DOCTORAL THESIS

The Impact of Sound on Virtual Landscape Perception

An Empirical Evaluation of Aural-Visual Interaction for 3D Visualization

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ABSTRACT

An understanding of quantitative and qualitative landscape characteristics is necessary to successfully articulate intervention or change in the landscape. In landscape planning and design **3D visualizations** have been used to successfully communicate various aspects of landscape to a **diverse population**, though they have been shown to **lag behind real-world experience** in perceptual experiments. There is evidence that engaging other senses can **alter the perception of 3D visualizations**, which this thesis used as a departure point for the research project.

Three research questions guide the investigation. The **first research question** is: How do fundamental elements in visualizations (i.e. terrain, vegetation and built form) interact with fundamental sound types (i.e. anthropogenic, mechanical and natural) to affect perceived realism of, and preference for, 3D landscape visualization? The research used empirical methods of a controlled experiment and statistical analysis of quantitative survey responses to examine the perceptual responses to the interaction aural and visual stimuli in St. James's Park, London, UK. The visualizations were sourced from Google Earth, and the sounds recorded in situ, with Google Earth chosen as it is being used more frequently in landscape planning and design processes, though has received very little perceptual research focus. The **second research question** is: Do different user characteristics interact with combined aural-visual stimuli to alter perceived realism and preferences for 3D visualization? The **final research question** emerged out of the experiment design concentrating on research methodology: How effective is the Internet for aural-visual data collection compared to the laboratory setting?

The results of the quantitative analysis can be summarized as follows: For **research question 1** the results show that sound alters 3D visualization perception both positively and negatively, which varies by landscape element. For **all visual conditions** mechanical sound significantly lowers preference. For visualizations showing **terrain only** perceived realism and preference are significantly lowered by anthropogenic sound and significantly raised by natural sound for both realism and preference. For visualizations showing a combination of **terrain with built form** anthropogenic and mechanical sound significantly raises perceived realism. For visualizations showing a combination of **terrain, vegetation and some built form** a more complicated interaction occurs for realism, which is moderated by the amount of built form in the scene, e.g. with no buildings in the scene traffic and speech significantly lower realism ratings in similar ways while a small amount of built form visible resulted in speech significantly raising realism ratings. Preference was significantly lowered by anthropogenic and mechanical sound the most out of all three visual conditions. **For research question 2** the results confirm that perception can vary for realism by gender and first language differences, and preference by age, first language, cultural and professional background and 3D familiarity. Finally for **research question 3** and implications for Internet-based multisensory experiments there is strong evidence that audio hardware and experimental condition (laboratory vs. online) do not significantly alter realism and preference ratings, though larger display sizes can have a significant but very small effect on preference ratings (+/- 0.08 on a 5-point scale).

The results indicate that **sound significantly alters the perception of realism and preference** for landscape simulated via 3D visualizations, with the **congruence of aural and visual stimuli** having a strong impact on both perceptual responses. The results provide **important empirical evidence** for future research to build upon, and raise important questions relating **to authenticity of landscape experience**, particularly when relying solely on visual material as **visuals alone do not accurately simulate landscape experience**. In addition the research confirms the **cross-sensory** nature of perception in virtual environments. As a result the **inclusion of sound** for landscape visualization and aesthetic research is concluded to be of **critical importance**. The research results suggest that when using sound with 3D visualizations the **sound content match the visualized material**, and to avoid using sounds that contain human speech unless there is a very strong reason to do so (e.g. there are humans in the visualization). The final chapter discusses **opportunities for integrating sound with 3D visualizations** in order to increase the perception of realism and preference in landscape planning and design processes, and concludes with areas for future research.

