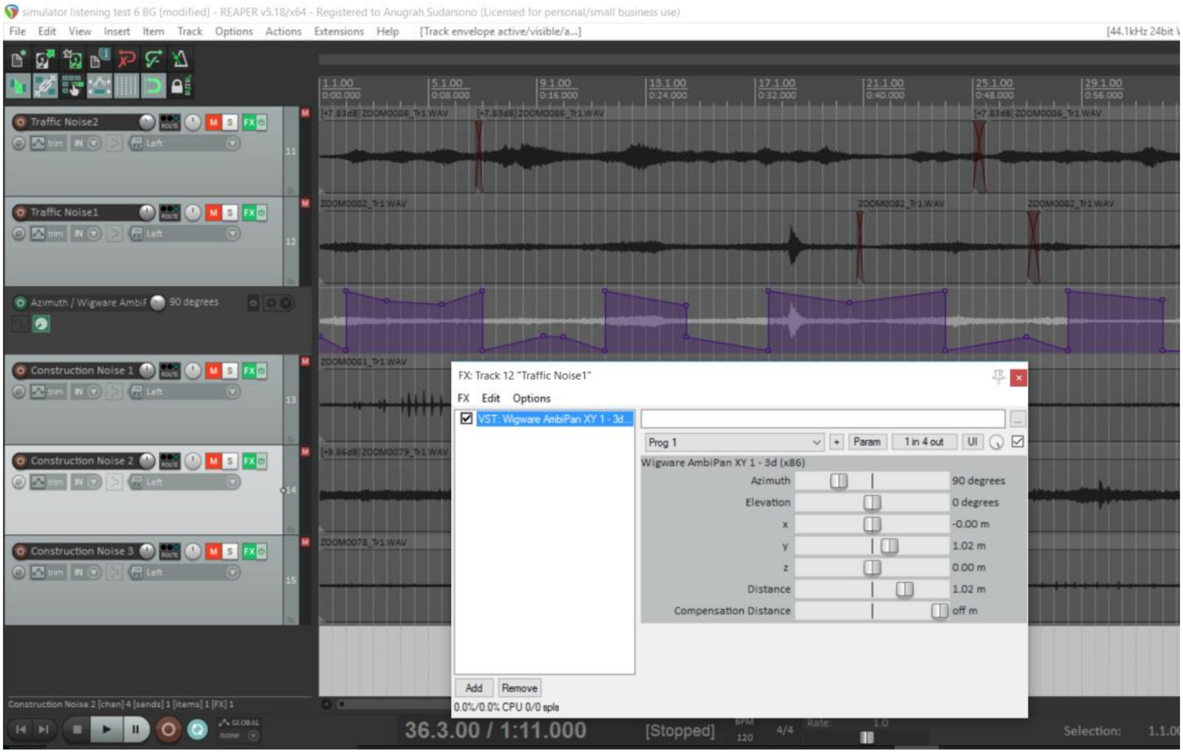


Figure 6-9 Movement Imitation of Traffic Noise
(Azimuth automation shown in purple)

The movement of sound objects recorded from static sound objects is replicated using automation of both the azimuth and the sound level, as shown in the red graph (for sound level automation), and purple graph (for azimuth automation) in **Figure 6.10.** The figure shows a recording of the sound of footsteps that was actually created artificially, using a repeated recording of one tap of the shoe. The sound level automation was implemented so that the sound level will get louder when the sound object moves toward the composer and become weaker as it moves away. This automation is then combined with the azimuth panning automation.

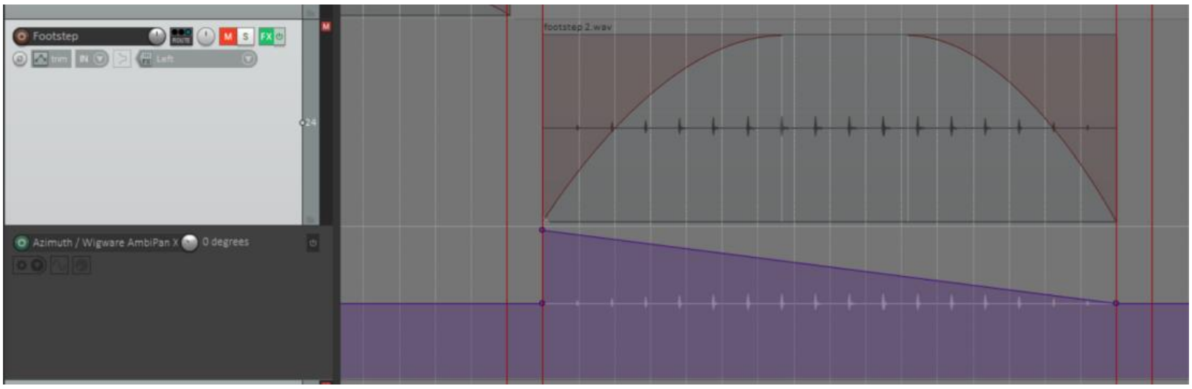


Figure 6-10 Movement Imitation of the Sound of Footsteps
(Azimuth automation shown in purple, sound level automation shown in red)

The implementation of the ambisonic panner enables the output of each sound object into a B-format output. The outputs of all the sound objects are mixed together and sent to the ambisonic decoder. Using the Regular Shape 1st order decoder from Wigware, the B-format signals are decoded into an eight-channel signal, which is sent to the audio interface and speakers. The decoder is shown in **Figure 6.11**. The soundscape environment simulator was designed using a two-dimensional ambisonic system with eight speakers. The same decoder was used to reproduce soundscape in the previous experiment examining soundscape reproduction.

All of the sound objects in the simulator are encoded as a B-format recording consisting of four channels (W, X, Y, and Z). Next, the B-format signals are decoded, using Regular Shape 1st order decoder from Wigware, into an eight-channel signal that is sent to the audio interface and speakers, set up as shown in **Figure 6.6.** Again, the soundscape environment simulator was designed using the same two-dimensional ambisonic system using eight speakers that was used in the previous experiment.

Figure 6-11 WigWare Ambisonic Decoder

6.2.4 Recording the Soundscape Compositions

The soundscape environment simulator has a feature that can record compositions in the B-format signal using Jack Audio software. Jack Audio is software that makes virtual channels, which enables the connection of DAW software outputs and inputs, as shown in **Figure 6.12.** The figure shows how Jack Audio connects the output of Reaper into the input of Reaper.

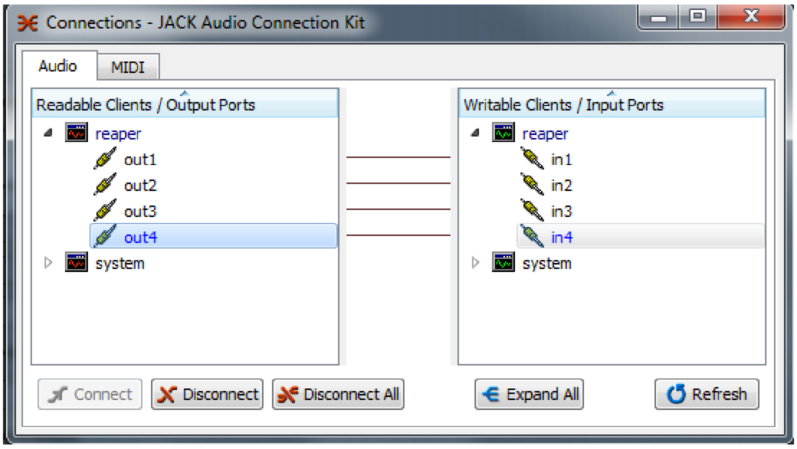


Figure 6-12 Reaper input and output connections with Jack Audio

The recording schematic is shown in **Figure 6.13**.The implementation of the ambisonic panner in every track converts the output into B-format signals, and these signals are mixed together in the mixing track. The outputs of the mixing track are then sent to the virtual outputs in Jack Audio, which also connect to the inputs of Reaper. The four-channel inputs are recorded into an empty recording track, resulting in a B-format signal of the soundscape composition.

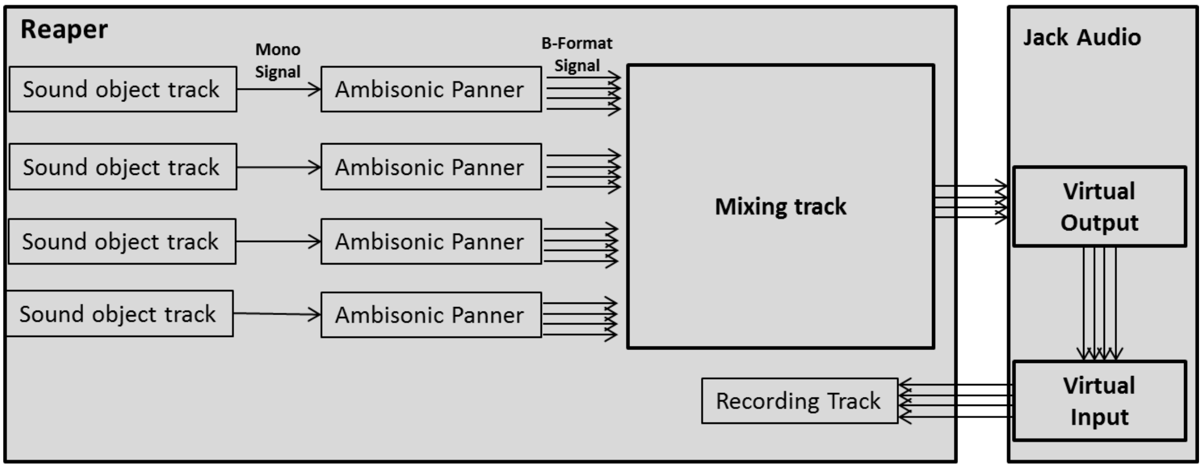


Figure 6-13 Recording Schematic

6.2.5 Recording the Sound Objects and Calibration of the Soundscape Environment Simulator

The sound objects were recorded using an Audio-Technica AT-815A unidirectional microphone and a Zoom H6 sound recorder, as shown in **Figure 6.14**. The unidirectional microphone was selected to reduce surrounding noise. All sound was recorded in mono signal.

Figure 6-14 Audio-Technica AT-815A and Zoom H6 Used in Sound Object Recording

Nineteen sound objects were recorded at several different locations, as shown in **Table 6.1**. The soundscape environment simulator was developed using nine background sound objects and ten event sound objects.

Table 6-1 Sound Objects used in the Soundscape Environment Simulator and their Recording Locations around Manchester, United Kingdom

Background Sound Objects	Recording Locations
Water Fountain	St Ann Square
Water Stream	Heaton Park
Bird Chirping	Heaton Park
Accordion Music	Market Street
String Instrument Music	Piccadilly Gardens
People Talking	Piccadilly Gardens
Pop Music	Northern Quarter
Traffic	The Crescent
Construction Noise	University of Salford

Event Sound Objects	Recording Locations
Tram	Piccadilly Garden
Bird Flying	National Football Museum
Bird Chirping	Heaton Park
Bus Passing	The Crescent
Car Passing	The Crescent
Footsteps	St Ann Square
Woman Talking	Piccadilly Gardens
Trolley Bag	St Ann Square
Bicycle	University of Salford
Child talking	Exchange Square

Two types of calibration were applied in the soundscape environment simulator: first, the calibration of the output of each speaker, and second, the calibration of the overall sound level. The calibration of speaker output was done by reproducing omnidirectional white noise. This signal was sent to each of the speakers, and each of the speakers was set to have the same output.

The overall sound level was calibrated by measuring the sound level of each sound object as reproduced by the speaker system using a measurement microphone. The relative sound level of each sound object was set to 0 dB, and each was played and measured individually by the measurement microphone. The sound level measurements are shown in **Table 6.2.** In addition to the sound level measurement of the sound objects, another measurement was also taken, using a white noise signal reproduced omnidirectionally with the speakers. This was to establish a standard signal so that if the simulator needs to be rebuilt, it can be easily calibrated by reproducing the white noise signals and setting the sound level of the speakers to reach the calibration level.

Table 6-2 The Sound Level (L_{Aeq} in dB) of Sound Objects at Calibration

Background Sound Objects	Sound Level on Calibration (dB)
Water Fountain	59.2
Water Stream	54.2
Bird Chirping	53.3
Accordion Music	59.5
String Instrument Music	60.9
People Talking	61.8
Pop Music	61.1
Traffic	64.2
Construction Noise	64.3
White Noise	67.0

Event Sound Objects	Sound Level on Calibration (dB)
Tram	49.4
Bird Flying	43.8
Bird Chirping	38.6
Bus Passing	53.9
Car Passing	44.1
Footsteps	49.0
Woman Talking	52.0
Trolley Bag	42.7
Bicycle	55.6
Child talking	55.5

6.3 The Validity of the Soundscape Environment Simulator

The validity of soundscape environment simulator was tested by reproducing the urban soundscape composition for participants and asking them to rate the soundscape using the same semantic scales used in the in-situ soundwalk and in the laboratory experiment with soundscape recording. Principal Component Analysis (PCA) was applied to the data, and the components from the PCA were compared with the in situ experiment.

6.3.1 Method

Two experiments were need to validate the soundscape environment simulator: first, the soundscape composition experiment; and second, the rating of the soundscapes created in the composition experiment. In the soundscape composition experiment, the participants were asked to create four compositions that represented the dimensions of relaxation and dynamics in an urban area.

The second experiment was conducted to analyse the validity of the soundscapes composed in the soundscape environment simulator. In this experiment, the signal of the composed soundscapes were reproduced using a pantophonic system, and participants were requested to rate the soundscape according to the same nineteen semantic scales used in **Chapter 4**.

6.3.2 Experiment

The first experiment regarding soundscape composition was conducted in a listening room at the University of Salford, using the soundscape environment simulator as shown in **Figure 6.15.**

Figure 6-15 Soundscape Environment Simulator Setup

Twenty-five volunteers (17 males and 8 females) participated in the experiment. Most of the participants were students (22-48 years old, mean age = 31) from various academic backgrounds (acoustics, engineering, and social sciences) and ethnicities (Indonesian, Chinese, Italian, British, Iraqi, Indian, Pakistani, and French). The experiment was conducted with each participant individually.

There were two sessions in this experiment. In the first, the soundscape environment simulator was explained to participants, and they were asked to try it out. After they had become familiar with the controls, they were asked to compose four soundscapes. As they finished each composition, the data were saved, and they went on to compose the next soundscape, and so on.

Each participant was asked to compose four urban soundscapes, each representing a different feeling: comfortable-simple, comfortable-varied, uncomfortable-simple, and uncomfortable-varied. All the compositions were recorded in B-format signals, resulting in 100 soundscape composition samples.

The second experiment was conducted using these soundscape composition samples. Twenty-five different participants (25-42 years old, mean age=32) from the first experiment were asked to listen to and evaluate the compositions from the first experiment The volunteers (19 males and 6 females) in the second experiment were from various backgrounds (acoustics, engineering, and social sciences) and ethnicities (Indonesian, Chinese, Italian, British, Iraqi, Indian, Pakistani, Germany, and French) and participated in the experiment individually.

The second experiment was also conducted in the Listening Room at the University of Salford. The B-format recording samples from the soundscape composition experiment were reproduced using a pantophonic reproduction system with eight speakers.

The experiment used an interface developed using PureData to play the audio samples, as shown in **Figure 6.16.** The participants could select a soundscape sample by clicking the number button. The time was indicated in the simulator to show the length of the sample, because the participants were directed to listen to each soundscape composition sample in its entirety. Two soundscape composition samples from each of the four perception categories (comfortable-simple, comfortable-varied, uncomfortable-simple, and uncomfortable-varied) were selected randomly from the soundscape composition database and presented in a random order in the simulator. Eight soundscape composition samples were reproduced for each participant – meaning that each of the soundscape composition samples was rated by two different participants – resulting in 200 responses to be analysed.

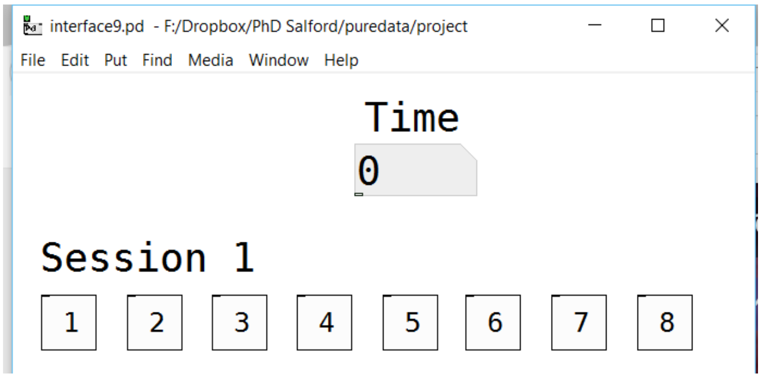


Figure 6-16 Interface for the Soundscape Environment Simulator Validity Experiment

As participants listened to each sample in the interface, they filled in a questionnaire made in Microsoft Excel, as shown in **Figure 6.17.**

Sample 1

	5	4	3	2	1	0	1	2	3	4	5	
Comfort	●	○	○	○	○	○	○	○	○	○	○	Discomfort
Quiet	○	●	○	○	○	○	○	○	○	○	○	Noisy
Pleasant	○	○	●	○	○	○	○	○	○	○	○	Unpleasant
Natural	○	○	○	●	○	○	○	○	○	○	○	Artificial
Like	○	○	○	○	●	○	○	○	○	○	○	Dislike
Gentle	○	○	○	○	○	●	○	○	○	○	○	Harsh
Boring	○	○	○	○	○	○	●	○	○	○	○	Interesting
Social	○	○	○	○	○	○	○	●	○	○	○	Unsocial
Communal	○	○	○	○	○	○	○	○	●	○	○	Private
Meaningful	○	○	○	○	○	○	○	○	○	●	○	Insignificant
Calming	○	○	○	○	○	○	○	○	○	○	●	Agitating
Smooth	○	○	○	○	○	○	○	○	○	●	○	Rough
Hard	○	○	○	○	○	○	○	○	●	○	○	Soft
Fast	○	○	○	○	○	○	○	●	○	○	○	Slow
Sharp	○	○	○	○	○	○	●	○	○	○	○	Flat
Varied	○	○	○	○	○	●	○	○	○	○	○	Simple
Reverberant (Echoic)	○	○	○	○	●	○	○	○	○	○	○	Anechoic (No Echo)
Far	○	○	○	●	○	○	○	○	○	○	○	Near
Directional	○	○	●	○	○	○	○	○	○	○	○	Universal

Figure 6-17 Questionnaire for the Soundscape Environment Simulator Validity Experiment

6.3.3 Results and Discussion

The data were analysed in two ways: using the sound level of soundscape compositions, and with Principal Component Analysis.

The sound levels of the soundscape compositions were compared with respect to the soundscape dimensions of relaxation and dynamics. Two-way Analysis of Variance (ANOVA) indicates that only the dimension of relaxation (comfortable and uncomfortable) significantly affects ($p<0.05$) the overall sound level of participants' compositions. **Figure 6.18** shows that the sound level difference between simple and varied compositions (dynamics dimension) is not significant, while the sound level difference between comfortable and uncomfortable compositions (relaxation dimension) is significant. In other words, composers tend to make uncomfortable soundscapes louder than comfortable ones.

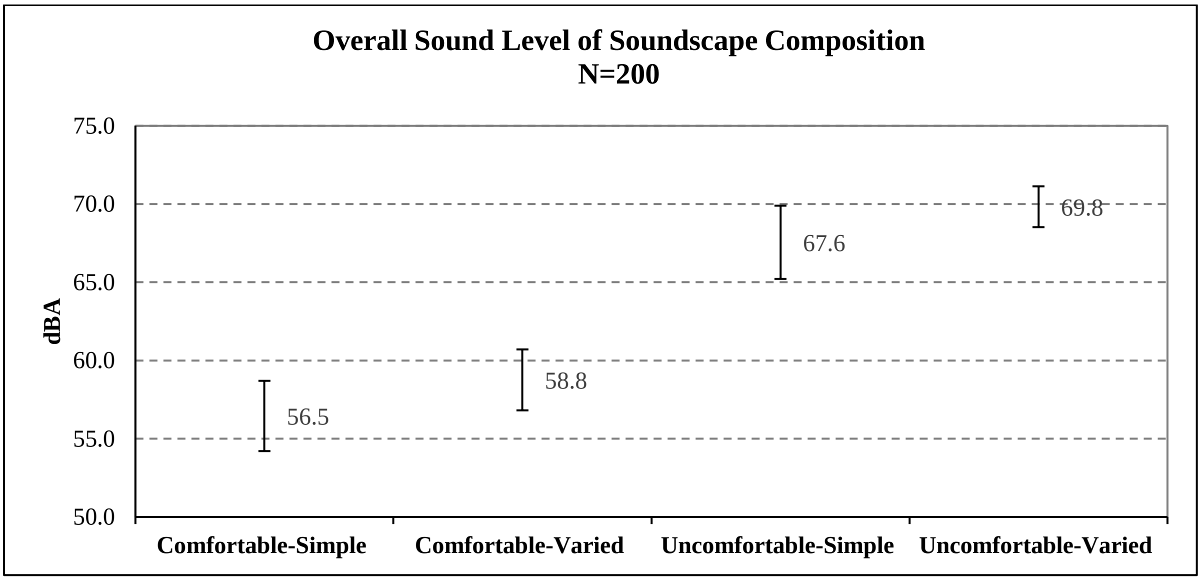


Figure 6-18 Overall Sound Level of Soundscape Composition (N=200)

Further analysis was done by comparing the overall sound levels of soundscape compositions with the sound levels measured in situ at selected urban locations. The in situ measurements were taken between the hours of 12.00-15.00 at several locations in Manchester's city centre: Piccadilly Gardens, Exchange Square, New Cathedral Street, St Ann's Square, the National Football Museum, Deansgate, and Market Street. The sound level comparison between comfortable soundscape compositions, uncomfortable soundscape compositions, and in-situ measurements is shown in **Figure 6.19.**

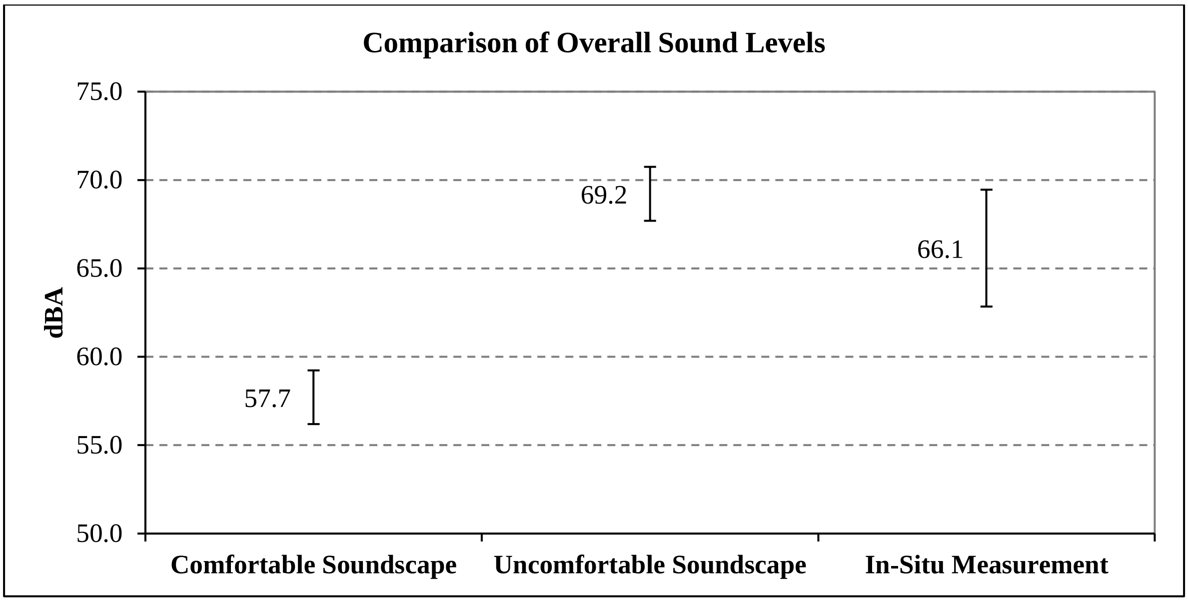


Figure 6-19 Comparison of Overall Sound Levels between Comfortable Soundscape Composition, Uncomfortable Soundscape Composition, and In-Situ Measurement

The uncomfortable soundscape compositions are 11.5 dB louder on average than the comfortable soundscape compositions. Some of the uncomfortable soundscape compositions are also louder than the sound levels measured at actual locations. When participants were asked to compose an uncomfortable soundscape, they tended to put in as many uncomfortable sound objects as possible, and make them as loud as possible, resulting in a loud soundscape composition.