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Note

- sounds used in the experiment are accessible at the following link:
https://drive.google.com/folderview?id=0B2pduiDnwLIZSzR6ODA1VjFGWVU&usp=sharing

LIST OF TABLES

LIST OF ABBREVIATIONS AND TERMS

2D	Two Dimensional
3D	Three Dimensional
ANOVA	Analysis of Variance
dB	Decibel (unweighted)
dB(A)	Decibel (A-weighted)
CAD	Computer Aided Design
GIS	Geographic Information System
Hz	Hertz (cycles per second)
Leq	Equivalent measured sound level in decibels measured over time
Lmax	Maximum measured sound level in decibels measured over time
Lmin	Minimum measured sound level in decibels measured over time
LOD	Level of Detail
SPL	Sound Pressure Level
SLM	Sound Level Metre
UKSM	UK Sound Map
VE	Virtual Environment
VR	Virtual Reality

1 INTRODUCTION

Protection, planning, design and management of landscape are a complex undertaking. To engage with landscape planning and design an understanding of existing and proposed physical characteristics is necessary, as well as human responses to both existing characteristics and proposed changes. The quality of designed landscape, particularly in the urban context, has continually shown to influence people's behaviour and well-being (Matsuoka & Kaplan, 2008). To be able to evaluate future landscape change it is crucial to understand responses to future scenarios presented (Lange, Hehl-Lange, & Brewer, 2008). In addition, the assessment of landscape is a key component of decision-making in planning and design (Steinitz, 2003). However, landscape has multiple and often overlapping meanings to different groups. As such, distinctive groups perceive the landscape differently, be those distinctions based on ethnicity (Lewis, 2010), age (Balling & Falk, 1982), or culture, living environment and general education level (Yu, 1995).

The ability to effectively communicate real or proposed landscapes to a broad segment of the population allows for democratic input on decisions made by a few people that affect many people. Three and four-dimensional digital visualization of environments (e.g. Figure 1) offer many advantages over traditional methods of spatial representation, particularly when communicating complex spatial arrangements to non-designers (IBishop, 2005; Kwartler, 2005).

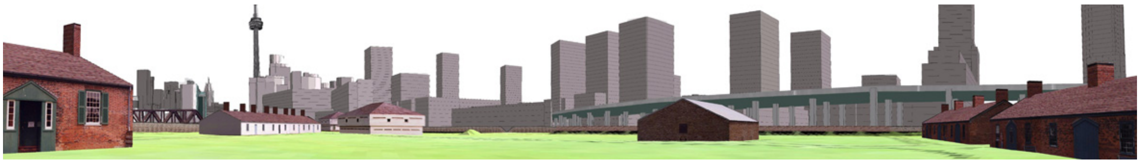


Figure 1: 3D visualization of Fort York, Toronto, Canada (© Centre for Landscape Research)

Visualizations can be used to open dialogue between groups that are otherwise at odds over divisive issues in the urban landscape (Lindquist, 2007) or to engage in discussion about volatile issues in a forest settings (Palmer, 2008). To date such methods of communicating have focused primarily on visual aspects, based on the dominance of the human visual system (Lange & Bishop, 2005). However, purely visual approaches to landscape experience have been criticized, citing the complex multi-sensory appreciation of individuals at differing socioeconomic levels (Scott, Carter, Brown, & White, 2009) and the important impact of sound on the evaluation of outdoor environments (Anderson, Mulligan, Goodman, & Regen, 1983). Further, there is a complex effect on landscape perception of combining aural and visual stimuli; there is an influence on sound perception by spatial imagery (e.g. Viollon, Lavandier, & Drake, 2002) and an effect on landscape preference by sounds (e.g. Carles, Barrio, & de Lucio, 1999).