Another interesting finding is the sound level of comfortable soundscape compositions. The participants composed comfortable soundscapes that were 8.4 dB lower on average than the in situ measurements. This seems consistent with the results from **Chapter 4,** which indicated that soundscape recordings should be reproduced 9.5 dB lower than the actual sound level in order to imitate the feeling of being at the actual location.

Further analysis was done using Principal Component Analysis (PCA) with Varimax rotation to understand the soundscape dimensions of composed soundscapes and comparing the results with the dimension of ratings from the in-situ experiment. The significant components from the PCA were determined based on their eigenvalues (eigenvalue > 1), and further analysis was done to test for reliability.

Principal Component Analysis (PCA) for the overall data was done by combining the results of the semantic scales from the comfortable and uncomfortable soundscape compositions. The PCA of the overall data, as shown in **Table 6.3**, showed that three reliable (Cronbach's Alpha > 0.7) components explain 63% of variance in the scale:

- **Component 1** (40%): **Calmness/Relaxation.** The scales of Comfort-Discomfort, Quiet-Noisy, Pleasant-Unpleasant, Natural-Artificial, Like-Dislike, Gentle-Harsh, Meaningful-Insignificant, Calming-Agitating, and Smooth-Rough load highly into this component. The Cronbach's Alpha of this component is 0.960.
- **Component 2** (12%): **Dynamics/Vibrancy.** The scales of Hard-Soft and Sharp-Flat load highly into this component. The Cronbach's Alpha of this component is 0.796.
- **Component 3** (11%): **Communication**. The scales of Social-Unsocial, Communal-Private, and Varied-Simple load highly into this component. The Cronbach's Alpha of this component is 0.705.

The overall data, therefore, show the same reliable soundscape dimensions as the in-situ experiment: Calmness/Relaxation (24%), Dynamics/Vibrancy (14%), and Communication (11%). Moreover, the dimensions of Dynamics and Communication in this experiment seem to explain a similar amount of variance as the in situ experiment.

Further investigation was conducted by analysing the PCA results of comfortable and uncomfortable soundscape compositions. According to the previous study in **Chapter 4**, the sound level of soundscape reproductions could affect participants' perceptions of them, and there is significant sound level difference between the comfortable and uncomfortable soundscape compositions in this experiment.

Table 6-3 PCA of Overall Soundscape Compositions

PCA Overall Soundscape Compositions (N= 200, Kaiser-Mayer-Olkin index 0.931, Bartlett's test of sphericity sig. 0.000)

	Component			
	40%	12%	11%	7%
Comfort- Discomfort	.896	-.265	.040	-.137
Quiet-Noisy	.799	-.314	-.090	-.137
Pleasant-Unpleasant	.907	-.212	-.006	-.141
Natural-Artificial	.748	.140	-.117	-.151
Like-Dislike	.907	-.213	-.015	-.162
Gentle-Harsh	.904	-.266	.051	-.107
Boring-Interesting	-.408	-.021	-.143	.570
Social-Unsocial	.296	-.150	.804	-.156
Communal-Private	-.053	-.003	.831	.030
Meaningful-Insignificant	.627	.044	.184	-.380
Calming-Agitating	.855	-.252	-.001	.016
Smooth-Rough	.849	-.326	.055	-.033
Hard-Soft	-.808	.387	.077	.130
Fast-Slow	-.386	.695	.235	.120
Sharp-Flat	-.287	.746	.195	.206
Varied-Simple	-.138	.295	.681	.082
Reverberant-Anechoic	-.033	.222	.120	.811
Far-Near	.201	-.564	.173	-.002
Directional-Universal	.387	.330	-.320	-.211
Cronbach's Alpha	**0.960**	**0.796**	**0.705**	**0.318**

Additional Principal Component Analysis (PCA) was done using the data from the uncomfortable and comfortable soundscape composition samples separately. The PCA of the uncomfortable soundscape data is shown in **Table 6.4,** and the PCA of the comfortable soundscape data is shown in **Table 6.5**. Both of these analyses showed three reliable components (Cronbach Alpha>0.7) that explained 56% of the variance in the uncomfortable soundscape dataset and 57% of the variance in the comfortable soundscape dataset:

- **Component 1** (34% in uncomfortable soundscape datasets and 35% in comfortable datasets): **Calmness/Relaxation.** The scales of Comfort-Discomfort, Quiet-Noisy, Pleasant-Unpleasant, Natural-Artificial, Like-Dislike, Gentle-Harsh, Calming-Agitating, and Smooth-Rough load highly into this component. The Cronbach's Alpha of this component is 0.928 for the uncomfortable soundscape dataset and 0.966 for the comfortable soundscape dataset.

- **Component 2** (12% in uncomfortable soundscape datasets and 11% in comfortable datasets): **Communication**. The scales of Social-Unsocial, Communal-Private, Varied-Simple load highly into this component for the uncomfortable dataset. The component for comfortable dataset consist of the scales of Social-Unsocial and Communal-Private. The Cronbach's Alpha of this component is 0.732 for the uncomfortable soundscape dataset and 0.767 for the comfortable soundscape dataset.
- **Component 3** (10 % in uncomfortable soundscape datasets and 11% in comfortable datasets): **Dynamics/Vibrancy.** The scales of Fast-Slow and Sharp-Flat load highly into this component for the uncomfortable dataset. The component for comfortable dataset consist of the scales of Fast-Slow, Sharp-Flat and Varied-Simple. The Cronbach's Alpha of this component is 0.735 for the uncomfortable soundscape dataset and 0.722 for the comfortable soundscape dataset.

The PCA data from the uncomfortable and comfortable soundscape composition samples therefore indicate similar results to the overall data, and the same reliable dimensions (Relaxation, Dynamics, and Communication) emerge from this set of data.

Table 6-4 PCA of Uncomfortable Soundscape Compositions

PCA Uncomfortable Soundscape Compositions (N= 100, Kaiser-Mayer-Olkin index 0.867, Bartlett's test of sphericity sig. 0.000)

	Component				
	34%	12%	10%	8%	7%
Comfort-Discomfort	.892	.060	-.136	.071	-.152
Quiet-Noisy	.783	-.090	-.138	-.069	-.119
Pleasant-Unpleasant	.871	-.019	-.142	.066	-.114
Natural-Artificial	.559	-.230	.075	.452	.048
Like-Dislike	.901	-.125	-.058	.164	-.095
Gentle-Harsh	.869	.086	-.180	.112	-.090
Boring-Interesting	-.152	-.185	-.042	-.482	.637
Social-Unsocial	.214	.838	-.115	.004	-.109
Communal-Private	-.022	.784	.059	-.115	.092
Meaningful-Insignificant	.473	.279	.022	.338	-.371
Calming-Agitating	.829	-.040	-.114	-.091	.052
Smooth-Rough	.800	.150	-.266	.099	-.021
Hard-Soft	-.712	.081	.489	-.082	.192
Fast-Slow	-.298	.260	.633	.123	.258
Sharp-Flat	-.291	.239	.728	.073	.169
Varied-Simple	-.260	.697	.253	-.129	.029
Reverberant-Anechoic	-.086	.124	.128	.135	.743
Far-Near	.082	.254	-.707	.205	.211
Directional-Universal	.029	-.218	-.070	.830	.017
Cronbach's Alpha	**0.928**	**0.732**	**0.735**	**-**	**0.279**

Table 6-5 PCA of Comfortable Soundscape Compositions

PCA Comfortable Soundscape Compositions (N= 100, Kaiser-Mayer-Olkin index 0.839, Bartlett's test of sphericity sig. 0.000)

	Component				
	35%	11%	11%	7%	6%
Comfort-Discomfort	.891	-.041	.040	.008	.044
Quiet-Noisy	.742	-.207	-.185	-.103	-.146
Pleasant-Unpleasant	.913	.078	-.052	.072	-.071
Natural-Artificial	.633	.223	.022	.341	-.132
Like-Dislike	.887	.026	.048	.001	-.139
Gentle-Harsh	.914	-.029	.044	-.072	-.013
Boring-Interesting	-.312	-.089	-.185	.211	.599
Social-Unsocial	.119	.122	.880	.007	.015
Communal-Private	-.051	.092	.908	.021	.025
Meaningful-Insignificant	.406	.001	.292	.499	-.235
Calming-Agitating	.825	-.101	.064	.093	.136
Smooth-Rough	.814	-.236	.102	-.046	.065
Hard-Soft	-.800	.229	.033	.032	-.009
Fast-Slow	-.284	.777	.059	.194	-.059
Sharp-Flat	.008	.843	-.053	.127	.067
Varied-Simple	-.059	.687	.355	-.219	.041
Reverberant-Anechoic	.187	.121	.192	-.142	.753
Far-Near	.132	-.094	.077	-.849	-.092
Directional-Universal	.324	.134	-.305	.256	-.017
Cronbach's Alpha	**0.966**	**0.722**	**0.767**	**-**	**0.318**

The PCA analysis of comfortable and uncomfortable soundscape compositions shows the same reliable soundscape dimensions as the overall soundscape compositions which is similar with the in-situ study **(Chapter 4)**. This result indicates that the simulator is able to imitate the perception of an actual soundscape.

6.4 Conclusion

A soundscape environment simulator was developed and its validity analysed in this study. The soundscape environment simulator was developed using three concepts: background-event sound objects, the structured perspective in soundscape composition, and the object-oriented concept.

This soundscape environment simulator has several advantages compared to the previous simulator developed by Bruce et al. in 2009 (N. S. Bruce et al., 2009). First, the interface is simpler and more intuitive compared to the previous simulator. Second, this simulator can be configured to use up to 90 sound objects and the interface can be customised. Third, the simulator has the flexibility to use different reproduction systems, because it uses B-format signals. Fourth, the simulator performs in real time, so the composer can listen to the soundscape composition while manipulating the parameters of the sound objects within it. Fifth, the compositions can be recorded for later reproduction.

The validity of the soundscape environment simulator was analysed by reproducing the soundscapes composed in the simulator for new participants. Principal Component Analysis shows the same reliable soundscape dimensions as the previous experiment, conducted in situ **(Chapter 4)**: Calmness/Relaxation, Dynamics/Vibrancy, and Communication.

The study in this chapter demonstrates the contribution made by the development of a soundscape environment simulator that is able to elicit the same feelings as actual soundscapes. The simulator can be used to design a soundscape, to understand the relationship between sound objects and soundscape dimensions, and to analyse soundscape in an alternative way (rather than using in situ soundwalk or reproduction of soundscape recordings). It is suggested that the simulator described here could be used for both further soundscape research and for the empirical design of physical environments.

The next chapter will discuss the application of the soundscape environment simulator to understand the relationship between sound objects and soundscape dimensions from the composer’s and listener’s points of view.

7 Comparing Soundscape Expectation and Preference

7.1 Introduction

Soundscape is commonly measured using either in-situ experience or a recording in the laboratory. After completing the studies outlined in previous chapters, both methods appeared to represent the perception of actual soundscapes in a valid way, but the relationship between particular sound objects and overall perception was still unknown.

A soundscape environment is made up of numerous sound objects, each of which has its own parameters. With the common methods described above, however, it is very hard both to measure these parameters and to separate the sound objects in the soundscape. However, a soundscape composed using the soundscape environment simulator has been proven to evoke the same perceptions as the actual soundscapes.

This chapter describes an attempt to determine the relationship between sound objects and soundscape dimensions using a new method. Two different methods are proposed to try and link the parameters of sound objects with soundscape dimensions: the composition of soundscape and the application of simulated soundscape. The soundscape composition method tries to understand the relationship between sound objects in a soundscape and soundscape dimensions by examining people's expectations of sound objects in a soundscape, while the application of simulated soundscape looks at the same issues by asking about people's preferences regarding sound objects in a soundscape.

Soundscape compositions were made using the soundscape environment simulator explained in the previous chapter. In this experiment, participants were asked to compose several soundscapes corresponding to the dimensions of Relaxation and Dynamics. They were also instructed to compose both general and urban soundscapes. Finally, they were asked to rate their own composition on the dimensions of Relaxation, Dynamics, and Communication.

The simulated soundscapes were used to understand the perception of soundscape from the listener's point of view. This method offers an important advantage compared to the other methods of measuring preference (in situ experiment, and reproduction of soundscape recording), namely, the ability to compose a large range of soundscapes that represent variations in the selection, parameters, and conditions of sound objects. In this experiment, the soundscapes created during the composition experiment were reproduced, and participants were asked to rate the soundscapes on the dimensions of Relaxation, Dynamics, and Communication.

This study not only tries to uncover the relationship between sound objects in a soundscape and the way participants rate the soundscape environment according to soundscape dimensions, but also tries to implement this relationship in the programming of the soundscape environment simulator so that it is capable of both composing soundscapes and of predicting perceptions of the soundscapes thus composed. This implementation of the perception model allows the simulator to work not only as a soundscape environment simulator, but also as a soundscape simulator.

7.2 Experiment

There were two experiments conducted in this part of the study: one in soundscape composition and the other in the application of simulated soundscape. These experiments were conducted to understand the relationship between sound objects in a soundscape and soundscape dimensions with respect to both expectation and preference.

For the soundscape composition experiment, participants were asked to compose several soundscapes corresponding to specific perceptions and soundscape types. They were also asked to rate their own soundscape compositions on to the dimensions of Relaxation, Dynamics, and Communication. Later, in the simulated soundscape application experiment, the soundscape compositions composed in the previous experiment were reproduced using a pantophonic reproduction system, and participants were asked to rate the soundscapes using the same scale as the previous experiment.

The soundscape environment has limitation because it uses the sound object recordings which are recorded outdoor and might include reverberation. Although the recordings might be suitable to represent the sound object from open area, they cannot represent sound object from semi-open space or closed space. The simulator fails to simulate the interaction between the sound objects and the environment correctly.

However, the focus of this study is to find the relationship between sound objects and the general perception of urban soundscape represented by the soundscape dimensions. The interaction between the sound objects and the environment is not discussed in this study. Moreover, the validation of soundscape environment simulator shows that the composed soundscape could bring out the same soundscape dimensions with the actual soundscapes.

7.2.1 Using Soundscape Composition to Understand Expectations of Sound Objects in a Soundscape

The soundscape composition experiment was conducted in a listening room at the University of Salford. The experiment was conducted using the soundscape environment simulator as explained in **Chapter 6.**

Twenty-five volunteers (seventeen males and eight females) participated in the study. Most of the participants were students (22-48 years old, mean age = 30) with a variety of backgrounds (acoustics, engineering, and social sciences) and ethnicities (Indonesian, Pakistani, Indian, Chinese, Iraqi, French, and British). Each of the participants completed the experiment individually.

There were two sessions in this experiment. In the first, participants heard an explanation of the soundscape environment simulator and were asked to try it out. After they had familiarised themselves with the simulator, they were asked to compose soundscapes. Each of the participants was asked to compose eight soundscapes, each representing a different combination of soundscape dimensions (Relaxation and Dynamics) and types (general and urban), as shown in **Table 7.1**. A general soundscape is one that does not relate to a certain kind of location, and an urban soundscape is one that relates to an urban area. After completing each composition, participants were asked to rate it on eleven-point scales of Relaxation (comfortable-uncomfortable), Dynamics (simple-varied), and Communication (communal-private). When the composition had been rated, the data were saved, the participant would continue on to compose the next soundscape, and so on. The experiment was conducted individually and lasted for 45 minutes.

Table 7-1 Types of soundscape composed in the experiment

No	Type of Soundscape	Relaxation	Dynamic
1	General	Comfortable	Simple
2	General	Comfortable	Varied
3	General	Uncomfortable	Simple
4	General	Uncomfortable	Varied
5	Urban	Comfortable	Simple
6	Urban	Comfortable	Varied
7	Urban	Uncomfortable	Simple
8	Urban	Uncomfortable	Varied

Later, based on the data saved from the experiments, the soundscape compositions were recreated and recorded as B-Format signals. This experiment generated 200 compositions representing various types of perception and soundscape. These soundscape composition samples would be used in the next experiment, about the application of simulated soundscape.

7.2.2 Using Simulated Soundscape to Understand Sound Object Preference in a Soundscape

The application of simulated soundscape experiment was conducted by reproducing the soundscape compositions from the previous experiment using a pantophonic reproduction system in the Listening Room at the University of Salford.

The samples used in the experiment were selected randomly from the soundscape composition database to represent two different types (general and urban), and four different perceptions (comfortable-simple, comfortable-varied, uncomfortable-simple, and uncomfortable-varied) of soundscape. Each participant was asked to listen to 24 soundscape composition samples and to rate each soundscape on the dimensions of Relaxation, Dynamics, and Communication. The interface used in the experiment is shown in **Figure 7.1**.

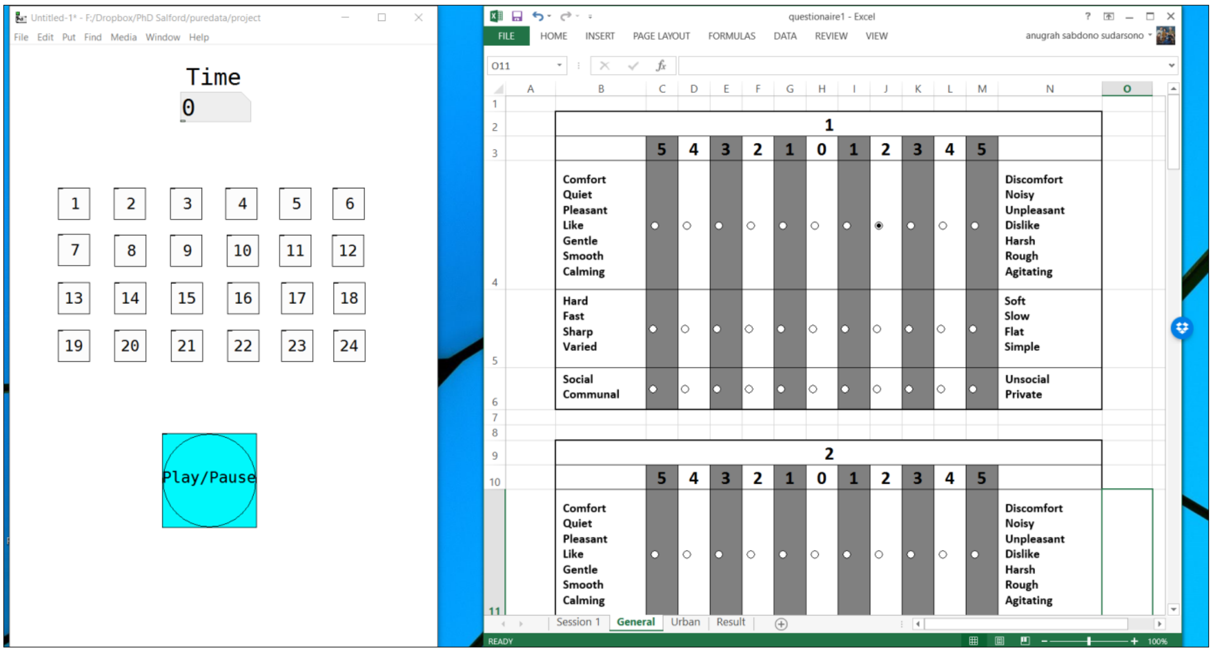


Figure 7-1 Interface for the Application of Simulated Soundscape Experiment
Left: Interface to Select the Soundscape Composition Samples
Right: Interface to Rate the Soundscape Compositions

The interface for this experiment was made using PureData and Microsoft Excel. The PureData interface was designed to select different soundscape compositions. The interface consisted of the timer, the selection button, and the Play/Pause Button. Experiment participants could select a sample by clicking its number. Each of the samples was 70 seconds long, and participants had to listen to the samples in their entirety.

The interface to rate the soundscapes was designed with Microsoft Excel, using the Macro function. The same questionnaire was used in the experiment that examined soundscape recording.

Twenty-five volunteers (twenty males and five females) participated in the experiment. Most of the participants were students (19-48 years old) with a variety of backgrounds (acoustics, engineering, and social sciences) and ethnicities (Indonesian, Iraqi, French, Germans, and British). Each of the participants completed the 45-minute experiment individually. Eight of the participants in this experiment also participated in the expectation experiment; they were given datasets that did not contain their own compositions.

7.3 Results

7.3.1 Selection of Sound Objects in Soundscape Composition

Expectations relating to sound objects in a soundscape were analysed from two points of view: the selection of sound objects in the soundscape, and the correlation between sound object parameters (location and sound level) and soundscape ratings.

The selection of sound objects for comfortable and uncomfortable soundscapes in general and urban areas is shown in **Figure 7.2** and **Figure 7.3. Figure 7.2** indicates that participants preferred to put natural sound objects in comfortable soundscapes. The sounds of birds chirping in the background (selected by 62% of participants), water stream (50% of participants), and water fountain (42% of participants) were the most-selected sound objects in comfortable, general soundscapes. This result is similar to the studies conducted by Brambilla et al. (Brambilla et al., 2013), and Axelsson et al. (Axelsson et al., 2010).

In the urban soundscape compositions, even when participants were composing comfortable soundscapes, the most-selected sound objects were those that represent urban areas, such as the sound of people talking in the background (82% of participants), footsteps (62% of participants), urban traffic (52% of participants), and bus passing (50% of participants).

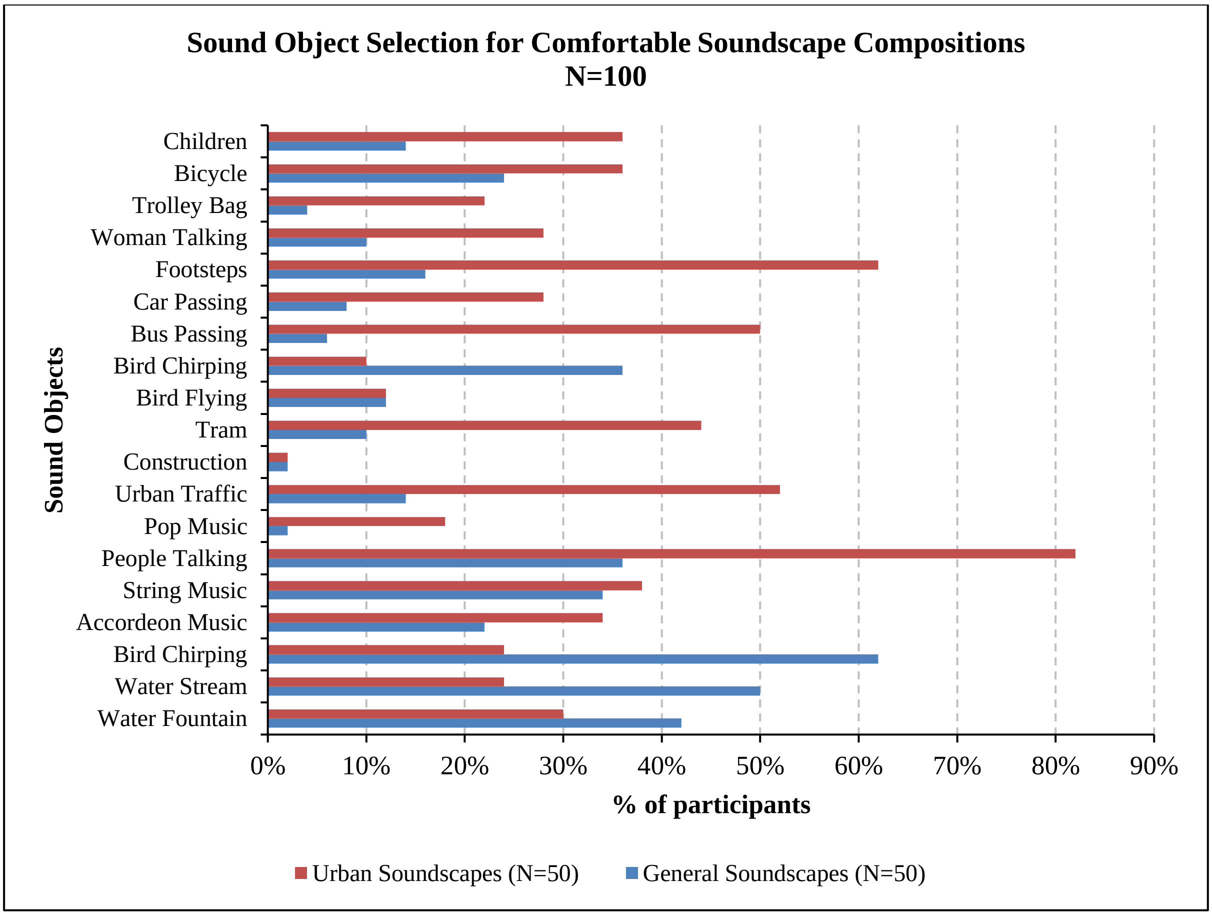


Figure 7-2 Sound Object Selection for Comfortable Soundscape Compositions

Figure 7.3 shows the selection of sound objects for uncomfortable soundscape compositions. For uncomfortable-general soundscape compositions, participants tended to select the sound objects that represent urban noise and the sound of people talking. The sound of urban traffic (selected by 72% of participants), construction noise (70% of participants), people talking in the background (56% of participants) and bus passing (50% of participants) were the most-selected sound objects to represent uncomfortable-general soundscapes. This result is similar to the study conducted by Hall et al. (Hall et al., 2013).

The selection of sound objects for the uncomfortable-urban soundscapes was different than for the general soundscape compositions. As was the case in the comfortable-urban soundscape compositions, the most-selected sound objects in the uncomfortable-urban soundscape compositions were the sound of people talking in the background (selected by 84% of participants), urban traffic (76% of participants), and bus passing (66% of participants). The only sound object consistently selected by participants to represent uncomfortable soundscape was the sound of construction noise (selected by 70% of participants for both urban and general soundscape types).

It seems that sound objects have two meanings in a soundscape: as a representation of the type of space they occupy, and as a factor in determining perception of the soundscape. The urban soundscape seems to be represented both by the sound of people talking in the background and the sound of urban traffic, since these two sound objects were the most-selected in urban soundscape compositions, whether comfortable or uncomfortable. This selection shows how participants' expectations of certain sound objects could come to represent the soundscape types.

According to the selection of sound objects in soundscape compositions, the sound of construction noise is the only sound object to represent uncomfortable soundscape, whether general or urban. This selection shows how the presence of certain sound objects could affect soundscape rating.

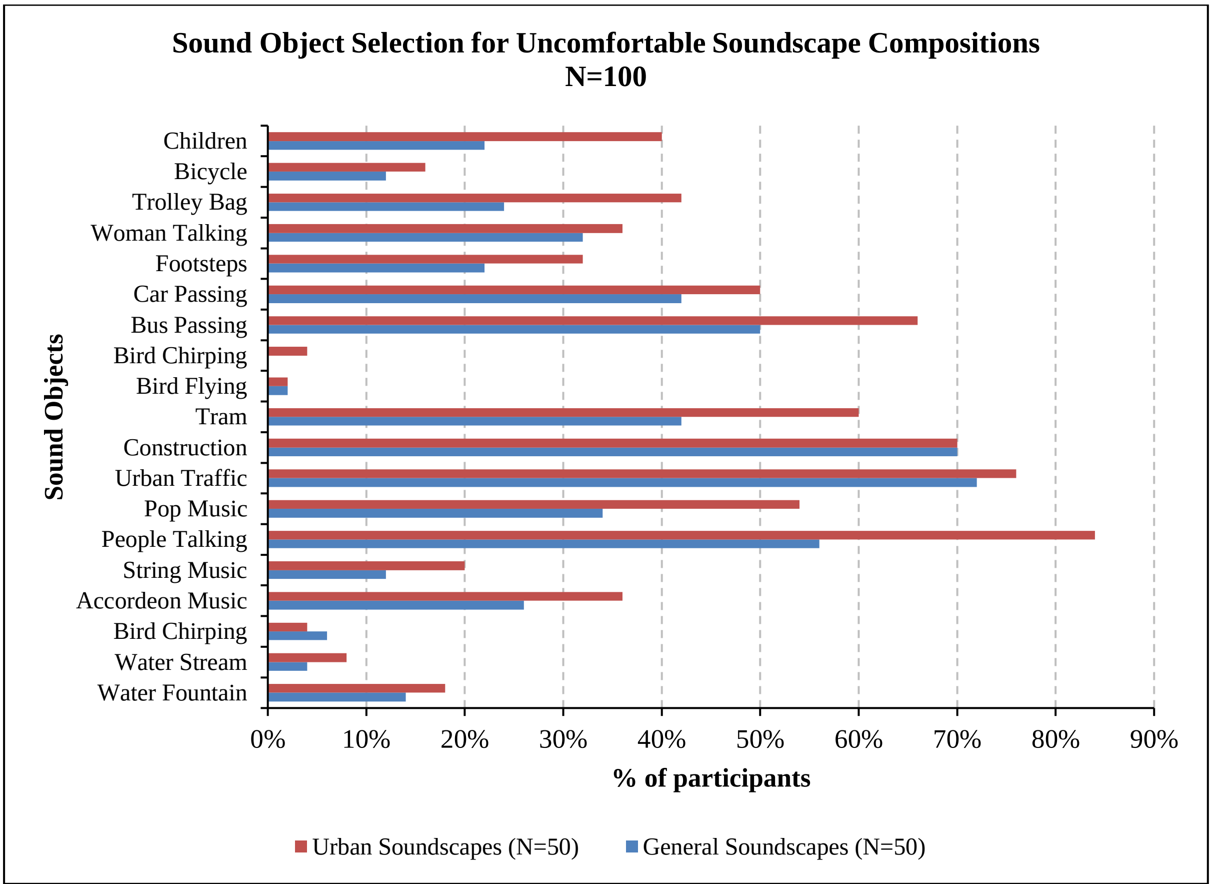


Figure 7-3 Sound Object Selection for Uncomfortable Soundscape Compositions

In addition to the analysis of how participants selected sound objects in composing their soundscapes, another analysis was done to determine the relationship between the sound level adjustments of sound objects and soundscape dimensions. **Table 7.2** displays the T-Test and effect size (using Cohen's d) calculation sound level adjustment representing comfortable and uncomfortable soundscape. The data from bird chirping sound object, bird flying, and construction noise cannot be calculated because of the insufficient amount of data. There is only one participant who uses the sound of bird chirping and bird flying to compose uncomfortable soundscape, and the construction noise to represent comfortable soundscape.

In general, when being asked to compose an uncomfortable soundscape, the participants tend to adjust the sound level of sound objects higher than in comfortable soundscapes as shown in **Figure 7.4.** T-Test reveals significant different for most of the sound objects except for the sound of string music, bird chirping (event sound object), and the sound of bicycle. Further analysis using effect size shows that the significant sound objects also have large effect size (Cohen’s d > 0.8).

Table 7-2 T-Test and Effect Size Calculation from the Sound Level Adjustment of Comfortable and Uncomfortable Soundscape

Grey area indicates significant difference from T-Test (sig<0.05)

Sound Objects	T-Test	Cohen's d
Water Fountain	0.003	-1.356
Water Stream	0.008	-1.841
Bird Chirping	-	-
Accordeon Music	0.002	-1.142
String Music	0.749	-0.129
People Talking	0.000	-1.630
Pop Music	0.011	-1.328
Urban Traffic	0.000	-2.790
Construction	-	-

Sound Objects	T-Test	Cohen's d
Tram	0.000	-1.890
Bird Flying	-	-
Bird Chirping	0.904	-0.091
Bus Passing	0	-1.817
Car Passing	0.001	-1.476
Footsteps	0.009	-0.841
Woman Talking	0.018	-0.927
Trolley Bag	0.000	-0.825
Bicycle	0.242	-0.522
Children	0.001	-1.218

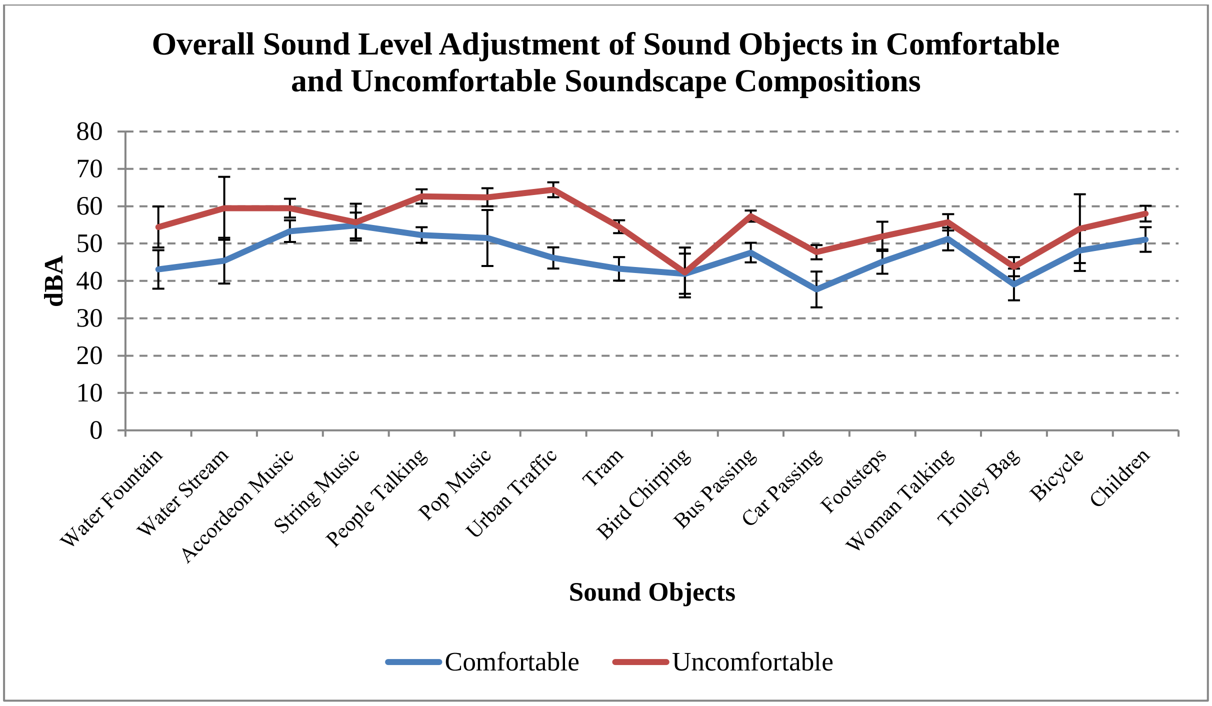


Figure 7-4 Overall Sound Level Adjustment of Sound Objects in Comfortable and Uncomfortable Soundscape Compositions (Three sound objects are not included because the data is insufficient: bird chirping, construction, and bird flying)

In general, the composition of soundscape according to the dimension of Relaxation might affect both the selection of sound objects and their sound level adjustment. The sound of construction noise is the sound object that makes a soundscape feel most uncomfortable. The analysis also confirms that the selection of sound objects is affected by the type of soundscape being composed in the simulator, whether general or urban. The sound of people talking in the background and the sound of urban traffic are the sound objects that best represent urban soundscape.

The selection of sound objects in the simple and varied soundscapes is shown in **Figure 7.5** and **Figure 7.6.** When composing general soundscapes, participants make them varied by adding more sound objects to the soundscape, as shown in **Figure 7.5**. All sound objects were selected more frequently for varied soundscape compositions except for the sounds of birds chirping and flying, and the sound of the water stream, which may indicate that these sound objects affect the rating of simplicity in a soundscape.

The most-selected sound objects for varied-general soundscape are the sound of people talking in the background (selected by 76% of participants) and the sound of urban noise in the background (58% of participants). These two sound objects may be significant in representing varied soundscapes.

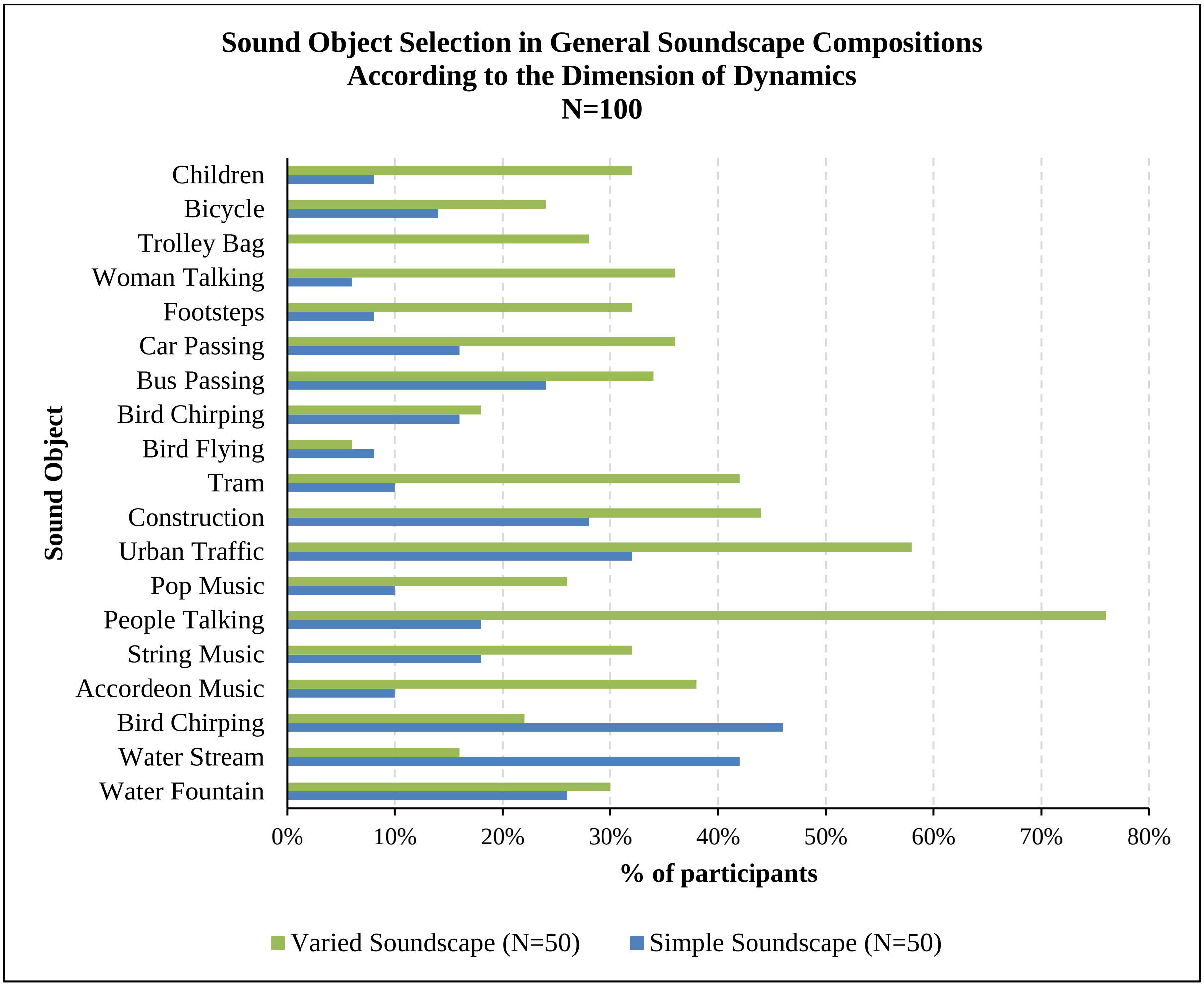


Figure 7-5 Sound Object Selection in General Soundscape Compositions According to the Dimension of Dynamics

Similar things are also observed in the composition of urban soundscapes, as shown in **Figure 7.6.** Participants compose varied soundscapes by adding more sound objects – but not the sound of the water stream or birds chirping. The most-selected sound objects to represent varied soundscape in a composition are the same as in urban soundscape: the sound of people talking in the background (selected by 88% of participants) and the sound of urban traffic (72% of participants).