In the real world the impact of sound on the perception of public space is increasingly under scrutiny. Interest by government and policymakers is increasing in this area, particularly in the regulation and abatement of sound in the form of environmental noise from road traffic, aircraft, railway and machinery and their impact on health and safety (Directive 2002/49/EC). “Soundscape”, defined by the ISO/TC43/SC1/WG54 working group as “the perceived sound environment in context by an individual, a group, or a society” (Kang, 2010), has emerged as a research area concerned with studying the impact of sound on an environment and its perception. Soundscape research seeks a more objective starting point than noise abatement programs, which typically engage with environmental sound as a negative occurrence. A growing body of knowledge is emerging through empirical study of soundscape in the urban environment, particularly urban plazas (Yang & Kang, 2005b) and green spaces (Irvine et al., 2009). Soundscape research has engaged with virtual environment research, with perceptually based audio rendering available (Tsingos, Gallo, & Drettakis, 2004) as well as more physically accurate techniques (Richmond, Smyrnova, Maddock, & Kang, 2010).

Landscape architects and planners have, in recent years, turned their attention to design and planning of, and incorporating, soundscape. Auditory concepts for design and planning have been outlined (Hedfors & Berg, 2003) and expanded to a toolkit for professionals to use (Hedfors, 2003b) and an entire methodology (Hedfors, 2003a). In the area of landscape planning and management there have been advocates for audio design (Brown & Muhar, 2004) as well as auditory planning (Brown, 2004). More recently, the soundscape approach has been applied to early stage urban planning (De Coensel et al., 2010), as well as, frameworks for future research and practical needs outlined (Kang, 2010). With proposals for incorporating sound into the design and planning process, and tested methods of visualization in this process, there is a lack of research on the perception of the interaction of visualizations and sound.

The importance of identifying flexible and malleable design and planning mechanisms has been identified, which would enable professionals to respond to the "four-dimensional city" (Bishop & Williams, 2012), what has been identified as our current construct of urbanism, where physical permanence is less fixed and forms of temporary urbanism adapt and change, over space and time. Four-dimensional design, which requires "the use of looser conceptual strategies instead of inflexible land zoning and rigid masterplans…(providing) broad but realistic visions around which inclusive stakeholder alliances can be formed…(and) is a mechanism for flexible implementation" (Bishop & Williams, 2012, p. 215). Bishop and Williams propose flexible planning zones, and is a concept supported by other research (e.g. Campbell, 2011).

Visualizations tools for future scenarios have been enhanced with survey input from the public for greenspace planning (Lange, et al., 2008) and with biodiversity tools in environmental assessment and planning (Mörtberg, Balfors, & Knol, 2007). Augmenting visualizations with sound has the potential to impact visualization use, on par with these enhancements. Such impact could contribute to widening participation, and allow for the inclusion in planning and design of different user groups, particularly those that don't or can't respond to visual stimuli, the need for which has been identified by researchers (e.g. Scott, et al., 2009). In the context of public space in general, and urban parks in particular, such increased cultural diversity has been identified as positively contributing to a successful public space (Low, Taplin, & Scheld, 2005). A framework for incorporating soundscape concepts with scenario tools is lacking; one of the outcomes of this research will be a contribution to the realisation of such a framework through empirical evidence of the impact of sound on the perception of 3D landscape visualizations.

1.1 Research questions, aims and objectives

In order to relate the research to landscape design and planning processes, user requirements and broader research methods, three research questions are addressed in this research project:

> **Research question 1: How do different landscape elements in visualizations (i.e. terrain, vegetation and built form) interact with different sounds to alter perceived realism of, and preference for, 3D landscape visualizations?**

Hypotheses on landscape elements in visualizations are derived in chapter 2. Hypotheses on soundscape and the interaction of aural and visual stimuli are derived in chapter 3. The first research question is addressed in the quantitative analysis of responses in chapter 7.

> **Research question 2: Do different user characteristics interact with combined aural-visual stimuli to alter perception of realism and preference for 3D landscape visualizations?**

Hypotheses on potentially distinct group characteristics for visualizations and soundscape are derived in the literature review. The second research question is addressed in the analysis of quantitative results presented in chapter 8.

> **Research question 3: How effective is the Internet for aural-visual data collection compared to a laboratory setting?**

The third research question emerged out of the experiment design and seeks to determine the validity of web-based surveys for aural-visual data collection vs. more conventional methods (i.e. controlled laboratory setting). The online survey design and comparative procedure is outlined in chapter 6. The final research question is addressed in the quantitative analysis of responses in chapter 9.

The aim of this research is to establish the extent to which audio augmentation of virtual environments can influence perceived realism of the simulation, and preference for the scene being simulated.

The objectives of this research are:

- To assess the effects of audio augmentation of virtual environments on landscape preference and perception
- To determine any differences by user characteristics (e.g. gender, professional background) on the perception of virtual landscapes augmented with sound

1.2 Contribution to knowledge

This thesis contributes to the body of knowledge by evaluating the perception of different visualization elements, and the impact of sound on the perception of these varying elements. The study presented here addresses two fundamental knowledge areas in landscape visualization – multimodal perception and perceptual differences based on user characteristics. These two concepts have the potential to impact and influence the visualization community, landscape planning and design research as well as wider practice. The research responds specifically to repeated unanswered calls for empirical focus on perceptual responses multimodal stimuli (i.e. that engage more than one sense) (Bell, 2001; Ervin, 2001; Lange, 2011; Lange & Bishop, 2005), and more broadly the impact of multimodal interactions on landscape perception (Palmer, 2003). Specifically this research:

1. Situates the research project by evaluating alternatives for using visual abstraction in 3D visualizations at various stages of the design and planning process
2. Evaluates alternatives for sourcing sounds to use in in conjunction with 3D visualizations at various stages of the design and planning process as well as methods of abstraction for sound
3. Develops a theoretical framework for combining visual and aural stimuli in the design, planning and evaluation of landscape
4. Explains how the interaction of aural stimuli with 3D visualizations alters landscape preference and perceived visualization realism via a questionnaire-based evaluation and statistical analysis

The theoretical framework for the project is illustrated in Figure 2.