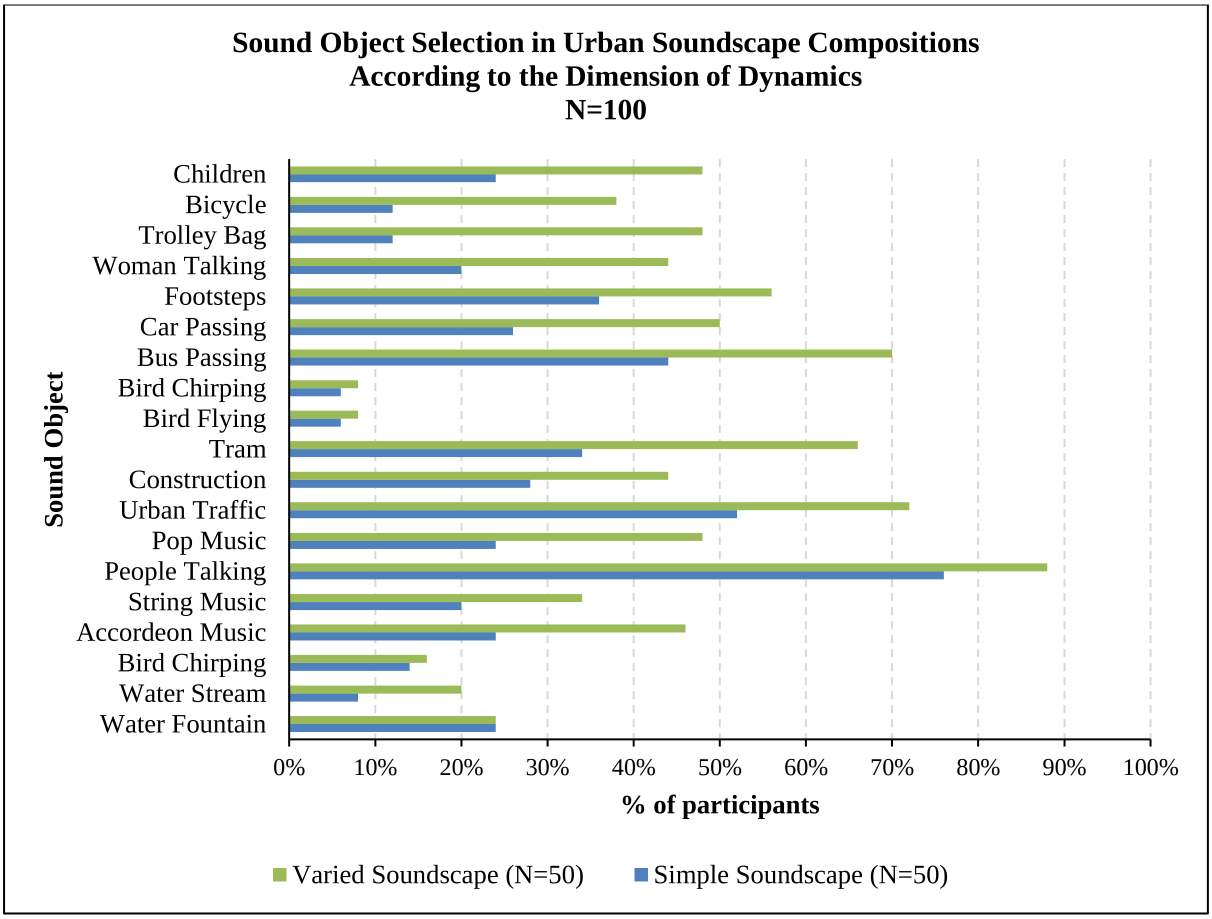


Figure 7-6 Sound Object Selection in Urban Soundscape Compositions According to the Dimension of Dynamics

The Dynamics dimension seems to be affected by the number of sound objects in the soundscape. **Figure 7.7** shows the comparison of sound level adjustment between the simple and varied soundscape compositions, and the analysis using T-Test (**Table 7.3**) shows that the difference is not significant ($p>0.05$) for most sound objects. There are three sound objects that demonstrate significant sound level difference: urban traffic ($p=0.023$), car passing ($p=0.049$), and children ($p=0.046$). Further analysis for the significant sound objects is conducted by using effect size, and Cohen's d value showing moderate effect (Cohen's d between 0.447-0.580)

Table 7-3 T-Test and Effect Size Calculation from the Sound Level Adjustment of Simple and Varied Soundscape

Grey area indicates significant difference from T-Test (sig<0.05)

Sound Objects	T-Test	Cohen's d	Sound Objects	T-Test	Cohen's d
Water Fountain	0.906	-0.033	**Tram**	0.198	-0.302
Water Stream	0.443	-0.232	**Bird Flying**	0.425	-0.442
Bird Chirping	0.792	-0.078	**Bird Chirping**	0.208	0.548
Accordeon Music	0.457	-0.203	**Bus Passing**	0.063	-0.407
String Music	0.287	-0.303	**Car Passing**	0.049	-0.501
People Talking	0.849	0.035	**Footsteps**	0.067	-0.490
Pop Music	0.241	-0.346	**Woman Talking**	0.981	-0.008
Urban Traffic	0.023	-0.447	**Trolley Bag**	0.073	-0.736
Construction	0.774	0.069	**Bicycle**	0.295	0.373
			Children	0.046	-0.58

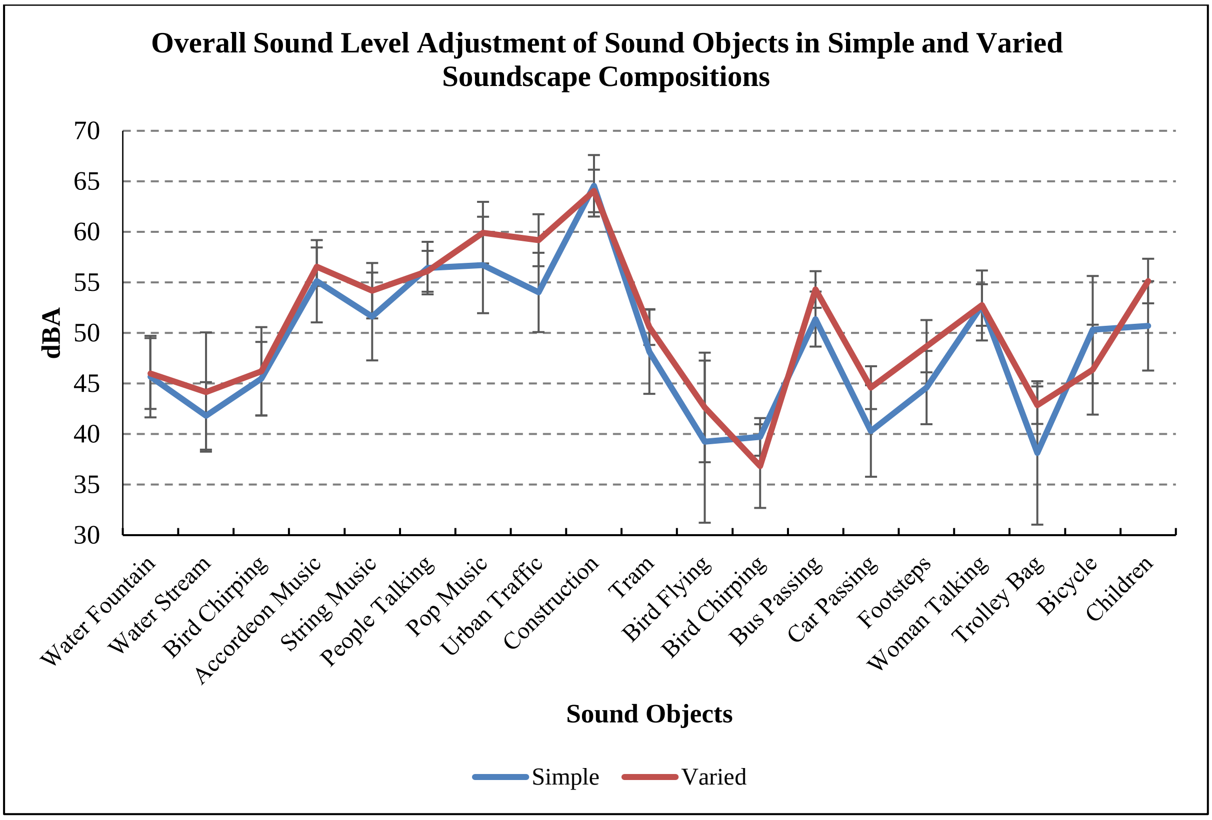


Figure 7-7 Overall Sound Level Adjustment of Sound Objects in Simple and Varied Soundscape Compositions

In general, then, the varied soundscapes are composed by adding more sound objects, especially those that represent urban noise and human activities. In addition, the sound of people talking in the background and the sound of urban traffic seem to affect the dimension of Dynamics most when compared to other sound objects. The Dynamics dimension also seems to be affected more by the number of sound objects selected for the composition than by the sound level of those sound objects.

7.3.2 Expectation of Sound Objects in Soundscape Composition

The expectation of sound objects in a soundscape composition was analysed by comparing the sound level of the sound objects and the rating of the soundscape composition. The position of the sound objects was not examined because according to an Analysis of Variance, the effect of the position was not significant ($p>0.05$) to the rating of the soundscape. It seems that participants can adjust the position anywhere, as long as they can feel the sound objects come from several directions.

The first analysis was conducted using a Forward Linear Regression to determine the relationship between the sound objects and the rating of the composition. The Pearson's Correlation of the Forward Linear Model is shown in **Table 7.4** and indicates that the dimension of Relaxation has a strong correlation with the sound level adjustment of the sound objects in a soundscape composition (Pearson's Correlation of 0.847). The other dimensions show only moderate correlation (0.675 for the dimension of Dynamics and 0.696 for the dimension of Communication) to the sound level of the sound objects. Further analysis is conducted only with respect to the dimension of Relaxation due to the strong correlation shown in the model.

Table 7-4 Pearson's Correlation of the Forward Linear Model of Sound Objects Expectation

No	Dimension	R
1	Relaxation	0.847
2	Dynamic	0.675
3	Communication	0.696

The forward linear model indicates five significant background sound objects that represent the dimension of Relaxation: construction noise, traffic noise, pop music, birds chirping, and the water stream. Surprisingly, there are not any significant event sound objects in the model. This might suggest that the dimension of Relaxation is only affected by background sound objects. The forward linear model is shown in **Table 7.5.**

Table 7-5 Forward Linear Model of Sound Objects Expectation: Relaxation Dimension

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.732[a]	.536	.535	2.927
2	.797[b]	.635	.634	2.598
3	.822[c]	.676	.674	2.450
4	.839[d]	.704	.702	2.342
5	.847[e]	.718	.716	2.288

a. Predictors: (Constant), Construction
b. Predictors: (Constant), Construction, Traffic
c. Predictors: (Constant), Construction, Traffic, Pop_Music
d. Predictors: (Constant), Construction, Traffic, Pop_Music, Bird Chirping
e. Predictors: (Constant), Construction, Traffic, Pop_Music, Bird Chirping, Water Stream

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.262	.151		-15.001	.000
	Construction	.100	.004	.732	26.007	.000
2	(Constant)	-3.068	.148		-20.681	.000
	Construction	.075	.004	.545	18.729	.000
	Traffic	.053	.004	.366	12.598	.000
3	(Constant)	-3.231	.141		-22.884	.000
	Construction	.071	.004	.519	18.815	.000
	Traffic	.044	.004	.304	10.733	.000
	Pop_Music	.038	.004	.217	8.593	.000
4	(Constant)	-2.267	.186		-12.166	.000
	Construction	.064	.004	.464	16.967	.000
	Traffic	.038	.004	.264	9.557	.000
	Pop_Music	.032	.004	.185	7.548	.000
	Bird Chirping	-.038	.005	-.195	-7.495	.000
5	(Constant)	-1.945	.192		-10.136	.000
	Construction	.062	.004	.452	16.830	.000
	Traffic	.036	.004	.251	9.240	.000
	Pop_Music	.030	.004	.173	7.169	.000
	Bird Chirping	-.029	.005	-.148	-5.501	.000
	Water Stream	-.031	.006	-.135	-5.346	.000

The effect of a sound object's level adjustment to the rating along the Relaxation dimension is conducted by comparing the Standardized Beta Coefficient of the model, as shown in

Table 7.5. A positive value indicates that the sound object makes participants feel uncomfortable. Three background sound objects significantly affect the uncomfortable rating: construction noise, traffic noise, and pop music. The sound of construction noise is the sound object that affects the uncomfortable rating the most (Standardized Beta Coefficient = 0.452).

There are two background sound objects that significantly affect the comfortable rating (as represented by a negative Standardized Beta Coefficient value): birds chirping and the water stream. The sound of birds chirping is the sound object that affects the comfortable rating the most (Standardized Beta Coefficient = -0.148).

A different approach to the analysis was tried by converting the perception scale into the binary scale and applying forward logistic regression to the data. The conversion was done by converting the negative value into 0 and the positive value into 1. Logistic regression was applied, and the resulting model was able predict the data with high accuracy (92.5% for the dimension of Relaxation, 82.1% for the dimension of Dynamics, and 90.1% for the dimension of Communication), as shown in **Table 7.6**. This result might suggest that the perception of soundscape is better measured with a dichotomous scale than an ordinal scale.

Table 7-6 Percentage Correct of Forward Logistic Regression Model of Sound Objects Expectation

No	Dimension	Percentage Correct
1	Relaxation	92.5%
2	Dynamic	82.1%
3	Communication	90.1%

The Forward Logistic Regression for the dimension of Relaxation indicates that the dichotomous rating is only affected by background sound objects. Four sound objects significantly affect the rating of comfortable/uncomfortable as shown in **Table 7.7**: the water stream, pop music, traffic noise, and construction noise.

The effect of the significant sound objects was analysed using the value of Exp(B)/Odds ratios. The water stream is the only sound object that causes a soundscape composition to be rated as comfortable. Each 1 dB addition of water stream sound to the composition would increase the probability of the soundscape being rated as comfortable by a factor of 1.056.

The sounds of pop music, traffic, and construction significantly affect the uncomfortable rating, with the sound of construction noise having the biggest effects. Each 1 dB addition of construction noise to the composition would increase the probability of the soundscape being rated as comfortable by a factor of 1.105.

Table 7-7 Forward Logistic Model of Sound Objects Expectation: Relaxation Dimension

Observed			Predicted		
			Relax_Logit_compose		Percentage Correct
			0	1	
Step 1	Relax_Logit_compose	0	287	6	98.0
		1	86	208	70.7
	Overall Percentage				84.3
Step 2	Relax_Logit_compose	0	276	17	94.2
		1	40	254	86.4
	Overall Percentage				90.3
Step 3	Relax_Logit_compose	0	280	13	95.6
		1	25	269	91.5
	Overall Percentage				93.5
Step 4	Relax_Logit_compose	0	277	16	94.5
		1	28	266	90.5
	Overall Percentage				92.5

		B	S.E.	Wald	df	Sig.	Exp(B) Uncomfortable	Exp(B) Comfortable
Step 1[a]	Construction	0.086	0.009	86.284	1	0	1.089	0.918
	Constant	-1.238	0.124	99.857	1	0	0.29	3.448
Step 2[b]	Traffic	0.05	0.005	82.528	1	0	1.051	0.951
	Construction	0.088	0.01	71.381	1	0	1.092	0.916
	Constant	-2.35	0.211	124.594	1	0	0.095	10.526
Step 3[c]	Pop_Music	0.061	0.008	55.06	1	0	1.063	0.941
	Traffic	0.053	0.007	61.855	1	0	1.054	0.949
	Construction	0.097	0.011	72.958	1	0	1.102	0.907
	Constant	-3.077	0.285	116.531	1	0	0.046	21.739
Step 4[d]	Stream	-0.055	0.014	15.992	1	0	0.947	1.056
	Pop_Music	0.054	0.008	43.293	1	0	1.055	0.948
	Traffic	0.046	0.007	47.11	1	0	1.047	0.955
	Construction	0.1	0.014	54.775	1	0	1.105	0.905
	Constant	-2.436	0.291	70.186	1	0	0.088	11.364

a. Variable(s) entered on step 1: Construction.
b. Variable(s) entered on step 2: Traffic.
c. Variable(s) entered on step 3: Pop_Music.
d. Variable(s) entered on step 4: Stream.

The Dynamics rating of soundscape compositions is affected by significant background and event sound objects as shown in **Table 7.8.** The background sound objects that significantly affect the Dynamics rating of a soundscape are the sounds of music (accordion, string music, and pop music), people talking, and traffic noise. Each 1 dB addition of these sound objects would increase the probability of the soundscape being rated as varied by a factor of 1.027-1.040.

Event sound objects seem only to affect the Dynamics rating of the soundscape. The other dimensions, Relaxation and Communication, are not affected by event sound objects. There are six event sound objects that significantly affect the Dynamics rating of the soundscape: the tram, birds flying, birds chirping, bus passing, car passing and bicycle. The Dynamics rating of a soundscape composition seems to be affected more by the number of event sounds selected in the soundscape than the sound level of the event sound objects. The total number of event sounds (Event NO in **Table 7.8**) affects the rating the most compared to the other factors. Each additional sound object would increase the probability of the soundscape being rated as varied by a factor of 3.734. In contrast, the effect of a sound level adjustment (each addition of 1 dB of event sound objects) would only increase the probability of the soundscape being rated as simple by a factor of 1.019-1.057.

Table 7-8 Forward Logistic Model of Sound Objects Expectation: Dynamic Dimension

Observed			Predicted		
			Dynamic_Logit_compose		Percentage Correct
			0	1	
Step 1	Dynamic_Logit_compose	0	232	70	76.8
		1	75	211	73.8
	Overall Percentage				75.3
Step 2	Dynamic_Logit_compose	0	244	58	80.8
		1	83	203	71.0
	Overall Percentage				76.0
Step 3	Dynamic_Logit_compose	0	224	78	74.2
		1	61	225	78.7
	Overall Percentage				76.4
Step 4	Dynamic_Logit_compose	0	240	62	79.5
		1	59	227	79.4
	Overall Percentage				79.4
Step 5	Dynamic_Logit_compose	0	252	50	83.4
		1	55	231	80.8
	Overall Percentage				82.1
Step 6	Dynamic_Logit_compose	0	237	65	78.5
		1	48	238	83.2
	Overall Percentage				80.8
Step 7	Dynamic_Logit_compose	0	238	64	78.8
		1	46	240	83.9
	Overall Percentage				81.3
Step 8	Dynamic_Logit_compose	0	239	63	79.1
		1	47	239	83.6
	Overall Percentage				81.3
Step 9	Dynamic_Logit_compose	0	234	68	77.5
		1	51	235	82.2
	Overall Percentage				79.8
Step 10	Dynamic_Logit_compose	0	245	57	81.1
		1	53	233	81.5
	Overall Percentage				81.3
Step 11	Dynamic_Logit_compose	0	246	56	81.5
		1	49	237	82.9
	Overall Percentage				82.1

		B	S.E.	Wald	df	Sig.	Exp(B) Simple	Exp(B) Varied
Step 1[a]	People_Talking	-.036	.003	115.554	1	.000	.964	1.037
	Constant	.966	.131	54.100	1	.000	2.627	0.381
Step 2[b]	People_Talking	-.029	.004	62.621	1	.000	.972	1.029
	Event_NO	-.423	.060	50.280	1	.000	.655	1.527
	Constant	1.562	.165	89.090	1	.000	4.768	0.210
Step 3[c]	Accordeon	-.026	.004	34.712	1	.000	.974	1.026
	People_Talking	-.029	.004	60.092	1	.000	.971	1.030
	Event_NO	-.390	.060	41.638	1	.000	.677	1.477
	Constant	1.888	.183	106.638	1	.000	6.605	0.151
Step 4[d]	Accordeon	-.034	.005	49.564	1	.000	.967	1.034
	String_Music	-.033	.005	40.370	1	.000	.968	1.033
	People_Talking	-.026	.004	44.214	1	.000	.974	1.027
	Event_NO	-.491	.067	53.525	1	.000	.612	1.634
	Constant	2.536	.230	121.376	1	.000	12.630	0.079
Step 5[e]	Accordeon	-.034	.005	47.416	1	.000	.966	1.035
	String_Music	-.030	.005	31.529	1	.000	.971	1.030
	People_Talking	-.027	.004	45.068	1	.000	.973	1.028
	Bus_Passing_E	.027	.006	17.965	1	.000	1.027	0.974
	Event_NO	-.715	.091	61.785	1	.000	.489	2.043
	Constant	2.516	.232	117.137	1	.000	12.375	0.081
Step 6[f]	Accordeon	-.040	.006	53.528	1	.000	.961	1.041
	String_Music	-.037	.006	41.021	1	.000	.964	1.038
	People_Talking	-.021	.004	23.124	1	.000	.979	1.021
	Traffic	-.026	.005	27.548	1	.000	.975	1.026
	Bus_Passing_E	.036	.007	26.818	1	.000	1.037	0.965
	Event_NO	-.716	.094	57.604	1	.000	.489	2.046
	Constant	2.946	.256	132.378	1	.000	19.035	0.053
Step 7[g]	Accordeon	-.041	.006	53.196	1	.000	.960	1.042
	String_Music	-.038	.006	42.312	1	.000	.963	1.039
	People_Talking	-.020	.004	20.117	1	.000	.980	1.020
	Traffic	-.027	.005	28.432	1	.000	.973	1.027
	Bus_Passing_E	.041	.007	32.178	1	.000	1.042	0.959
	Bicycle_E	.024	.008	8.772	1	.003	1.025	0.976
	Event_NO	-.856	.109	61.595	1	.000	.425	2.355
	Constant	2.975	.265	126.339	1	.000	19.599	0.051
Step 8[h]	Accordeon	-.040	.006	51.344	1	.000	.960	1.041
	String_Music	-.037	.006	38.715	1	.000	.964	1.037
	People_Talking	-.020	.005	19.216	1	.000	.980	1.020
	Traffic	-.026	.005	25.540	1	.000	.975	1.026
	Bird_Flying_E	.039	.013	8.664	1	.003	1.040	0.962
	Bus_Passing_E	.047	.008	37.004	1	.000	1.049	0.954
	Bicycle_E	.026	.008	9.880	1	.002	1.026	0.975
	Event_NO	-.965	.117	67.466	1	.000	.381	2.624
	Constant	2.907	.266	119.874	1	.000	18.305	0.055
Step 9[i]	Accordeon	-.041	.006	50.449	1	.000	.960	1.042
	String_Music	-.039	.006	41.119	1	.000	.962	1.039
	People_Talking	-.020	.005	18.776	1	.000	.980	1.020
	Pop_Music	-.016	.006	6.702	1	.010	.984	1.016
	Traffic	-.024	.005	20.962	1	.000	.977	1.024
	Bird_Flying_E	.040	.014	8.547	1	.003	1.041	0.961
	Bus_Passing_E	.054	.008	40.930	1	.000	1.055	0.948
	Bicycle_E	.026	.008	9.905	1	.002	1.026	0.974
	Event_NO	-.992	.121	66.935	1	.000	.371	2.697
	Constant	3.011	.274	120.849	1	.000	20.310	0.049

Step 10[j]	Accordeon	-.040	.006	47.209	1	.000	.961	1.041
	String_Music	-.037	.006	37.964	1	.000	.963	1.038
	People_Talking	-.021	.005	19.329	1	.000	.980	1.021
	Pop_Music	-.018	.006	8.458	1	.004	.982	1.018
	Traffic	-.023	.005	18.659	1	.000	.978	1.023
	Bird_Flying_E	.046	.014	10.451	1	.001	1.047	0.955
	Bus_Passing_E	.051	.009	35.177	1	.000	1.052	0.950
	Car_Passing_E	.021	.010	4.170	1	.041	1.022	0.979
	Bicycle_E	.027	.008	11.034	1	.001	1.028	0.973
	Event_NO	-1.120	.141	62.972	1	.000	.326	3.066
	Constant	3.019	.273	121.954	1	.000	20.468	0.049
Step 11[k]	Accordeon	-.039	.006	43.697	1	.000	.962	1.040
	String_Music	-.037	.006	36.917	1	.000	.963	1.038
	People_Talking	-.021	.005	20.589	1	.000	.979	1.022
	Pop_Music	-.019	.006	9.464	1	.002	.981	1.019
	Traffic	-.027	.006	22.418	1	.000	.973	1.027
	Tram_E	.019	.009	4.164	1	.041	1.019	0.981
	Bird_Flying_E	.056	.015	13.180	1	.000	1.057	0.946
	Bus_Passing_E	.052	.008	37.835	1	.000	1.053	0.949
	Car_Passing_E	.027	.011	6.141	1	.013	1.027	0.974
	Bicycle_E	.031	.008	13.779	1	.000	1.032	0.969
	Event_NO	-1.318	.174	57.356	1	.000	.268	3.734
	Constant	3.151	.288	119.754	1	.000	23.353	0.043

a. Variable(s) entered on step 1: People_Talking.
b. Variable(s) entered on step 2: Event_NO.
c. Variable(s) entered on step 3: Accordeon.
d. Variable(s) entered on step 4: String_Music.
e. Variable(s) entered on step 5: Bus_Passing_E.
f. Variable(s) entered on step 6: Traffic.
g. Variable(s) entered on step 7: Bicycle_E.
h. Variable(s) entered on step 8: Bird_Flying_E.
i. Variable(s) entered on step 9: Pop_Music.
j. Variable(s) entered on step 10: Car_Passing_E.
k. Variable(s) entered on step 11: Tram_E.