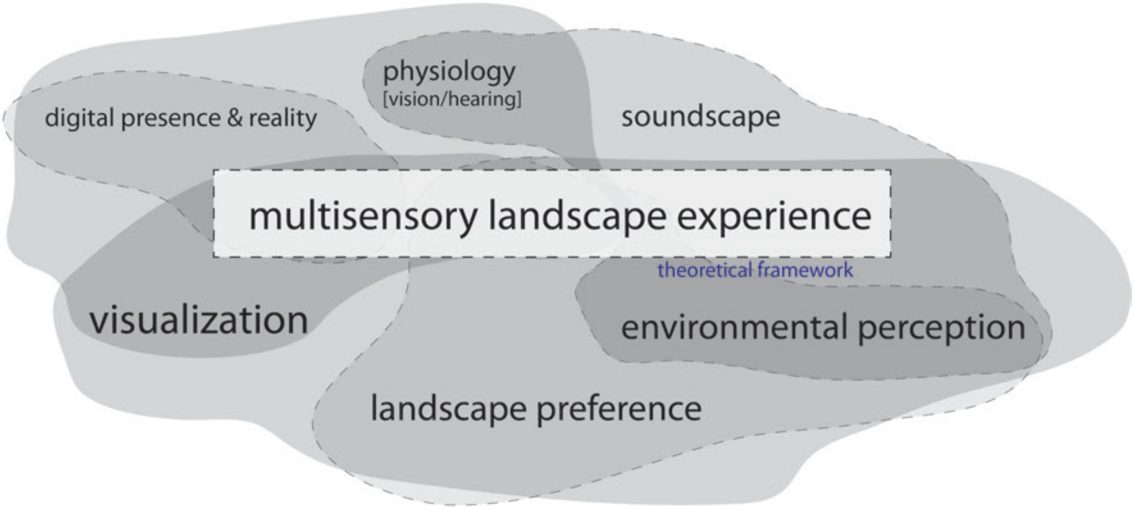


Figure 2: Theoretical framework

1.3 Scope of the thesis

This thesis explores responses to visual landscape stimuli, soundscape stimuli and the interaction of the two modalities within the context of landscape design and planning. While acknowledging the importance of other sense modalities on the perception of landscape, this research is restricted to comparing aural-visual interactions. The scope for the project was limited to focus on design-scale, experiential views (e.g. first person, ground level) as these are commonly used in design and planning processes and would match experientially with the sounds. In addition, computer generated landscape visualisations in Google Earth were used for visual stimuli as they are commonly being employed in the landscape design and planning process, though to date have not been evaluated as to their perceptual effectiveness. Real sounds were used for the experiment, though it is acknowledged that research on different types of sounds (e.g. synthesized) is also needed.

1.4 Structure

The thesis presents a literature review and background before describing the experimental procedure.

Chapter 2 provides an overview of 3D Visualization in landscape planning and design with a specific focus on the relationship between visualization realism and abstraction.

Chapter 3 presents concepts of soundscape and the relationship between soundscape, landscape, and landscape visualization as well as a discussion of potential sources of sound for developing future scenarios.

Chapter 4 provides the research hypothesis and outlines the aims, objectives and research questions.

Chapter 5 details the study site selection criteria and characteristics of the chosen site.

Chapter 6 outlines the experimental method, methodology, participants and materials.

Chapters 7 - 9 present the results of the experiment, providing detail of data analysis and statistical outcomes.

Chapter 10 discusses the conclusions and outlines areas for future research.

2 LITERATURE REVIEW: 3D-VISUALIZATION FOR LANDSCAPE PLANNING AND DESIGN

This thesis combines components of 3D landscape visualization and soundscape. In order to contextualize the research presented this chapter aims to review studies and concepts on landscape perception and visualization, with the next chapter providing the same for soundscape. Section 2.1 provides a background on landscape perception and preference research. Section 2.2 discusses landscape visualization followed by examples of visualization application in section 2.3. Section 2.4 presents a specific type of landscape visualization, virtual globes. Sections 2.5 and 2.6 detail research and concepts around visualization realism and abstraction, respectively. Section 2.7 presents theories and concepts supporting the use of other senses to augment visualizations are explored. Finally section 2.8 presents a summary of the literature review on 3D visualization for landscape planning and design and discusses the potential for using sound in the process.

2.1 Landscape perception and preference

Landscape has been described as a visual resource (Kaplan, 1985) which acknowledges human vision and hence perception in the definition. Perceptual aspects of landscape necessitate a human component and thus are not only a measure of physical attributes but also reactions to and cognition of physical attributes by people. Various frameworks to evaluate visual quality and character have been developed (e.g. Daniel & Vining, 1983; Lothian, 1999; Zube, Sell, & Taylor, 1982). Approaches focusing on landscape character have attempted to address the complications of human perception in categorizing landscape preference (Landscape Institute & Institute of Environmental Management and Assessment, 2002; U.S. Forest Service, 1974). Lothian (1999) proposes that studying visual properties of landscape could be defined either as an object oriented and expert led approach, or a subjective and experiential approach. Zube et al. define four paradigms for landscape perception including the expert paradigm, the psychophysical paradigm, the cognitive paradigm and the experiential paradigm (1982, p. 8). The fourth paradigm, also referred to as phenomenological by Daniel and Vining (1983) was reported to be by far the least covered in academic literature, with a view that its contribution was more to theoretical understanding than application. This could be due to the complications of engaging in a more experiential way with landscape both technically and conceptually.

Recently attempts have been made to link more closely character assessment and peoples experiences (Tveit, Ode, & Fry, 2006). Virtual environments have been identified as having developed sufficiently to enable investigations of experiential approaches with significant impacts reported for perception researchers (Bishop, Ye, & Karadaglis, 2001). In an urban context the validity and generalizability of empirical research has been questioned more than three decades ago by Ittelson (1978), who raised important issues on the nature of environmental perception in relation to environmental experience from one geographic location to another. Landscape quality and preference has been evaluated by research primarily employing psychophysical instrumentation with an emphasis on perceptual responses in which the resulting data relates to the objects (landscape) (Daniel & Meitner, 2001). This is contrasted with psychometric methods where data collected refers to the respondent (human).

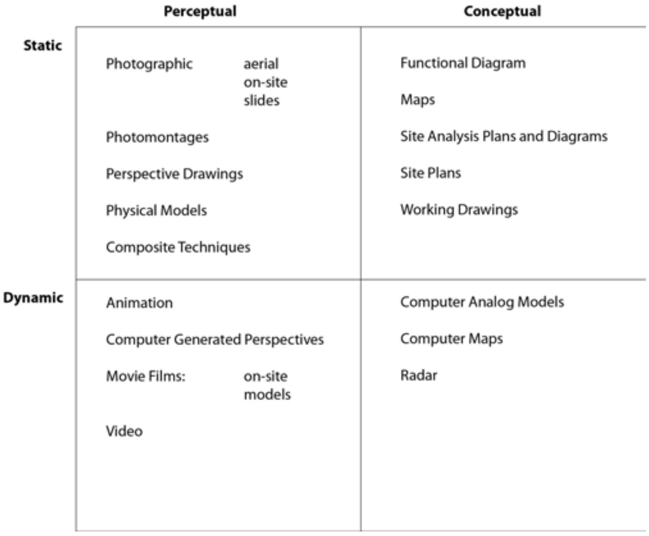
Theories regarding landscape preference can be broadly divided into two groups: 1) people's preference for landscape is innate (e.g. based on places where the human species evolved); and 2) people's preference for landscape is shaped by experience and/or knowledge (e.g. cultural background, familiarity). Supporting the first paradigm is a large body of historical evidence from environmental psychology indicating that people generally prefer natural to urban environments regardless of their background or beliefs (e.g. Kaplan, Kaplan, & Wendt, 1972; Kaplan & Kaplan, 1982). In addition, research has demonstrated a preference for high quality tropical Savannah-like landscapes based on the idea that this is the environment where humans evolved (Orians & Heerwagen, 1992), with further evidence that trees that appear like those found on the Savannah (i.e. small trunks and canopies that are broader than they are tall) are the most preferred (Balling & Falk, 1982; Falk & Balling 2010; Sommer 1997). In addition there is evidence that people prefer scenes that have more trees with larger clump diameters to those with fewer and smaller clump diameters (Schroeder & Orland 1994) and that in a suburban park context an increase in tree density and size and a decrease in understory density increases pleasure (Hull & Harvey, 1989). In addition the study demonstrated that the presence or absence of a pathway had a significant effect on responses.

Empirical studies have been used to identify four main influences on preference for landscape via a scene; the gradation of natural to manmade features, the degree of topographic variation, the existence of water and the amount of open space, with more natural features seeming to have the largest impact (Hagerhall, Purcell, & Taylor, 2004 citing Kaplan & Kaplan, 1982; Kaplan, Kaplan, & Wendt, 1972; Purcell & Lamb, 1984). Hagerhall et al. (2004) contribute further to an understanding of the influences on landscape perception, with their study demonstrating complex influences on landscape evaluation showing a relationship between the fractal dimension of a landscape silhouette and landscape preference. In addition, landscape preference has been shown to be impacted by both distance of view and the presence of human-made structures (i.e. wind turbines) (de Vries, de Groot, & Boers, 2012).