An interesting thing is shown in the odds ratios (Exp (B)) of individual event sound objects, namely, the sound level of the event sound objects significantly affects the rating of the Dynamics dimension. Each 1 dB addition of individual sound objects would increase the likelihood of the soundscape being rated as simple by a factor of 1.109-1.057.

Although the sound level of event sound objects could cause a soundscape to be perceived as simple, the effect is not as great as the addition of event sound objects in the soundscape. The effect of the addition of one sound object is more than three times greater than the effect of a sound level adjustment to individual sound objects. Indeed, the odds ratio of the number of sound objects (Event NO) is larger than all the other significant sound objects. This phenomenon indicates that the Dynamics of a soundscape are mainly affected by the variation or the number of sound objects in it.

The rating of the Communication dimension is significantly affected by two background sound objects as shown in **Table 7.9**: a bird chirping and people talking. The sound of birds chirping causes the soundscape to be rated as private, and the sound of people talking in the background causes the soundscape to be rated as communal. Each 1dB increase in the sound level of birds chirping increases the probability of a private rating by a factor of 1.052, and each 1 dB increase in the sound level of people talking increases the probability of a communal rating by a factor of 1.051.

Table 7-9 Forward Logistic Model of Sound Objects Expectation: Communication Dimension

Observed			Predicted		
			Communication_Logit_compose		Percentage Correct
			0	1	
Step 1	Communication_Logit_compose	0	368	56	86.8
		1	58	106	64.6
	Overall Percentage				80.6
Step 2	Communication_Logit_compose	0	407	17	96.0
		1	41	123	75.0
	Overall Percentage				90.1

		B	S.E.	Wald	df	Sig.	Exp(B) Private	Exp(B) Communal
Step 1[a]	Bird_Chirping	.057	.005	144.002	1	.000	1.058	0.945
	Constant	-2.054	.155	176.398	1	.000	.128	7.797
Step 2[b]	Bird_Chirping	.050	.005	86.895	1	.000	1.052	0.951
	People_Talking	-.050	.006	73.225	1	.000	.951	1.051
	Constant	-1.009	.177	32.668	1	.000	.365	2.743

a. Variable(s) entered on step 1: Bird_Chirping.
b. Variable(s) entered on step 2: People_Talking.

In general, the logistic ratings of Relaxation and Communication are affected only by background sound objects, whereas the rating of Dynamics is affected by both background and event sound objects. This study has defined the relationship between soundscape dimensions and the expectation of sound objects in the soundscape environment simulator, especially the effect of sound object selection and sound level of sound objects on the rating of soundscapes according to the soundscape dimensions.

The results of this study also suggest that the perception of soundscape was better explained with a dichotomous scale than an ordinal scale. The ordinal scale only applies to the rating of the Relaxation dimension (Pearson Correlation 0.847) and might not be suitable for rating Dynamics and Communication. This could have implications for future soundscape survey instruments.

7.3.3 Preference of Sound Objects in a Soundscape

The preference of sound objects in a soundscape was analysed by reproducing the simulated soundscapes composed in the previous experiment and asking participants to rate them. Two models were determined using Linear Regression and Logistic Regression.

A Forward Linear Regression was implemented to determine the relationship between sound objects and soundscape dimensions in the linear model. The Pearson's Correlation of the model is shown in **Table 7.10.** The dimension of Relaxation showed the highest correlation with the sound objects; the Pearson's Correlation of 0.772 is considered a strong one. The others two dimensions, Dynamics and Communication, show moderate and weak correlation. Further analysis is done to the linear model of the dimension of Relaxation due to the strong correlation.

Table 7-10 Pearson's Correlation of the Forward Linear Model of Sound Objects Preference

No	Dimension	R
1	Relaxation	0.722
2	Dynamics	0.572
3	Communication	0.309

The linear forward model indicates five background sound objects which represent the dimension of Relaxation: construction noise, traffic noise, pop music, birds chirping, and people talking in the background. Surprisingly, there are not any significant event sound objects in the model. This may suggest that the dimension of Relaxation is only affected by background sound objects, which would be consistent with the result of the previous experiment about the expectation of sound objects in a soundscape.

Table 7-11 Forward Linear Model of Sound Objects Preference: Relaxation Dimension

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.622[a]	.386	.385	2.726
2	.676[b]	.457	.455	2.567
3	.705[c]	.496	.494	2.474
4	.718[d]	.516	.513	2.427
5	.722[e]	.521	.517	2.417

a. Predictors: (Constant), Construction
b. Predictors: (Constant), Construction, Traffic
c. Predictors: (Constant), Construction, Traffic, Bird Chirping
d. Predictors: (Constant), Construction, Traffic, Bird Chirping, Pop_Music
e. Predictors: (Constant), Construction, Traffic, Bird Chirping, Pop_Music, People_Talking

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.552	.140		-11.053	.000
	Construction	.069	.004	.622	19.209	.000
2	(Constant)	-2.103	.147		-14.344	.000
	Construction	.051	.004	.464	13.073	.000
	Traffic	.036	.004	.309	8.704	.000
3	(Constant)	-1.218	.192		-6.337	.000
	Construction	.044	.004	.396	11.108	.000
	Traffic	.029	.004	.251	7.138	.000
	Bird Chirping	-.036	.005	-.227	-6.784	.000
4	(Constant)	-1.421	.193		-7.360	.000
	Construction	.043	.004	.386	11.031	.000
	Traffic	.025	.004	.215	6.076	.000
	Bird Chirping	-.031	.005	-.199	-5.960	.000
	Pop_Music	.022	.004	.153	4.879	.000
5	(Constant)	-1.673	.219		-7.636	.000
	Construction	.043	.004	.386	11.087	.000
	Traffic	.023	.004	.196	5.437	.000
	Bird Chirping	-.028	.005	-.179	-5.249	.000
	Pop_Music	.021	.004	.150	4.805	.000
	People_Talking	.009	.004	.076	2.398	.017

The effect of different sound objects' level adjustment on a soundscape's Relaxation dimension rating can be compared using the Standardized Beta Coefficient of the model, as shown in **Table 7.11.** A positive value indicates that a sound object makes the participants feel uncomfortable. Four sound objects significantly affect uncomfortable ratings: construction noise, traffic noise, pop music, and people talking in the background. The sound of construction noise affects uncomfortable ratings the most (Standardized Beta Coefficient =

0.386). The only sound object that affects comfortable ratings is the sound of a bird chirping (Standardized Beta Coefficient = -0.179).

In general, the results of this preference experiment are similar to those of the expectation experiment, which indicates three things: the linear model is only applied to the dimension of Relaxation; the dimension of Relaxation is only affected by background sounds; and the dimension of Relaxation is affected by similar sound objects to the expectation experiment. This linear model also confirms that Relaxation dimension ratings are affected by the sound level adjustment of the sound objects. The other two dimensions of soundscape (Dynamics and Communication) seem to be affected more by the presence of certain sound objects than by their sound level. Further analysis is done using Logistic Regression.

Forward Logistic regression was implemented, and the model could predict 72.1%-86.1% of the data, as shown in **Table 7.12**. As in the expectation experiment, the dimension of Relaxation shows higher accuracy than the other dimensions.

Table 7-12 Percentage Correct of Forward Logistic Regression Model of Sound Objects Preference

No	Dimension	Percentage Correct
1	Relaxation	86.1%
2	Dynamics	73.8%
3	Communication	72.1%

The Forward Logistic Regression analysis of the dimension of Relaxation is shown in **Table 7.13**. Again, as in the expectation experiment, the dimension of Relaxation is only affected by background sound objects.

Two sound objects significantly cause a soundscape to be rated more comfortable: birds chirping and accordion music. The sound of a bird chirping in the background affects comfortable ratings the most. Each addition of 1 dB of bird chirping sound increases the probability of a soundscape being rated as comfortable by a factor of 1.026.

Interestingly, the sound objects that significantly affect comfortable ratings are different in the preference and expectation experiments. This phenomenon does not occur, however, for sound objects that provoke uncomfortable ratings, which are the same in the preference and expectation experiments: pop music, urban traffic and construction noise. The most uncomfortable sound object is also consistent with the expectation experiment (construction noise).

Table 7-13 Forward Logistic Model of Soundscape Preference: Relaxation Dimension

			Predicted		
			Relax_Logit_listen		
Observed			0	1	Percentage Correct
Step 1	Relax_Logit_listen	0	267	22	92.4
		1	100	186	65.0
	Overall Percentage				78.8
Step 2	Relax_Logit_listen	0	263	26	91.0
		1	61	225	78.7
	Overall Percentage				84.9
Step 3	Relax_Logit_listen	0	264	25	91.3
		1	70	216	75.5
	Overall Percentage				83.5
Step 4	Relax_Logit_listen	0	255	34	88.2
		1	52	234	81.8
	Overall Percentage				85.0
Step 5	Relax_Logit_listen	0	261	28	90.3
		1	52	234	81.8
	Overall Percentage				86.1

		B	S.E.	Wald	df	Sig.	Exp(B) Uncomfortable	Exp(B)Comfortable
Step 1[a]	Construction	.052	.004	147.952	1	.000	1.053	0.950
	Constant	-1.015	.118	74.251	1	.000	.362	2.760
Step 2[b]	Traffic	.028	.004	45.336	1	.000	1.028	0.973
	Construction	.044	.005	96.117	1	.000	1.045	0.957
	Constant	-1.522	.151	101.777	1	.000	.218	4.581
Step 3[c]	Pop_Music	.030	.006	27.639	1	.000	1.030	0.971
	Traffic	.023	.004	28.888	1	.000	1.023	0.977
	Construction	.044	.005	92.517	1	.000	1.045	0.957
	Constant	-1.719	.162	112.554	1	.000	.179	5.579
Step 4[d]	Bird_Chirping	-.023	.006	13.450	1	.000	.977	1.023
	Pop_Music	.025	.006	18.596	1	.000	1.025	0.976
	Traffic	.019	.004	19.413	1	.000	1.019	0.981
	Construction	.040	.005	72.275	1	.000	1.040	0.961
	Constant	-1.216	.200	37.081	1	.000	.296	3.373
Step 5[e]	Bird_Chirping	-.026	.006	15.841	1	.000	.975	1.026
	Accordeon	-.010	.005	4.196	1	.041	.990	1.010
	Pop_Music	.024	.006	18.238	1	.000	1.025	0.976
	Traffic	.019	.004	18.549	1	.000	1.019	0.981
	Construction	.040	.005	71.953	1	.000	1.041	0.961
	Constant	-1.026	.217	22.364	1	.000	.358	2.791

a. Variable(s) entered on step 1: Construction.
b. Variable(s) entered on step 2: Traffic.
c. Variable(s) entered on step 3: Pop_Music.
d. Variable(s) entered on step 4: Bird_Chirping.
e. Variable(s) entered on step 5: Accordeon.

Bruce and Davies suggest that the rating of soundscape (i.e. whether the soundscape is perceived as positive or negative) is affected by the expectation of space (N. S. Bruce & Davies, 2014), and the present experiment shows that the expectation of sound objects is only consistent with preference for the uncomfortable sound objects.

The analysis of expectation and preference of sound objects with linear and logistic regression indicates that some sound objects consistently affect the dimension of Relaxation. The sound of a bird chirping in the background causes a significantly higher rating of the soundscape as relaxing. Previous studies suggest that natural sounds are perceived as good (Axelsson et al., 2010; Brambilla et al., 2013), but this study shows that not all natural sounds affect the comfort ratings of a soundscape: for example, the sound of birds chirping significantly affects comfort ratings, while water sound does not.

The sounds of construction noise, traffic noise and pop music cause the soundscape to be rated significantly uncomfortable. Previous studies found that mechanical sounds are rated as uncomfortable (Catherine Guastavino, 2006; Hall et al., 2013), and this study shows how the sounds of construction noise, traffic noise and pop music affect the uncomfortable ratings of a soundscape. Furthermore, this study shows that the sound of construction noise is more uncomfortable than traffic noise or pop music.

A Forward Logistic Regression analysis of the Dynamics dimension in the preference experiment gives a different result than the expectation experiment. In the expectation experiment, ratings of the Dynamics dimension are affected by both event sound objects and background sound objects, while in the preference experiment, ratings are affected mainly by background sound objects, as shown in **Table 7.14.**

Table 7-14 Forward Logistic Model of Soundscape Preference: Dynamic Dimension

Observed			Predicted		
			Dynamic_Logit_listen		Percentage Correct
			0	1	
Step 1	Dynamic_Logit_listen	0	174	160	52.1
		1	34	204	85.7
	Overall Percentage				66.1
Step 2	Dynamic_Logit_listen	0	237	97	71.0
		1	84	154	64.7
	Overall Percentage				68.4
Step 3	Dynamic_Logit_listen	0	229	105	68.6
		1	68	170	71.4
	Overall Percentage				69.8
Step 4	Dynamic_Logit_listen	0	248	86	74.3
		1	71	167	70.2
	Overall Percentage				72.6
Step 5	Dynamic_Logit_listen	0	261	73	78.1
		1	71	167	70.2
	Overall Percentage				74.8
Step 6	Dynamic_Logit_listen	0	260	74	77.8
		1	76	162	68.1
	Overall Percentage				73.8

		B	S.E.	Wald	df	Sig.	Exp(B) Simple	Exp(B) Varied
Step 1[a]	Construction	-.032	.003	82.833	1	.000	.969	1.032
	Constant	.278	.106	6.915	1	.009	1.320	0.758
Step 2[b]	Traffic	-.018	.004	24.288	1	.000	.982	1.018
	Construction	-.025	.004	42.765	1	.000	.976	1.025
	Constant	.564	.123	21.197	1	.000	1.758	0.569
Step 3[c]	Stream	.021	.005	14.550	1	.000	1.021	0.980
	Traffic	-.015	.004	16.146	1	.000	.985	1.015
	Construction	-.022	.004	33.525	1	.000	.978	1.023
	Constant	.229	.149	2.370	1	.124	1.257	0.795
Step 4[d]	Stream	.018	.005	10.777	1	.001	1.018	0.982
	Pop_Music	-.014	.005	7.808	1	.005	.986	1.014
	Traffic	-.013	.004	11.365	1	.001	.987	1.013
	Construction	-.022	.004	31.370	1	.000	.979	1.022
	Constant	.338	.155	4.788	1	.029	1.402	0.713
Step 5[e]	Stream	.016	.006	8.607	1	.003	1.017	0.984
	People_Talking	-.010	.004	6.417	1	.011	.991	1.010
	Pop_Music	-.013	.005	7.147	1	.008	.987	1.013
	Traffic	-.011	.004	7.442	1	.006	.989	1.011
	Construction	-.022	.004	30.956	1	.000	.979	1.022
	Constant	.554	.179	9.606	1	.002	1.740	0.575
Step 6[f]	Stream	.017	.006	8.954	1	.003	1.017	0.983
	People_Talking	-.013	.004	9.898	1	.002	.987	1.013
	Pop_Music	-.016	.005	9.808	1	.002	.984	1.016
	Traffic	-.012	.004	9.336	1	.002	.988	1.013
	Construction	-.022	.004	31.987	1	.000	.978	1.022
	Event_NO	-.155	.059	6.920	1	.009	.857	1.167
	Constant	.404	.188	4.637	1	.031	1.498	0.667

a. Variable(s) entered on step 1: Construction.
b. Variable(s) entered on step 2: Traffic.
c. Variable(s) entered on step 3: Stream.
d. Variable(s) entered on step 4: Pop_Music.
e. Variable(s) entered on step 5: People_Talking.
f. Variable(s) entered on step 6: Event_NO.

The other difference shown in the preference experiment is that background sound objects contribute significantly to simple soundscape ratings, while in the expectation experiment, all the significant background sound objects could cause a soundscape to be rated as varied.

This difference indicates that participants act differently when they are able to compose a soundscape than when they listen to one. This phenomenon only appeared in the dimension of Dynamics (not in Relaxation or Communication).

When participants compose a soundscape, they have more interaction with the event sound objects, which could be the reason why individual event sound objects significantly affect ratings of the Dynamics dimension; when they listen to a soundscape composition, their interaction with the individual sound objects is not as great. The individual event sound objects only appear once in each soundscape composition sample, while when a participant composes a soundscape in the simulator, they can play the event sound as often as they like and even adjust the sound level.

The different nature of the interactions between participants and the event sound objects may also cause a difference in the effect of overall event sound objects (indicated by the Event NO variable) between the expectation and preference experiments. In the expectation experiment, the odds ratio (Exp (B)) of the Event NO variable (representing the number of event sounds in the soundscape) is more than three times higher than in the preference experiment. In the expectation experiment, each additional event sound object would make the likelihood of the soundscape being rated as varied increase by a factor of 3.734, while in the preference experiment, each additional event sound object would make it 1.167 times more likely that the soundscape would be rated as varied.

Although the number of event sounds in a soundscape shows different effects in the expectation and preference experiments, this variable affects the rating of the Dynamics dimension the most when compared with individual sound objects (both background sound objects and event sound objects). This phenomenon indicates that the dimension of Dynamics is affected most by the variety of sound objects in a soundscape. The greater the variation of sound objects in a soundscape, the more varied it will be rated. This result is consistent with the expectation experiment.

The consistency between the expectation and preference experiments is demonstrated by three background sound objects: people talking, pop music and traffic noise. The previous study by Axelsson et al. states that people consider sound objects related to human activity to be related to the dimension of Eventful (Axelsson et al., 2010), without specifying what the sound objects were or how they affected the dimension. This study has shown both which specific sound objects significantly affect the dimension of Dynamics and how they do so.

Table 7-15 Forward Logistic Model of Soundscape Preference: Communication Dimension

Observed			Predicted		
			Communication_logit_listen		Percentage Correct
			0	1	
Step 1	Communication_logit_listen	0	396	0	100.0
		1	174	0	0.0
	Overall Percentage				69.5
Step 2	Communication_logit_listen	0	361	35	91.2
		1	124	50	28.7
	Overall Percentage				72.1

		B	S.E.	Wald	df	Sig.	Exp(B) Private	Exp(B) Private
Step 1[a]	People_Talking	-.021	.003	35.582	1	.000	.979	1.021
	Constant	-.304	.120	6.358	1	.012	.738	1.355
Step 2[b]	Bird_Chirping	.015	.004	11.725	1	.001	1.015	0.985
	People_Talking	-.017	.004	20.607	1	.000	.983	1.017
	Constant	-.651	.161	16.465	1	.000	.521	1.918

a. Variable(s) entered on step 1: People_Talking.
b. Variable(s) entered on step 2: Bird_Chirping.

A Forward Logistic Regression analysis for the Communication dimension shows a result consistent with that of the expectation experiment as shown in **Table 7.15**. The dimension of Communication is affected by the background sounds of a bird chirping and of people talking. As in the expectation experiment, the sound of birds chirping cause the soundscape to be rated as private, while the sound of people talking in the background cause the soundscape be rated as communal. Each 1 dB increase in the sound level of birds chirping increases the probability of the soundscape being rated as private by a factor of 1.015, just as each 1 dB increase in the sound level of people talking increases the probability of the soundscape being rated as communal by a factor of 1.017.

Although the relationship between specific sound objects and soundscape dimensions has been successfully determined using the expectation and the preference approach, the assessment of this relationship is limited by the possible sound level range of sound objects reproduced in the simulator. The soundscape simulator was only able to reproduce each sound object at a maximum of 12 dB above the calibrated sound level, which means that the models determined from this study are only valid when a sound object's sound level is below the maximum. The maximum sound level of each of sound object is shown in **Table 7.16.**

Table 7-16 Maximum Sound Level (L_{Aeq} in dB) of Each Sound Object in the Soundscape Environment Simulator

Background Sound Objects	Max Sound Level (dB)
Water Fountain	71.2
Water Stream	66.2
Bird Chirping	65.3
Accordion Music	71.5
String Instrument Music	72.9
People Talking	73.8
Pop Music	73.1
Traffic	76.2
Construction Noise	76.3
White Noise	79.0

Event Sound Objects	Max Sound Level (dB)
Tram	61.4
Bird Flying	55.8
Bird Chirping	50.6
Bus Passing	65.9
Car Passing	56.1
Footsteps	61.0
Woman Talking	64.0
Trolley Bag	54.7
Bicycle	67.6
Child talking	67.5

7.4 Implementation of the Soundscape Model in the Soundscape Environment Simulator

The relationship of sound objects and soundscape dimensions has been determined, and the Logistic Regression Model seems adequate to explain the relationship. The soundscape environment simulator was therefore further developed by implementing the Perception Model so that the simulator could predict different scenarios of soundscape composition. This soundscape environment simulator, with its perception prediction capacity, would therefore be suitable to design new soundscape scenarios or to evaluate and fix existing soundscapes.

The interface of the simulator with the model implemented is shown in **Figure 7.8**. The rating of the soundscape composition is shown at the bottom of the interface. The value represents the probability of a soundscape rating according to each soundscape dimension. As the value approaches 1, the soundscape has a higher probability of being rated according to the right side of the scale (Uncomfortable, Soft, and Private); as the value approaches 0, the soundscape has a higher probability of being rated according to the left side of the scale (Comfortable, Varied, and Communal).

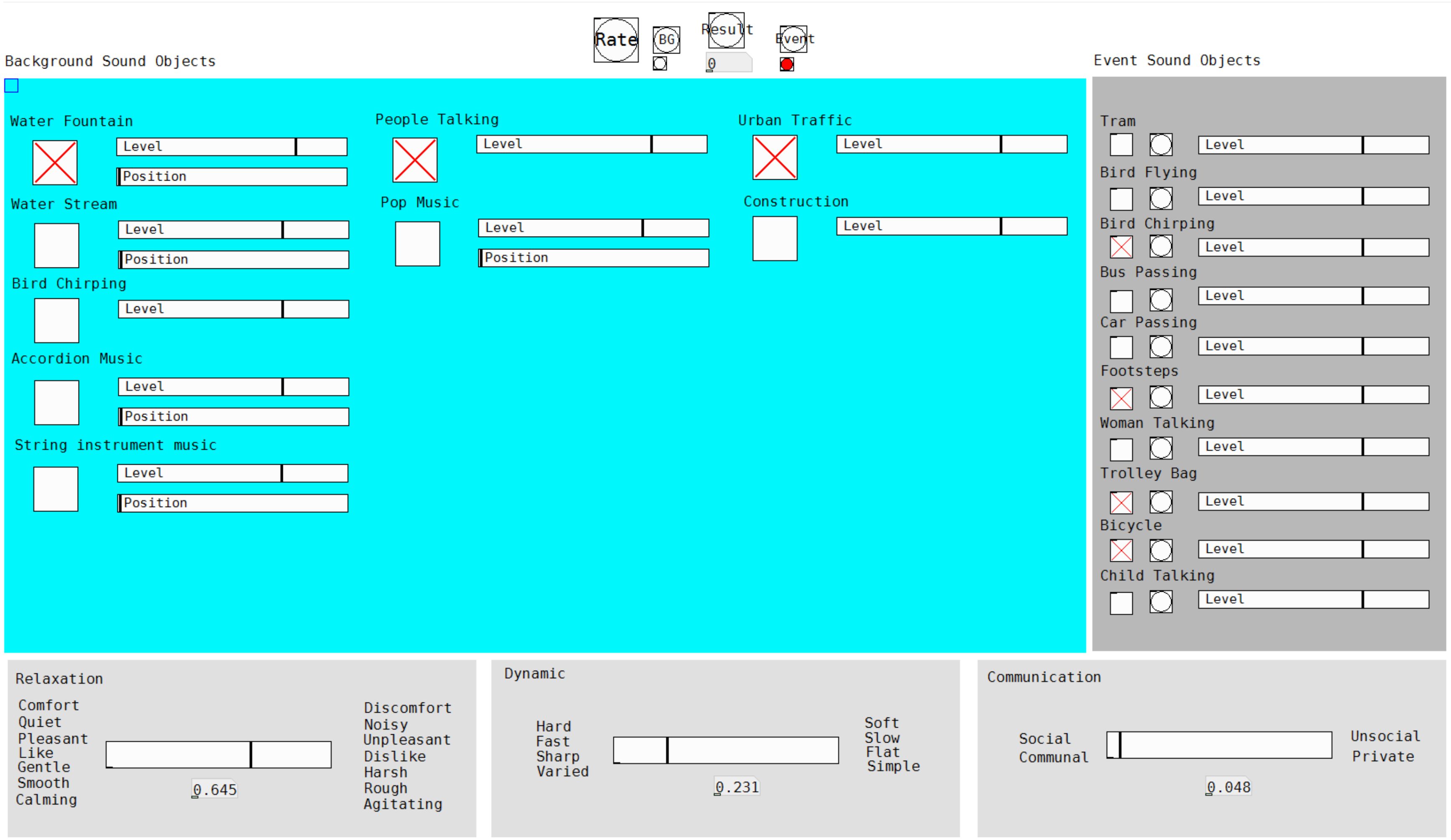


Figure 7-8 Soundscape Simulator Interface with Implementation of Perception Model
(The light grey area shows the perception rating of the soundscape composition)

The Perception Model was implemented using input from the slider (representing the sound level adjustment of sound objects) and the selection of sound objects. The output of the model is a value between 0-1, representing the probability that the given soundscape will be rated on one or the other side of each soundscape dimension scale (Relaxation, Dynamics, and Communication); the PureData syntax is shown in **Appendix 10.6**.

The perception model implemented in the simulator was the one that resulted from the preference experiment, which asked participants to rate soundscape compositions. By implementing this model, the simulator is able predict the perception of a soundscape composition from the listener's point of view rather than the composer's.

Three models are implemented in the soundscape environment simulator, representing the dimensions of Relaxation, Dynamics and Communication. The models are developed according to the Preference Model of Forward Logistic Regression **(Table 7.13-7.15).** The Logistic models for Relaxation, Dynamics, and Communication are shown in **Equations 7.1-7.3**. The input for the model is the sound level of sound objects.

$$\boldsymbol{Relaxation} = \mathbf{1/(1+\exp(-(-\mathit{Bird\ Chirping}_{BG} * 0.026 - \mathit{Accordion\ Music}_{BG} * 0.010 + \mathit{Pop\ Music}_{BG} * 0.024 + \mathit{Traffic}_{BG} * 0.019 + \mathit{Construction}_{BG} * 0.040 - 1.216)))}$$ **Equation 7.1**

$$\boldsymbol{Dynamics} = \mathbf{1/(1+\exp(-(\mathit{Stream}_{BG} * 0.017 - \mathit{People\ Talking}_{BG} * 0.013 - \mathit{Pop\ Music}_{BG} * 0.016 - \mathit{Traffic}_{BG} * 0.012 - \mathit{Construction}_{BG} * 0.022 - \mathit{Event\ NO} * 0.155 + 0.404)))}$$ **Equation 7.2**

$$\boldsymbol{Communication} = \mathbf{1/(1+\exp(-(\mathit{Bird\ Chirping}_{BG} * 0.015 - \mathit{People\ Talking}_{BG} * 0.017 - 0.015)))}$$ **Equation 7.3**

The addition of the perception model is a positive development of the soundscape environment simulator. The simulator is not only able to compose a soundscape, but also to predict its perception from the listener's point of view. Finally, the ability to predict perception allows the simulator to be both a soundscape environment simulator and a soundscape simulator.

7.5 Discussions

This study has analysed the relationship between sound objects and soundscape dimensions by using an expectation approach in which participants were asked to compose and rate soundscapes, and a preference approach in which participants were asked to listen to and rate soundscape compositions.

According to the selection of sound objects in the soundscape environment simulator, it seems that sound objects have two meanings in a soundscape: as a representation of a type of space, and as a determinant in the perception of the soundscape. The participants in the experiment seemed to correlate an urban area with the sound of people talking in the background (selected by 84 % of participants), urban traffic (76% of participants), and bus passing (66% of participants). These three were the most selected sound objects in urban soundscape compositions, in both the comfortable and uncomfortable conditions. Their selection shows how the expectation of certain sound objects can come to represent soundscape types.

The relationship between sound objects and perception of soundscape was analysed using linear and logistic regression, which revealed an interesting finding. It turns out that the perception of a soundscape appears to be easier to explain with binary choices such as comfortable/uncomfortable, varied/simple and communal/private. The logistic model obtained using binary perception ratings was able to predict more than 72% of the data.

Although the logistic regression could predict a high percentage of the data, the linear model observed a strong relationship (Pearson's Correlation 0.847 for the expectation experiment and 0.772 for the preference experiment) between the sound level of the background sound objects and ratings on the Relaxation dimension. The other two dimensions of soundscape – Dynamics and Communication – seem to be more affected by the presence of sound objects than by their sound level.

The study shows that expectation of sound objects affects their selection in a soundscape, as well as how the sound objects influence the overall soundscape rating. Participants in this experiment seem to correlate urban areas with the sound of traffic (selected by 72% of participants), construction noise (70% of participants) and people talking in the background (56 % of the participants).

The dimension of Relaxation is significantly affected by the expectation of the sounds of a water stream, pop music, traffic noise, and construction noise (predicting 92.5% of the data). The sound of a water stream significantly affects the overall comfortable rating more than the other significant sound objects do. With each 1 dB rise in the level of water sound, the probability that people will rate the soundscape as comfortable increases by a factor of 1.056. The most uncomfortable sound object is the sound of construction noise. Each 1 dB increase in construction noise sound level increases the probability that people will rate the soundscape as uncomfortable by a factor of 1.105.

The dimension of Dynamics is affected by the expectation of the background sounds of music, people talking, and traffic noise; the event sound objects of urban traffic and a bird chirping; and the number of event sound objects in a soundscape (predicting 82.1% of the data). The number of event sound objects is the strongest factor affecting the dimension of Dynamics. The addition of one event sound in a soundscape will increase the probability of it being rated as dynamic by a factor of 3.734. Each 1 dB increase in the music sound level increases the probability of people rating a soundscape as dynamic by a factor of 1.022-1.040. Each 1 dB addition to the sound of people talking and traffic noise increases the probability of people rating a soundscape as dynamic by a factor of 1.022. Each 1 dB increase in the sound level of event sound objects would increase the likelihood of people rating a soundscape as dynamic by a factor of 1.019 -1.057. In addition, it appears that event sound objects only significantly affect the dimension of Dynamics.

The dimension of Communication is significantly affected by the expectation of the background sounds of birds chirping and people talking (predicting 90.1% of the data). Each 1 dB increase in the sound level of birds chirping in the background increases the probability of people rating a soundscape as private by a factor of 1.052, while each 1 dB addition of people talking in the background increases the probability of people rating a soundscape as communal by a factor of 1.052.

The dimension of Relaxation in the preference experiment is significantly affected by a preference for the background sounds of birds chirping, pop music, traffic noise, and construction noise (predicting 84.4% of the data). The sound of birds chirping is the only significant sound object that affected the dimension of Relaxation. Each 1 dB of additional sound of birds chirping in the background increases the probability of people rating a soundscape as relaxing by a factor of 1.026. Construction noise is the sound object that caused people to rate the soundscape as uncomfortable most often. Each 1 dB of additional construction noise increases the likelihood of an uncomfortable soundscape rating by a factor of 1.041. The sounds of pop music and traffic noise offers a similar result with smaller effects (where each 1 dB addition increases the probability of a soundscape being rated as uncomfortable by a factor of 1.02). According to our results, it seems that the sound of a bird chirping would be suitable for masking uncomfortable sound objects.

The dimension of Dynamics in the preference experiment is affected significantly by the background sounds of the water stream, people talking, pop music, traffic noise, and construction, as well as the number of event sounds in the soundscape (predicting 73.4% of the data). The most influential factor in the rating of Dynamics is the number of event sounds in a soundscape. Each additional sound object increases the probability of the soundscape being rated as dynamic by a factor of 1.167. The sound of the water stream is the only sound object that causes the soundscape to be rated as simple. Each 1 dB of additional water stream sound increases the probability of the soundscape being rated as simple by a factor of 1.017. Each 1 dB addition of the other significant sound objects – the background sounds of people talking, pop music, traffic noise, and construction noise – increases the probability of the soundscape being rated as dynamic by a factor of 1.013-1.022.

The dimension of Communication in the preference experiment is affected significantly by the sound of birds chirping and by the sound of people talking in the background (predicting 72.1% of the data). Each 1 dB increase in the sound level of birds chirping in the background increases the probability of a soundscape being rated as private by a factor of 1.017, just as each 1 dB addition of people talking in the background increases the probability of people rating a soundscape as communal by a factor of 1.015.

In general, the background sound objects affect the perception of soundscape more than the event sound objects especially for the dimension of Relaxation and Communication. The Dimension of Relaxation and Communication are only affected by the background sound objects. This result is also consistent between the listener-participants (preference experiment) and the composer-participants (expectation experiment). When listening to a soundscape, people tend to relate the Dynamics dimension with background sound objects only, while when composing a soundscape, they tend to relate its Dynamics with its event sound objects. A soundscape composer has more interaction with event sound objects, so they relate their perception of composition with both background and event sound objects. This may be the reason why soundscape preference and expectation are different for the Dynamics dimension.

The analysis with respect to the expectation and preference of sound objects using linear and logistic regression indicates that some background sound objects consistently affect the dimension of Relaxation. The sound of a bird chirping in the background causes the soundscape to be rated as significantly more relaxing compared to other natural sound objects. This study shows that not all natural sounds can affect the comfort ratings of a soundscape. The sound of birds chirping, for example, significantly affects soundscape comfort, while the effect of a water sound is not significant.

The sound of water stream is the only comfortable sound object that significant in the expectation experiment and the sound of accordion music is only comfortable sound object that significant in the preference experiment. In contrast, the significant uncomfortable sound objects (construction noise, traffic noise, and pop music) are consistent among the expectation and preference experiments. This phenomenon indicates that the perception of comfortable sound objects might be different from the expectation and preference point of view, but not on the uncomfortable sound objects.

The sounds of construction noise, traffic noise and pop music contribute significantly to ratings of a soundscape as uncomfortable. Furthermore, this study shows that the sound of construction noise is rated as more uncomfortable than traffic noise and pop music.

The number of event sounds in a soundscape produces different effects in the expectation and preference experiments, but this variable affects ratings of the Dynamics dimension the most in comparison to the individual sound objects (both background and event sound objects). This phenomenon indicates that the dimension of Dynamics is affected most by the variability of sound objects in a soundscape. The greater the variety of sound objects in a soundscape, the more varied it is rated. This result is consistent with that of the expectation experiment.

The experimental consistency between the expectation and preference experiments for the Dynamics dimension is demonstrated by three background sound objects: people talking, pop music, and traffic noise. This study has shown which specific sound objects significantly affect the dimension of Dynamics and discussed how they do so.

The Forward Logistic Regression analysis for the Communication dimension shows a result consistent with the expectation experiment. The dimension of Communication is affected by the background sounds of a bird chirping and of people talking. As in the expectation experiment, the sound of birds chirping causes a soundscape to be rated as private, while the sound of people talking causes it to be rated as communal.

Further development of the soundscape environment simulator involved implementing the perception model of soundscape dimensions and sound objects, enabling the soundscape environment simulator to predict the perception of a composed soundscape. This implementation of the perception model allows the simulator to work not only as a soundscape environment simulator, but also as a soundscape simulator. This simulator can be helpful to urban planners designing soundscape or ameliorating unpleasant soundscape.

7.6 Conclusion

This study has analysed the relationship between sound objects and soundscape dimensions by using an expectation approach in which participants were asked to compose and rate soundscapes, and a preference approach in which participants were asked to listen to and rate the soundscape compositions.

According to the selection of sound objects in the soundscape environment simulator, it seems that sound objects have two meanings in a soundscape: as a representation of a type of space, and as a determinant in the perception of the soundscape.

The relationship between sound objects and perception of soundscape is analysed using linear and logistic regression, which reveals an interesting finding. It turns out that the perception of a soundscape appears to be easier to explain with binary choices such as comfortable/uncomfortable, varied/simple and communal/private.

In general, the background sound objects affect the perception of soundscape more than the event sound objects especially for the dimension of Relaxation and Communication. The Dimension of Relaxation and Communication are only affected by the background sound objects. This result is also consistent between the listener-participants (preference experiment) and the composer-participants (expectation experiment). The dimension of Dynamics is affected mostly by the variability of sound objects in a soundscape.

This study has managed to explain the relationship between the sound objects and the soundscape dimensions. The mathematical model of the relationship has been determined and implemented in the soundscape environmental simulator, enabling the simulator to predict the perception of soundscape from the soundscape composition.

8 Conclusion and Further Work

8.1 Conclusion and Contribution

The aim of this study was to find the relationship between sound objects in a soundscape and the perception of soundscape with respect to soundscape dimensions. The first contribution of this study is the determination of reliable soundscape dimensions to rate a soundscape. Three reliable soundscape dimensions are identified according to our experiment at actual locations and using soundscape recordings: Relaxation, Dynamics, and Communication.

The study is then proceeded to discover the relationship between specific sound objects and soundscape dimensions using experiments conducted in the laboratory. The second contribution is the validation of laboratory experiment and the evaluation of sound level adjustment in reproducing soundscape. A laboratory experiment using pantophonic reproduction system can give the similar perception with the in-situ experiment according to Semantic Differential Analysis. It is found that sound level adjustment should be implemented when soundscape is reproduced in the laboratory. The experiments using Semantic Differential Analysis show that the sound level of soundscape reproduction should be adjusted to 9.5 dB below the actual level to imitate the perception of the actual soundscape

The third contribution is the development and validation of soundscape environmental simulator. This study tries to understand the relationship of sound objects and soundscape dimensions using a soundscape environment simulator, which is developed to compose complex soundscape in the laboratory. The simulator is also validated in this study by comparing the soundscape dimensions of compositions made in the simulator with the soundscape dimensions of actual soundscapes. Since the same soundscape dimensions emerged from our experiment as in the in situ experiment – Relaxation, Dynamics and

Communication – it is successfully demonstrated that the soundscape environment simulator is able to represent actual soundscape.

The simulator than applied to analysed the relationship between sound objects and soundscape dimensions by using an expectation approach in which participants were asked to compose and rate soundscapes, and a preference approach in which participants were asked to listen to and rate soundscape compositions. The relationship between the sound objects and the soundscape dimensions has been determined according to the expectation and preference of sound objects in the soundscape compositions. The perception models, which explains the interaction between soundscape dimensions and sound objects in the simulator, have been determined and become the fourth contribution. The fifth contribution is the implementation of soundscape composition concept in order to find the relationship between sound objects and soundscape dimensions.

The soundscape environment simulator was further developed by implementing the perception model of soundscape dimensions and sound objects in the simulator, enabling it to predict the perception of composed soundscapes. This implementation of the perception model allows the simulator to work not only as a soundscape environment simulator, but also as a soundscape simulator. This simulator might help urban planners who attempt to design or improve soundscape. This development of the soundscape simulator is the sixth contribution of this study.

8.2 Comparison with other Soundscape Studies

This study contributes new knowledge in soundscape study. The validity of laboratory experiment has not been validated using the same semantic scale with the in-situ experiment resulting different sound objects. The in-situ study was conducted by Kang using twenty-eight scales (Kang, 2007). The other studies conducted in the laboratory using different scales: Axelsson et al used 116 semantic scales (Axelsson et al., 2010), Cain et al used fives semantic scales (Cain et al., 2013), Davies et al used nineteen semantic scales (Davies & Murphy, 2012), Guillen and Barrio used eighteen semantic scales, and Hall et al used six semantic scales (Guillén & López Barrio, 2007).

In contrast, this study has validated the laboratory experiment by comparing the soundscape dimensions which emerge from in-situ experiment and laboratory experiment using the same semantic scales.

The study soundscape implements semantic differential analysis resulting soundscape dimensions to rate a soundscape (Axelsson et al., 2010; Cain et al., 2013; Davies & Murphy, 2012; Guillén & López Barrio, 2007; Kang, 2007). Although the soundscape dimensions have been determined, the reliability of the scale has not yet been analysed. This study includes reliability test in addition to Semantic Differential Analysis to find out the reliable soundscape dimensions.

The soundscape environment simulator has been developed to compose complex soundscape and soundscape composition has been analysed as a new method to understand the relationship between sound objects and the perception of soundscapes according to the expectation and preference. The perception of soundscape has been analysed from both the expectation and the preference of soundscape, while the other studies only analysed the perception from one aspect (either the expectation (N. Bruce, Davies, & Adams, 2009; N. S. Bruce & Davies, 2014) or the preference of soundscape (Adams et al., 2008; Axelsson et al., 2010; Cain et al., 2013; Davies et al., 2014; Guillén & López Barrio, 2007; Hall et al., 2013; Jeon et al., 2013, 2011, 2010; Liu et al., 2014; Semidor, 2006))

The previous studies have managed to grouped the general sound objects according to certain perception (such as relaxation and eventfulness) (Axelsson et al., 2010; Brambilla et al., 2013; Dubois et al., 2006; Catherine Guastavino, 2006; Hall et al., 2013; Marry & Defrance, 2013; R. Pheasant et al., 2008), but they have not explained the relation and interaction between the sound objects and the perception of soundscapes. This study has managed to determine the relationship between the specific sound objects and the soundscape dimensions. Furthermore, mathematical model has developed from the relationship and has been implemented into soundscape environment simulator. The implementation gives the ability for this simulator to predict the perception of composed soundscape, while the other simulators are only able to compose a soundscape without predicting the perception.

8.3 Further Work

8.3.1 Sound Level Adjustment

- The study of soundscape reproduction with the pantophonic system in the laboratory revealed the necessity of adjusting the overall sound level to obtain perceptions similar to the actual locations. This study has not yet identified the reason why the sound level adjustment is necessary. It could be due to the feeling of being in an enclosed space, to the dimensions of the space, or to background noise in the laboratory. Further study should be done, as this could suggest explanations for how we perceive noise/sound in a room or enclosed space.
- Further study can be done to determine whether sound level calibration of soundscape reproduction according to the sound level expectation of actual soundscape.

8.3.2 Sound Reproduction System to Reproduce Soundscape

- The experiment in our study was conducted using a pantophonic reproduction system. A comparison with another type of reproduction (a stereo system, headphones with head tracking, or a surround system) should be made in order to understand the effect of different reproduction systems on soundscape in the laboratory.

8.3.3 Soundscape Environment Simulator

- The soundscape simulator used the recording of sound object from outdoor or from a room which include reverberation in it. The simulator could be developed further by using dry signal with a system to add reverberation to the signal.

8.3.4 Soundscape Composition

- The soundscape environment simulator includes only 9 background sound objects and 10 event sound objects at this time. More sound objects could be added to enable composition of more complex soundscapes and discovery of more significant sound objects affecting soundscape dimensions.
- This study focuses on simulating a general urban soundscape. Further study can be done to simulate specific soundscapes, such as soundscape of the urban park or indoor soundscape.
- This study tried to separate the sound objects in a soundscape into background and event sound objects. The results show that event sound objects only affect the dimension of Dynamics, and that they behave differently in the expectation and preference experiments. Further study can be done to understand how event sound objects affect perception.
- This study only focuses on the relationship between sound objects and soundscape dimensions. Further analysis can be done to find the relationship between sound objects and another aspect of perception such as spatial recognition, or the study of soundscape from the past.

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10 Appendix

10.1 List of Publication

- The results of **Chapter 4** have been published in *Applied Acoustics* under the title "**The effect of sound level on perception of reproduced soundscape**".
- The part of the study in **Chapter 5** was presented at SPARC 2016 under the title "**Simulated Soundscape as an Approach to Analyse the Relationship between Sound Objects and Soundscape Perception.**"
- The material in this **Chapter 6** was presented at the University of Salford CSE PGR Symposium 2016 under the title "**The Development of Soundscape Simulator to Analyse Soundscape Perception Based on Expectation of Sound Objects**".
- The result of **Chapter 6** has been submitted to **Acta Acoustica** under the title "**The Validation of Soundscape Environment Simulator to Determine the Relationship between Sound Objects and the Perception of Soundscape**" and still being reviewed
- The material in **Chapter 7** was presented at **Inter Noise 2016** under the title "**Soundscape Perception Analysis Using Soundscape Simulator**"

10.2 Ethical Approval

Academic Audit and Governance Committee

College of Science and Technology Research Ethics Panel (CST)

University of Salford MANCHESTER

To	**Anugrah Sudarsono (and Prof Yiu Lam)**
cc:	**Prof Sunil Vadera, Head of School of CSE**
From	**Nathalie Audren Howarth, College Research Support Officer**
Date	**19th May 2014**

MEMORANDUM

Subject:	**Approval of your Project by CST**
Project Title:	**Soundscape Composition of Manchester City Centre Area**
REP Reference:	**CST 14/18**

Following your responses to the Panel's queries, based on the information you provided, I can confirm that they have no objections on ethical grounds to your project.