In contrast to the above-mentioned *innate* paradigm there are researchers that consider preference to be dependent on cultural experience or prior knowledge (e.g. Cosgrove, 1998, Nassauer, 1988; Thayer, 1989). Proponents of this paradigm indicate that an alignment of landscape aesthetics and ecological function may be possible through design and knowledge based interventions (e.g. Gobster, Nassauer, Daniel, & Fry, 2007). However, empirical research has demonstrated that using information to alter preference had little effect (Hill & Daniel, 2007). One recent study sought to confront the divide between paradigms showing that participants prefer landscapes experienced during childhood, but seem to attach more easily to qualities that are suggested to have an innate significance (Adevi & Grahn, 2011), providing some support for both views.

Photography has long been viewed as a valid surrogate for on-site experience in landscape evaluation, evaluated for validity starting over forty years in landscape preference studies (e.g. Rabinowitz & Coughlin, 1971; Shafer & Richards, 1974; Shuttleworth, 1980). It has been presented that very few historical photography based studies reported reliability or validity coefficients and indeed many could be deemed invalid and did not focus on individual photographs or variables (Palmer & Hoffman, 2001). More recently an empirical study compared on-site experience, wide angle and standard photographs and found that for over half the variables measured there was no difference in validity between stimulus types (Sevenant & Antrop, 2011). Other studies have inverted more conventional methods of showing participants an image and evaluating their individual responses, and instead had participants provide the content and then analyse this content for patterns or relationships. For example, to determine views and locations of interest a recent study provided participants with GPS enabled cameras and tracked their photograph locations on site, allowing for analysis by kernel density estimation or ‘hot spots’ of the most photographed places (Sugimoto, 2011, 2013). While there are differences when using any surrogate in place of real experience, photography based assessment has, among other limitations, a weakness in the control of variables within a scene, which 3D visualization can overcome.

The different types of simulations available for landscape investigation and communication, by analogue or digital means, offer strengths and weaknesses depending on what type of information is to be communicated. Zube et al. (1987, adapted from McKechnie, 1977) categorized landscape simulation typologies based on their suitability to perceptual or conceptual information, and further divide these into static or dynamic representations (Figure 3). The perceptual simulations communicate physical characteristics and experience, while conceptual simulations communicate non-visual phenomena (e.g. natural processes). The authors are careful to elaborate that no category is mutually exclusive.



	Perceptual	**Conceptual**
Static	Photographic: aerial on-site slides Photomontages Perspective Drawings Physical Models Composite Techniques	Functional Diagram Maps Site Analysis Plans and Diagrams Site Plans Working Drawings
Dynamic	Animation Computer Generated Perspectives Movie Films: on-site models Video	Computer Analog Models Computer Maps Radar

Figure 3: Landscape simulation typologies (Zube et al., 1987)

More recently it has been shown that collaborative landscape planning exercises can benefit at three levels (i.e. design, analysis and negotiation) using a touch table and spatial decision support tools (Arciniegas & Janssen, 2012). In addition, landscape scenario development has been shown to require both analytical and experiential elements to enable participants to both understand (analytically) and engage (experientially) with socio-ecological change (Vervoort, Kok, Beers, Van Lammeren, & Janssen, 2012).

2.2 Landscape visualization

Visualizations, 3D digital simulations of real or proposed environments, have been used by planners and landscape architects since the 1970's and are becoming technologically robust (e.g. Visualizations can range from non-immersive and static to dynamic and immersive (Danahy, 2001; Lange, 2001). Visualizations have steadily increased in both their level of realism and efficiency of creation since their first use. A thorough overview of the evolution of 3D digital perspectival-based visualization has been presented by Lange and Bishop (2005). Some major developments in landscape visualization are summarized in Table 1.