If there are any changes to the project and/or its methodology, please inform the Panel as soon as possible.

Regards,

Nathalie Audren Howarth
College Research Support Officer

For enquiries please contact:
College of Science and Technology
College Research Support Officer
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10.3 Consent Form

Soundscape Composition of Manchester City Centre Area Consent Form

		Please Initial
1	I confirm that I have understood the description of the test Date ……../……../……..	
2	I have been given opportunity to ask questions.	
3	I understand that my participation is voluntary and I may withdraw at any time without giving a reason	
4	I agree that the data generated from my participation can be held and published anonymously	
5	I agree that the data can be shared with other researcher with the maintained standards of data protection	
6	I agree to participate in this study	

Name of Participant:	Date:	Signature:
Name of Researcher:	Date:	Signature:

Any complain can be sent to me or my supervisor:

A.S.Sudarsono@edu.salford.ac.uk

Supervisor:

Prof. Yiu W. Lam

Y.W.Lam@salford.ac.uk

Ver_2, 28 Apr. 14 A.S.Sudarsono@edu.salford.ac.uk

10.4 Semantic Scales Questionnaire

Please Rate the Soundscape

Comfort	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Discomfort**
Quiet	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Noisy**
Pleasant	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Unpleasant**
Natural	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Artificial**
Like	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Dislike**
Gentle	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Harsh**
Boring	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Interesting**
Social	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Unsocial**
Communal	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Private**
Meaningful	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Insignificant**
Calming	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Agitating**
Smooth	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Rough**
Hard	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Soft**
Fast	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Slow**
Sharp	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Flat**
Varied	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Simple**
Reverberant (Echoic)	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Anechoic (No Echo)**
Far	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Near**
Directional	**5**	**4**	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**	**5**	**Universal**

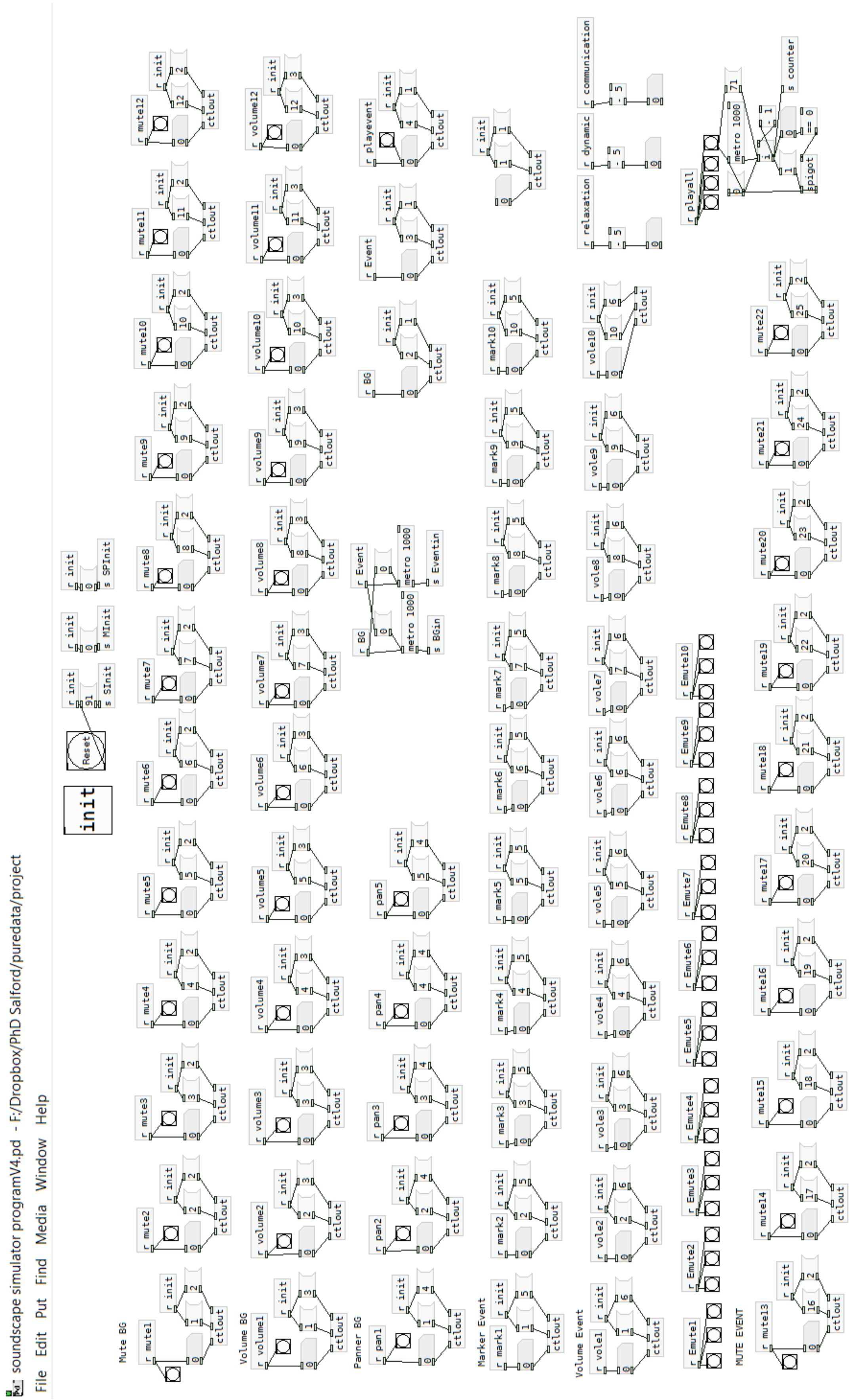
10.5 PureData MIDI Value to Sound Level Adjustment in Reaper

MIDI Value	Sound Level (dB)
1	-123.3
2	-103.4
3	-92.3
4	-84.5
5	-78.5
6	-73.6
7	-69.6
8	-66.4
9	-63.3
10	-60.4
11	-57.9
12	-55.6
13	-53.5
14	-51.5
15	-49.6
16	-48.1
17	-46.5
18	-45
19	-43.6
20	-42.2
21	-40.9
22	-39.6
23	-38.5
24	-37.5
25	-36.4
26	-35.3
27	-34.3
28	-33.3
29	-32.4
30	-31.5
31	-30.6
32	-29.9
33	-29
34	-28.2
35	-27.4
36	-26.7
37	-25.9
38	-25.2
39	-24.5
40	-23.9
41	-23.2
42	-22.6

MIDI Value	Sound Level (dB)
43	-21.9
44	-21.3
45	-20.7
46	-20.1
47	-19.5
48	-18.9
49	-18.4
50	-17.8
51	-17.2
52	-16.7
53	-16.2
54	-15.6
55	-15.1
56	-14.7
57	-14.2
58	-13.7
59	-13.2
60	-12.7
61	-12.2
62	-11.7
63	-11.2
64	-10.8
65	-10.4
66	-9.97
67	-9.53
68	-9.08
69	-8.64
70	-8.21
71	-7.72
72	-7.4
73	-6.98
74	-6.56
75	-6.15
76	-5.74
77	-5.33
78	-4.92
79	-4.52
80	-4.17
81	-3.78
82	-3.38
83	-2.99
84	-2.6

MIDI Value	Sound Level (dB)
85	-2.22
86	-1.84
87	-1.46
88	-1.13
89	-0.75
90	-0.38
91	0
92	0.36
93	0.72
94	1.09
95	1.45
96	1.77
97	2.12
98	2.48
99	2.83
100	3.19
101	3.54
102	3.89
103	4.23
104	4.54
105	4.88
106	5.22
107	5.56
108	5.9
109	6.24
110	6.58
111	6.91
112	7.2
113	7.54
114	7.87
115	8.2
116	8.52
117	8.85
118	9.17
119	9.5
120	9.78
121	10.1
122	10.4
123	10.7
124	11
125	11.3
126	11.6
127	12

10.6 PureData Code for Soundscape Simulator



10.7 Forward Linear Regression of Soundscape Expectation According to the Dimension of Relaxation

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Construction		Forward (Criterion: Probability-of-F-to-enter <= .050)
2	Traffic		Forward (Criterion: Probability-of-F-to-enter <= .050)
3	Pop_Music		Forward (Criterion: Probability-of-F-to-enter <= .050)
4	Bird Chirping		Forward (Criterion: Probability-of-F-to-enter <= .050)
5	Water Stream		Forward (Criterion: Probability-of-F-to-enter <= .050)

a. Dependent Variable: Relaxation_compose

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.732[a]	.536	.535	2.927
2	.797[b]	.635	.634	2.598
3	.822[c]	.676	.674	2.450
4	.839[d]	.704	.702	2.342
5	.847[e]	.718	.716	2.288

a. Predictors: (Constant), Construction
b. Predictors: (Constant), Construction, Traffic
c. Predictors: (Constant), Construction, Traffic, Pop_Music
d. Predictors: (Constant), Construction, Traffic, Pop_Music, Bird Chirping
e. Predictors: (Constant), Construction, Traffic, Pop_Music, Bird Chirping, Water Stream

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5793.809	1	5793.809	676.384	.000[b]
	Residual	5019.592	586	8.566		
	Total	10813.401	587			
2	Regression	6865.045	2	3432.522	508.572	.000[c]
	Residual	3948.357	585	6.749		
	Total	10813.401	587			
3	Regression	7308.194	3	2436.065	405.871	.000[d]
	Residual	3505.208	584	6.002		
	Total	10813.401	587			
4	Regression	7616.244	4	1904.061	347.204	.000[e]
	Residual	3197.158	583	5.484		
	Total	10813.401	587			
5	Regression	7765.894	5	1553.179	296.619	.000[f]
	Residual	3047.507	582	5.236		
	Total	10813.401	587			

a. Dependent Variable: Relaxation_compose
b. Predictors: (Constant), Construction
c. Predictors: (Constant), Construction, Traffic
d. Predictors: (Constant), Construction, Traffic, Pop_Music
e. Predictors: (Constant), Construction, Traffic, Pop_Music, Bird Chirping
f. Predictors: (Constant), Construction, Traffic, Pop_Music, Bird Chirping, Water Stream

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.262	.151		-15.001	.000
	Construction	.100	.004	.732	26.007	.000
2	(Constant)	-3.068	.148		-20.681	.000
	Construction	.075	.004	.545	18.729	.000
	Traffic	.053	.004	.366	12.598	.000
3	(Constant)	-3.231	.141		-22.884	.000
	Construction	.071	.004	.519	18.815	.000
	Traffic	.044	.004	.304	10.733	.000
	Pop_Music	.038	.004	.217	8.593	.000
4	(Constant)	-2.267	.186		-12.166	.000
	Construction	.064	.004	.464	16.967	.000
	Traffic	.038	.004	.264	9.557	.000
	Pop_Music	.032	.004	.185	7.548	.000
	Bird Chirping	-.038	.005	-.195	-7.495	.000
5	(Constant)	-1.945	.192		-10.136	.000
	Construction	.062	.004	.452	16.830	.000
	Traffic	.036	.004	.251	9.240	.000
	Pop_Music	.030	.004	.173	7.169	.000
	Bird Chirping	-.029	.005	-.148	-5.501	.000
	Water Stream	-.031	.006	-.135	-5.346	.000

10.8 Forward Logistic Regression of Soundscape Expectation According to the Dimension of Relaxation

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	587	97.8
	Missing Cases	13	2.2
	Total	600	100.0
Unselected Cases		0	0.0
Total		600	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
0	0
1	1

Classification Table[a,b]

Observed			Predicted		
			Relax_Logit_compose		Percentage Correct
			0	1	
Step 0	Relax_Logit_compose	0	0	293	0.0
		1	0	294	100.0
	Overall Percentage				50.1

a. Constant is included in the model.
b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	.003	.083	.002	1	.967	1.003

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	Fountain	15.851	1	.000
		Stream	122.339	1	.000
		Bird_Chirping	159.575	1	.000
		Accordeon	2.401	1	.121
		String_Music	22.938	1	.000
		People_Talking	44.479	1	.000
		Pop_Music	111.285	1	.000
		Traffic	216.865	1	.000
		Construction	308.480	1	.000
		Tram_E	78.076	1	.000
		Bird_Flying_E	17.835	1	.000
		Bird_Chirping_E	90.733	1	.000
		Bus_Passing_E	130.204	1	.000
		Car_Passing_E	99.691	1	.000
		Footstep_E	1.144	1	.285
		Woman_Talking_E	46.325	1	.000
		Trolley_Bag_E	49.357	1	.000
		Bicycle_E	7.453	1	.006
		Children_E	6.202	1	.013
		Event_NO	32.829	1	.000
	Overall Statistics		416.933	20	.000

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	380.792	1	.000
	Block	380.792	1	.000
	Model	380.792	1	.000
Step 2	Step	102.578	1	.000
	Block	483.370	2	.000
	Model	483.370	2	.000
Step 3	Step	72.128	1	.000
	Block	555.498	3	.000
	Model	555.498	3	.000
Step 4	Step	21.884	1	.000
	Block	577.383	4	.000
	Model	577.383	4	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	432.961[a]	.477	.636
2	330.383[a]	.561	.748
3	258.255[b]	.612	.816
4	236.370[b]	.626	.835

Classification Table[a]

Observed			Predicted		
			Relax_Logit_compose		Percentage Correct
			0	1	
Step 1	Relax_Logit_compose	0	287	6	98.0
		1	86	208	70.7
	Overall Percentage				84.3
Step 2	Relax_Logit_compose	0	276	17	94.2
		1	40	254	86.4
	Overall Percentage				90.3
Step 3	Relax_Logit_compose	0	280	13	95.6
		1	25	269	91.5
	Overall Percentage				93.5
Step 4	Relax_Logit_compose	0	277	16	94.5
		1	28	266	90.5
	Overall Percentage				92.5

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B) Uncomfortable	Exp(B) Comfortable
Step 1[a]	Construction	0.086	0.009	86.284	1	0	1.089	0.918
	Constant	-1.238	0.124	99.857	1	0	0.29	3.448
Step 2[b]	Traffic	0.05	0.005	82.528	1	0	1.051	0.951
	Construction	0.088	0.01	71.381	1	0	1.092	0.916
	Constant	-2.35	0.211	124.594	1	0	0.095	10.526
Step 3[c]	Pop_Music	0.061	0.008	55.06	1	0	1.063	0.941
	Traffic	0.053	0.007	61.855	1	0	1.054	0.949
	Construction	0.097	0.011	72.958	1	0	1.102	0.907
	Constant	-3.077	0.285	116.531	1	0	0.046	21.739
Step 4[d]	Stream	-0.055	0.014	15.992	1	0	0.947	1.056
	Pop_Music	0.054	0.008	43.293	1	0	1.055	0.948
	Traffic	0.046	0.007	47.11	1	0	1.047	0.955
	Construction	0.1	0.014	54.775	1	0	1.105	0.905
	Constant	-2.436	0.291	70.186	1	0	0.088	11.364

a. Variable(s) entered on step 1: Construction.
b. Variable(s) entered on step 2: Traffic.
c. Variable(s) entered on step 3: Pop_Music.
d. Variable(s) entered on step 4: Stream.

10.9 Forward Logistic Regression of Soundscape Expectation According to the Dimension of Dynamic

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	588	98.0
	Missing Cases	12	2.0
	Total	600	100.0
Unselected Cases		0	0.0
Total		600	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
0	0
1	1

Classification Table[a,b]

Observed			Predicted		
			Dynamic_Logit_compose		Percentage Correct
			0	1	
Step 0	Dynamic_Logit_compose	0	302	0	100.0
		1	286	0	0.0
	Overall Percentage				51.4

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.054	.083	.435	1	.509	.947

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	Fountain	.699	1	.403
		Stream	23.079	1	.000
		Bird_Chirping	22.839	1	.000
		Accordeon	51.790	1	.000
		String_Music	24.754	1	.000
		People_Talking	127.682	1	.000
		Pop_Music	26.092	1	.000
		Traffic	45.799	1	.000
		Construction	9.215	1	.002
		Tram_E	76.787	1	.000
		Bird_Flying_E	.293	1	.589
		Bird_Chirping_E	.134	1	.715
		Bus_Passing_E	9.080	1	.003
		Car_Passing_E	30.669	1	.000
		Footstep_E	61.886	1	.000
		Woman_Talking_E	82.347	1	.000
		Trolley_Bag_E	71.921	1	.000
		Bicycle_E	4.410	1	.036
		Children_E	55.952	1	.000
		Event_NO	112.610	1	.000
	Overall Statistics		272.454	20	.000

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	133.890	1	.000
	Block	133.890	1	.000
	Model	133.890	1	.000
Step 2	Step	58.965	1	.000
	Block	192.855	2	.000
	Model	192.855	2	.000
Step 3	Step	38.289	1	.000
	Block	231.143	3	.000
	Model	231.143	3	.000
Step 4	Step	44.963	1	.000
	Block	276.107	4	.000
	Model	276.107	4	.000
Step 5	Step	20.263	1	.000
	Block	296.370	5	.000
	Model	296.370	5	.000
Step 6	Step	30.116	1	.000
	Block	326.486	6	.000
	Model	326.486	6	.000
Step 7	Step	9.085	1	.003
	Block	335.571	7	.000
	Model	335.571	7	.000
Step 8	Step	8.927	1	.003
	Block	344.499	8	.000
	Model	344.499	8	.000
Step 9	Step	6.801	1	.009
	Block	351.300	9	.000
	Model	351.300	9	.000
Step 10	Step	4.274	1	.039
	Block	355.574	10	.000
	Model	355.574	10	.000
Step 11	Step	4.282	1	.039
	Block	359.856	11	.000
	Model	359.856	11	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	680.816[a]	.204	.272
2	621.851[b]	.280	.373
3	583.562[b]	.325	.433
4	538.599[b]	.375	.500
5	518.336[b]	.396	.528
6	488.219[b]	.426	.568
7	479.134[c]	.435	.580
8	470.207[c]	.443	.591
9	463.406[c]	.450	.600
10	459.132[c]	.454	.605
11	454.850[c]	.458	.610

Classification Table[a]

Observed			Predicted		
			Dynamic_Logit_compose		Percentage Correct
			0	1	
Step 1	Dynamic_Logit_compose	0	232	70	76.8
		1	75	211	73.8
	Overall Percentage				75.3
Step 2	Dynamic_Logit_compose	0	244	58	80.8
		1	83	203	71.0
	Overall Percentage				76.0
Step 3	Dynamic_Logit_compose	0	224	78	74.2
		1	61	225	78.7
	Overall Percentage				76.4

Step 4	Dynamic_Logit_compose	0	240	62	79.5
		1	59	227	79.4
	Overall Percentage				79.4
Step 5	Dynamic_Logit_compose	0	252	50	83.4
		1	55	231	80.8
	Overall Percentage				82.1
Step 6	Dynamic_Logit_compose	0	237	65	78.5
		1	48	238	83.2
	Overall Percentage				80.8
Step 7	Dynamic_Logit_compose	0	238	64	78.8
		1	46	240	83.9
	Overall Percentage				81.3
Step 8	Dynamic_Logit_compose	0	239	63	79.1
		1	47	239	83.6
	Overall Percentage				81.3
Step 9	Dynamic_Logit_compose	0	234	68	77.5
		1	51	235	82.2
	Overall Percentage				79.8
Step 10	Dynamic_Logit_compose	0	245	57	81.1
		1	53	233	81.5
	Overall Percentage				81.3
Step 11	Dynamic_Logit_compose	0	246	56	81.5
		1	49	237	82.9
	Overall Percentage				82.1

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B) Simple	Exp(B) Varied
Step 1[a]	People_Talking	-.036	.003	115.554	1	.000	.964	1.037
	Constant	.966	.131	54.100	1	.000	2.627	0.381
Step 2[b]	People_Talking	-.029	.004	62.621	1	.000	.972	1.029
	Event_NO	-.423	.060	50.280	1	.000	.655	1.527
	Constant	1.562	.165	89.090	1	.000	4.768	0.210
Step 3[c]	Accordeon	-.026	.004	34.712	1	.000	.974	1.026
	People_Talking	-.029	.004	60.092	1	.000	.971	1.030
	Event_NO	-.390	.060	41.638	1	.000	.677	1.477
	Constant	1.888	.183	106.638	1	.000	6.605	0.151
Step 4[d]	Accordeon	-.034	.005	49.564	1	.000	.967	1.034
	String_Music	-.033	.005	40.370	1	.000	.968	1.033
	People_Talking	-.026	.004	44.214	1	.000	.974	1.027
	Event_NO	-.491	.067	53.525	1	.000	.612	1.634
	Constant	2.536	.230	121.376	1	.000	12.630	0.079
Step 5[e]	Accordeon	-.034	.005	47.416	1	.000	.966	1.035
	String_Music	-.030	.005	31.529	1	.000	.971	1.030
	People_Talking	-.027	.004	45.068	1	.000	.973	1.028
	Bus_Passing_E	.027	.006	17.965	1	.000	1.027	0.974
	Event_NO	-.715	.091	61.785	1	.000	.489	2.043
	Constant	2.516	.232	117.137	1	.000	12.375	0.081
Step 6[f]	Accordeon	-.040	.006	53.528	1	.000	.961	1.041
	String_Music	-.037	.006	41.021	1	.000	.964	1.038
	People_Talking	-.021	.004	23.124	1	.000	.979	1.021
	Traffic	-.026	.005	27.548	1	.000	.975	1.026
	Bus_Passing_E	.036	.007	26.818	1	.000	1.037	0.965
	Event_NO	-.716	.094	57.604	1	.000	.489	2.046
	Constant	2.946	.256	132.378	1	.000	19.035	0.053
Step 7[g]	Accordeon	-.041	.006	53.196	1	.000	.960	1.042
	String_Music	-.038	.006	42.312	1	.000	.963	1.039
	People_Talking	-.020	.004	20.117	1	.000	.980	1.020
	Traffic	-.027	.005	28.432	1	.000	.973	1.027
	Bus_Passing_E	.041	.007	32.178	1	.000	1.042	0.959
	Bicycle_E	.024	.008	8.772	1	.003	1.025	0.976
	Event_NO	-.856	.109	61.595	1	.000	.425	2.355
	Constant	2.975	.265	126.339	1	.000	19.599	0.051
Step 8[h]	Accordeon	-.040	.006	51.344	1	.000	.960	1.041

	String_Music	-.037	.006	38.715	1	.000	.964	1.037
	People_Talking	-.020	.005	19.216	1	.000	.980	1.020
	Traffic	-.026	.005	25.540	1	.000	.975	1.026
	Bird_Flying_E	.039	.013	8.664	1	.003	1.040	0.962
	Bus_Passing_E	.047	.008	37.004	1	.000	1.049	0.954
	Bicycle_E	.026	.008	9.880	1	.002	1.026	0.975
	Event_NO	-.965	.117	67.466	1	.000	.381	2.624
	Constant	2.907	.266	119.874	1	.000	18.305	0.055
Step 9[i]	Accordeon	-.041	.006	50.449	1	.000	.960	1.042
	String_Music	-.039	.006	41.119	1	.000	.962	1.039
	People_Talking	-.020	.005	18.776	1	.000	.980	1.020
	Pop_Music	-.016	.006	6.702	1	.010	.984	1.016
	Traffic	-.024	.005	20.962	1	.000	.977	1.024
	Bird_Flying_E	.040	.014	8.547	1	.003	1.041	0.961
	Bus_Passing_E	.054	.008	40.930	1	.000	1.055	0.948
	Bicycle_E	.026	.008	9.905	1	.002	1.026	0.974
	Event_NO	-.992	.121	66.935	1	.000	.371	2.697
	Constant	3.011	.274	120.849	1	.000	20.310	0.049
Step 10[j]	Accordeon	-.040	.006	47.209	1	.000	.961	1.041
	String_Music	-.037	.006	37.964	1	.000	.963	1.038
	People_Talking	-.021	.005	19.329	1	.000	.980	1.021
	Pop_Music	-.018	.006	8.458	1	.004	.982	1.018
	Traffic	-.023	.005	18.659	1	.000	.978	1.023
	Bird_Flying_E	.046	.014	10.451	1	.001	1.047	0.955
	Bus_Passing_E	.051	.009	35.177	1	.000	1.052	0.950
	Car_Passing_E	.021	.010	4.170	1	.041	1.022	0.979
	Bicycle_E	.027	.008	11.034	1	.001	1.028	0.973
	Event_NO	-1.120	.141	62.972	1	.000	.326	3.066
	Constant	3.019	.273	121.954	1	.000	20.468	0.049
Step 11[k]	Accordeon	-.039	.006	43.697	1	.000	.962	1.040
	String_Music	-.037	.006	36.917	1	.000	.963	1.038
	People_Talking	-.021	.005	20.589	1	.000	.979	1.022
	Pop_Music	-.019	.006	9.464	1	.002	.981	1.019
	Traffic	-.027	.006	22.418	1	.000	.973	1.027
	Tram_E	.019	.009	4.164	1	.041	1.019	0.981
	Bird_Flying_E	.056	.015	13.180	1	.000	1.057	0.946
	Bus_Passing_E	.052	.008	37.835	1	.000	1.053	0.949
	Car_Passing_E	.027	.011	6.141	1	.013	1.027	0.974
	Bicycle_E	.031	.008	13.779	1	.000	1.032	0.969
	Event_NO	-1.318	.174	57.356	1	.000	.268	3.734
	Constant	3.151	.288	119.754	1	.000	23.353	0.043

a. Variable(s) entered on step 1: People_Talking.
b. Variable(s) entered on step 2: Event_NO.
c. Variable(s) entered on step 3: Accordeon.
d. Variable(s) entered on step 4: String_Music.
e. Variable(s) entered on step 5: Bus_Passing_E.
f. Variable(s) entered on step 6: Traffic.
g. Variable(s) entered on step 7: Bicycle_E.
h. Variable(s) entered on step 8: Bird_Flying_E.
i. Variable(s) entered on step 9: Pop_Music.
j. Variable(s) entered on step 10: Car_Passing_E.
k. Variable(s) entered on step 11: Tram_E.

10.10 Forward Logistic Regression of Soundscape Expectation According to the Dimension of Communication

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	588	98.0
	Missing Cases	12	2.0
	Total	600	100.0
Unselected Cases		0	0.0
Total		600	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
0	0
1	1

Classification Table[a,b]

Observed			Predicted		
			Communication_Logit_compose		Percentage Correct
			0	1	
Step 0	Communication_Logit_compose	0	424	0	100.0
		1	164	0	0.0
	Overall Percentage				72.1

a. Constant is included in the model.

b. b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.950	.092	106.698	1	.000	.387

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	Fountain	1.833	1	.176
		Stream	85.878	1	.000
		Bird_Chirping	181.442	1	.000
		Accordeon	37.298	1	.000
		String_Music	2.462	1	.117
		People_Talking	155.246	1	.000
		Pop_Music	18.664	1	.000
		Traffic	72.797	1	.000
		Construction	40.353	1	.000
		Tram_E	40.136	1	.000
		Bird_Flying_E	.469	1	.494
		Bird_Chirping_E	22.241	1	.000
		Bus_Passing_E	25.953	1	.000
		Car_Passing_E	18.463	1	.000
		Footstep_E	38.226	1	.000
		Woman_Talking_E	32.358	1	.000
		Trolley_Bag_E	13.806	1	.000
		Bicycle_E	.100	1	.752
		Children_E	12.920	1	.000
		Event_NO	48.221	1	.000
	Overall Statistics		322.477	20	.000

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	175.283	1	.000
	Block	175.283	1	.000
	Model	175.283	1	.000
Step 2	Step	105.623	1	.000
	Block	280.906	2	.000
	Model	280.906	2	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	520.817[a]	.258	.371
2	415.194[a]	.380	.547

Classification Table[a]

Observed			Predicted		
			Communication_Logit_compose		Percentage Correct
			0	1	
Step 1	Communication_Logit_compose	0	368	56	86.8
		1	58	106	64.6
	Overall Percentage				80.6
Step 2	Communication_Logit_compose	0	407	17	96.0
		1	41	123	75.0
	Overall Percentage				90.1

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B) Private	Exp(B) Communal
Step 1[a]	Bird_Chirping	.057	.005	144.002	1	.000	1.058	0.945
	Constant	-2.054	.155	176.398	1	.000	.128	7.797
Step 2[b]	Bird_Chirping	.050	.005	86.895	1	.000	1.052	0.951
	People_Talking	-.050	.006	73.225	1	.000	.951	1.051
	Constant	-1.009	.177	32.668	1	.000	.365	2.743

c. Variable(s) entered on step 1: Bird_Chirping.
d. Variable(s) entered on step 2: People_Talking.

10.11 Forward Linear Regression of Soundscape Preference According to the Dimension of Relaxation

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Construction		Forward (Criterion: Probability-of-F-to-enter <= .050)
2	Traffic		Forward (Criterion: Probability-of-F-to-enter <= .050)
3	Bird Chirping		Forward (Criterion: Probability-of-F-to-enter <= .050)
4	Pop_Music		Forward (Criterion: Probability-of-F-to-enter <= .050)
5	People_Talking		Forward (Criterion: Probability-of-F-to-enter <= .050)

a. Dependent Variable: Relaxation_listen

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.622[a]	.386	.385	2.726
2	.676[b]	.457	.455	2.567
3	.705[c]	.496	.494	2.474
4	.718[d]	.516	.513	2.427
5	.722[e]	.521	.517	2.417

a. Predictors: (Constant), Construction
b. Predictors: (Constant), Construction, Traffic
c. Predictors: (Constant), Construction, Traffic, Bird Chirping
d. Predictors: (Constant), Construction, Traffic, Bird Chirping, Pop_Music
e. Predictors: (Constant), Construction, Traffic, Bird Chirping, Pop_Music, People_Talking

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2742.401	1	2742.401	369.000	.000[b]
	Residual	4355.143	586	7.432		
	Total	7097.544	587			
2	Regression	3241.773	2	1620.886	245.922	.000[c]
	Residual	3855.772	585	6.591		
	Total	7097.544	587			
3	Regression	3523.400	3	1174.467	191.903	.000[d]
	Residual	3574.145	584	6.120		
	Total	7097.544	587			
4	Regression	3663.586	4	915.896	155.496	.000[e]
	Residual	3433.958	583	5.890		
	Total	7097.544	587			
5	Regression	3697.181	5	739.436	126.561	.000[f]
	Residual	3400.364	582	5.843		
	Total	7097.544	587			

a. Dependent Variable: Relaxation_listen
b. Predictors: (Constant), Construction
c. Predictors: (Constant), Construction, Traffic
d. Predictors: (Constant), Construction, Traffic, Bird Chirping
e. Predictors: (Constant), Construction, Traffic, Bird Chirping, Pop_Music
f. Predictors: (Constant), Construction, Traffic, Bird Chirping, Pop_Music, People_Talking

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.552	.140		-11.053	.000
	Construction	.069	.004	.622	19.209	.000
2	(Constant)	-2.103	.147		-14.344	.000
	Construction	.051	.004	.464	13.073	.000
	Traffic	.036	.004	.309	8.704	.000
3	(Constant)	-1.218	.192		-6.337	.000
	Construction	.044	.004	.396	11.108	.000
	Traffic	.029	.004	.251	7.138	.000
	Bird Chirping	-.036	.005	-.227	-6.784	.000
4	(Constant)	-1.421	.193		-7.360	.000
	Construction	.043	.004	.386	11.031	.000
	Traffic	.025	.004	.215	6.076	.000
	Bird Chirping	-.031	.005	-.199	-5.960	.000
	Pop_Music	.022	.004	.153	4.879	.000
5	(Constant)	-1.673	.219		-7.636	.000
	Construction	.043	.004	.386	11.087	.000
	Traffic	.023	.004	.196	5.437	.000
	Bird Chirping	-.028	.005	-.179	-5.249	.000
	Pop_Music	.021	.004	.150	4.805	.000
	People_Talking	.009	.004	.076	2.398	.017

10.12 Forward Logistic Regression of Soundscape Preference According to the Dimension of Relaxation

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	575	95.8
	Missing Cases	25	4.2
	Total	600	100.0
Unselected Cases		0	0.0
Total		600	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
0	0
1	1

Classification Table[a,b]

Observed			Predicted		
			Relax_Logit_listen		Percentage Correct
			0	1	
Step 0	Relax_Logit_listen	0	289	0	100.0
		1	286	0	0.0
	Overall Percentage				50.3

a. Constant is included in the model.
b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.010	.083	.016	1	.900	.990

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	Fountain	11.733	1	.001
		Stream	63.794	1	.000
		Bird_Chirping	127.500	1	.000
		Accordeon	.001	1	.973
		String_Music	6.219	1	.013
		People_Talking	47.064	1	.000
		Pop_Music	78.181	1	.000
		Traffic	151.676	1	.000
		Construction	218.158	1	.000
		Tram_E	60.544	1	.000
		Bird_Flying_E	11.687	1	.001
		Bird_Chirping_E	56.634	1	.000
		Bus_Passing_E	103.599	1	.000
		Car_Passing_E	80.339	1	.000
		Footstep_E	2.340	1	.126
		Woman_Talking_E	40.527	1	.000
		Trolley_Bag_E	42.890	1	.000
		Bicycle_E	3.522	1	.061
		Children_E	10.426	1	.001
		Event_NO	31.444	1	.000
	Overall Statistics		297.789	20	.000

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	245.743	1	.000
	Block	245.743	1	.000
	Model	245.743	1	.000
Step 2	Step	46.892	1	.000
	Block	292.635	2	.000
	Model	292.635	2	.000
Step 3	Step	30.301	1	.000
	Block	322.936	3	.000
	Model	322.936	3	.000
Step 4	Step	14.160	1	.000
	Block	337.096	4	.000
	Model	337.096	4	.000
Step 5	Step	4.259	1	.039
	Block	341.355	5	.000
	Model	341.355	5	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	551.361[a]	.348	.464
2	504.469[b]	.399	.532
3	474.168[b]	.430	.573
4	460.008[b]	.444	.591
5	455.748[b]	.448	.597

Classification Table[a]

			Predicted		
			Relax_Logit_listen		
Observed			0	1	Percentage Correct
Step 1	Relax_Logit_listen	0	267	22	92.4
		1	100	186	65.0
	Overall Percentage				78.8
Step 2	Relax_Logit_listen	0	263	26	91.0
		1	61	225	78.7
	Overall Percentage				84.9
Step 3	Relax_Logit_listen	0	264	25	91.3
		1	70	216	75.5
	Overall Percentage				83.5
Step 4	Relax_Logit_listen	0	255	34	88.2
		1	52	234	81.8
	Overall Percentage				85.0
Step 5	Relax_Logit_listen	0	261	28	90.3
		1	52	234	81.8
	Overall Percentage				86.1

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B) Uncomfortable	Exp(B) Comfortable
Step 1[a]	Construction	.052	.004	147.952	1	.000	1.053	0.950
	Constant	-1.015	.118	74.251	1	.000	.362	2.760
Step 2[b]	Traffic	.028	.004	45.336	1	.000	1.028	0.973
	Construction	.044	.005	96.117	1	.000	1.045	0.957
	Constant	-1.522	.151	101.777	1	.000	.218	4.581
Step 3[c]	Pop_Music	.030	.006	27.639	1	.000	1.030	0.971
	Traffic	.023	.004	28.888	1	.000	1.023	0.977
	Construction	.044	.005	92.517	1	.000	1.045	0.957
	Constant	-1.719	.162	112.554	1	.000	.179	5.579
Step 4[d]	Bird_Chirping	-.023	.006	13.450	1	.000	.977	1.023
	Pop_Music	.025	.006	18.596	1	.000	1.025	0.976
	Traffic	.019	.004	19.413	1	.000	1.019	0.981
	Construction	.040	.005	72.275	1	.000	1.040	0.961
	Constant	-1.216	.200	37.081	1	.000	.296	3.373
Step 5[e]	Bird_Chirping	-.026	.006	15.841	1	.000	.975	1.026
	Accordeon	-.010	.005	4.196	1	.041	.990	1.010
	Pop_Music	.024	.006	18.238	1	.000	1.025	0.976
	Traffic	.019	.004	18.549	1	.000	1.019	0.981
	Construction	.040	.005	71.953	1	.000	1.041	0.961
	Constant	-1.026	.217	22.364	1	.000	.358	2.791

a. Variable(s) entered on step 1: Construction.
b. Variable(s) entered on step 2: Traffic.
c. Variable(s) entered on step 3: Pop_Music.
d. Variable(s) entered on step 4: Bird_Chirping.
e. Variable(s) entered on step 5: Accordeon.

10.13 Forward Logistic Regression of Soundscape Preference According to the Dimension of Dynamic

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	572	95.3
	Missing Cases	28	4.7
	Total	600	100.0
Unselected Cases		0	0.0
Total		600	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
0	0
1	1

Classification Table[a,b]

Observed			Predicted		
			Dynamic_Logit_listen		Percentage Correct
			0	1	
Step 0	Dynamic_Logit_listen	0	334	0	100.0
		1	238	0	0.0
	Overall Percentage				58.4

a. Constant is included in the model.
b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.339	.085	15.959	1	.000	.713

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	Fountain	3.217	1	.073
		Stream	55.889	1	.000
		Bird_Chirping	66.027	1	.000
		Accordeon	.008	1	.928
		String_Music	.962	1	.327
		People_Talking	38.070	1	.000
		Pop_Music	40.658	1	.000
		Traffic	79.015	1	.000
		Construction	97.143	1	.000
		Tram_E	30.716	1	.000
		Bird_Flying_E	11.320	1	.001
		Bird_Chirping_E	40.538	1	.000
		Bus_Passing_E	50.259	1	.000
		Car_Passing_E	33.883	1	.000
		Footstep_E	1.696	1	.193
		Woman_Talking_E	11.992	1	.001
		Trolley_Bag_E	22.014	1	.000
		Bicycle_E	.122	1	.727
		Children_E	1.748	1	.186
		Event_NO	10.346	1	.001
	Overall Statistics		171.392	20	.000

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	106.078	1	.000
	Block	106.078	1	.000
	Model	106.078	1	.000
Step 2	Step	24.768	1	.000
	Block	130.846	2	.000
	Model	130.846	2	.000
Step 3	Step	14.803	1	.000
	Block	145.649	3	.000
	Model	145.649	3	.000
Step 4	Step	8.338	1	.004
	Block	153.987	4	.000
	Model	153.987	4	.000
Step 5	Step	6.408	1	.011
	Block	160.396	5	.000
	Model	160.396	5	.000
Step 6	Step	7.087	1	.008
	Block	167.483	6	.000
	Model	167.483	6	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	670.694[a]	.169	.228
2	645.926[b]	.204	.275
3	631.123[b]	.225	.303
4	622.785[b]	.236	.318
5	616.376[b]	.245	.329
6	609.289[b]	.254	.342

Classification Table[a]

			Predicted		
			Dynamic_Logit_listen		
Observed			0	1	Percentage Correct
Step 1	Dynamic_Logit_listen	0	174	160	52.1
		1	34	204	85.7
	Overall Percentage				66.1
Step 2	Dynamic_Logit_listen	0	237	97	71.0
		1	84	154	64.7
	Overall Percentage				68.4
Step 3	Dynamic_Logit_listen	0	229	105	68.6
		1	68	170	71.4
	Overall Percentage				69.8
Step 4	Dynamic_Logit_listen	0	248	86	74.3
		1	71	167	70.2
	Overall Percentage				72.6
Step 5	Dynamic_Logit_listen	0	261	73	78.1
		1	71	167	70.2
	Overall Percentage				74.8
Step 6	Dynamic_Logit_listen	0	260	74	77.8
		1	76	162	68.1
	Overall Percentage				73.8

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B) Simple	Exp(B) Varied
Step 1[a]	Construction	-.032	.003	82.833	1	.000	.969	1.032
	Constant	.278	.106	6.915	1	.009	1.320	0.758
Step 2[b]	Traffic	-.018	.004	24.288	1	.000	.982	1.018
	Construction	-.025	.004	42.765	1	.000	.976	1.025
	Constant	.564	.123	21.197	1	.000	1.758	0.569
Step 3[c]	Stream	.021	.005	14.550	1	.000	1.021	0.980
	Traffic	-.015	.004	16.146	1	.000	.985	1.015
	Construction	-.022	.004	33.525	1	.000	.978	1.023
	Constant	.229	.149	2.370	1	.124	1.257	0.795
Step 4[d]	Stream	.018	.005	10.777	1	.001	1.018	0.982
	Pop_Music	-.014	.005	7.808	1	.005	.986	1.014
	Traffic	-.013	.004	11.365	1	.001	.987	1.013
	Construction	-.022	.004	31.370	1	.000	.979	1.022
	Constant	.338	.155	4.788	1	.029	1.402	0.713
Step 5[e]	Stream	.016	.006	8.607	1	.003	1.017	0.984
	People_Talking	-.010	.004	6.417	1	.011	.991	1.010
	Pop_Music	-.013	.005	7.147	1	.008	.987	1.013
	Traffic	-.011	.004	7.442	1	.006	.989	1.011
	Construction	-.022	.004	30.956	1	.000	.979	1.022
	Constant	.554	.179	9.606	1	.002	1.740	0.575
Step 6[f]	Stream	.017	.006	8.954	1	.003	1.017	0.983
	People_Talking	-.013	.004	9.898	1	.002	.987	1.013
	Pop_Music	-.016	.005	9.808	1	.002	.984	1.016
	Traffic	-.012	.004	9.336	1	.002	.988	1.013
	Construction	-.022	.004	31.987	1	.000	.978	1.022
	Event_NO	.155	.059	6.920	1	.009	.857	1.167
	Constant	.404	.188	4.637	1	.031	1.498	0.667

a. Variable(s) entered on step 1: Construction.
b. Variable(s) entered on step 2: Traffic.
c. Variable(s) entered on step 3: Stream.
d. Variable(s) entered on step 4: Pop_Music.
e. Variable(s) entered on step 5: People_Talking.
f. Variable(s) entered on step 6: Event_NO.

10.14 Forward Logistic Regression of Soundscape Preference According to the Dimension of Communication

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	570	95.0
	Missing Cases	30	5.0
	Total	600	100.0
Unselected Cases		0	0.0
Total		600	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
0	0
1	1

Classification Table[a,b]

Observed			Predicted		
			Communication_logit_listen		Percentage Correct
			0	1	
Step 0	Communication_logit_listen	0	396	0	100.0
		1	174	0	0.0
	Overall Percentage				69.5

a. Constant is included in the model.
b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.822	.091	81.751	1	.000	.439

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	Fountain	.566	1	.452
		Stream	8.323	1	.004
		Bird_Chirping	29.714	1	.000
		Accordeon	4.016	1	.045
		String_Music	.075	1	.784
		People_Talking	37.256	1	.000
		Pop_Music	1.962	1	.161
		Traffic	3.488	1	.062
		Construction	.897	1	.343
		Tram_E	3.556	1	.059
		Bird_Flying_E	.915	1	.339
		Bird_Chirping_E	.879	1	.348
		Bus_Passing_E	.148	1	.700
		Car_Passing_E	.591	1	.442
		Footstep_E	4.994	1	.025
		Woman_Talking_E	5.465	1	.019
		Trolley_Bag_E	.301	1	.583
		Bicycle_E	.686	1	.408
		Children_E	1.148	1	.284
		Event_NO	3.341	1	.068
	Overall Statistics		67.669	20	.000

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	38.355	1	.000
	Block	38.355	1	.000
	Model	38.355	1	.000
Step 2	Step	11.659	1	.001
	Block	50.014	2	.000
	Model	50.014	2	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	663.039[a]	.065	.092
2	651.380[b]	.084	.119

Classification Table[a]

Observed			Predicted		
			Communication_logit_listen		Percentage Correct
			0	1	
Step 1	Communication_logit_listen	0	396	0	100.0
		1	174	0	0.0
	Overall Percentage				69.5
Step 2	Communication_logit_listen	0	361	35	91.2
		1	124	50	28.7
	Overall Percentage				72.1

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B) Private	Exp(B) Private
Step 1[a]	People_Talking	-.021	.003	35.582	1	.000	.979	1.021
	Constant	-.304	.120	6.358	1	.012	.738	1.355
Step 2[b]	Bird_Chirping	.015	.004	11.725	1	.001	1.015	0.985
	People_Talking	-.017	.004	20.607	1	.000	.983	1.017
	Constant	-.651	.161	16.465	1	.000	.521	1.918

a. Variable(s) entered on step 1: People_Talking.
b. Variable(s) entered on step 2: Bird_Chirping.