Table 1: Milestones in 3D landscape visualization

Year	Construction	Vis Type	Hardware	Interaction	Output	Reference
1977	Manual	Wireframe	Mainframe	Static	Plot	(Myklestad & Wagar, 1977)
1977-80	Manual	Shaded relief Draped imagery Shaded building volume	Mainframe	Static	Screen/ Plot	(Faintich, 1980)
1986	Manual	Wireframe	Workstation	Dynamic	Screen	(Molnar, 1986)
1990	Manual	Photorealistic	Desktop	Rendered	Screen	(Peltz & Kleinman, 1990)
1994	Manual	Photorealistic	Workstation	Dynamic	Screen	(Lange, 1994)
1995	Automated	GIS data	Workstation	Dynamic	Screen	(Hoinkes & Lange, 1995)
2005	“Pre-made”	Virtual Globe	Consumer	Dynamic	Screen	(Sheppard & Cizek, 2009)

The construction methods outlined in Table 1 are indications of modelling evolution and not necessarily mutually excusive, as there are examples (e.g. in the context of city modelling and architectural façade modelling) where parametric procedural modelling, a method of generating digital models from numeric input, has been updated to allow interactive modelling (Lipp, Scherzer, Wonka, & Wimmer, 2011; Lipp, Wonka, & Wimmer, 2008). Procedural modelling that integrates natural resource indicators has also been presented (Wissen-Hayek, Halatsch, Kunze, Schmitt, & Grêt-Regamey, 2010).

Sheppard (1989) has identified three dimensions to evaluate visualizations: understanding, credibility and fairness in representing current or imagined conditions. This has been elaborated explicitly for experiential landscape visualizations incorporating users responses (Sheppard, 2005b) and adapted for use with virtual globes (Sheppard & Cizek, 2009) and is illustrated in Table 2.

Table 2: Criteria for evaluating landscape visualizations (Sheppard & Cizek, 2009)

Feature	Definition
Accuracy	Visualisations should simulate the actual or expected appearance of the landscape (at least for those landscape factors being judged), without distortion and at an appropriate level of abstraction/realism for the intended purpose.
Representativeness	Visualisations should represent typical or important views/conditions of the landscape.
Visual clarity	The details, components, and overall content of the visualisation should be clearly communicated
Interest	Visualisations should engage and hold the interest of the audience.
Legitimacy	Visualisations should be defensible and their level of accuracy demonstrable.
Access to visual information	Visualisations should be readily accessible to the public via a variety of formats and communication channels.
Framing and presentation	Important contextual and other relevant information (such as labelling, narration, mapping, etc.) should be presented in a clear, neutral fashion, along with the visualisation imagery.

The criteria identified in Table 2 focus primarily on the *visualizations*, while factors primarily concerning the *visualization environment* have been identified by Bishop and Lange (2005) and are illustrated in Table 3. Bishop and Lange indicate that in their view, the first three factors are the most important (Immersion, Interaction, Intensity/Realism). The focus on sound in the research presented here means that there are features from both sets of criteria that are of relevance to the current research project.

Table 3: Features deemed significant to a virtual environment (Bishop and Lange, 2005)

Feature	Definition
Immersion	Immersion describes the sensation of 'being in' the environment VR should deeply involve or absorb the user
Interaction	Enables a participant in a virtual experience to change their viewpoint on the environment and to change the relative position of their body (or body parts – hands) in relation to that of other objects Enables manipulation of the characteristics of environment components In VR, user and computer act reciprocally through the interface
Intensity (realism)	The detail with which objects and features of the environment are represented In VR the user encounters complex information and responds
Intelligence	The extent to which components of the environment exhibit context-sensitive 'behaviours' that can be characterized as exhibiting 'intelligence'
Illustration	VR offers information in a clear, descriptive and illuminating way
Intuition	Virtual information is easily perceived. Virtual tools are used in a 'human' way

The definition of immersion identified by Bishop and Lange in Table 3 in relation to landscape visualization has been defined in virtual environment research as "presence", which is one measure of virtual environment efficacy. Presence is commonly defined as the experience of 'Being There' in a synthetic or virtual environment (Draper, Kaber, & Usher, 1998) and has garnered much attention as a research topic in diverse fields of study. Presence has been further defined conceptually as being a multilevel construct ranging from lower-level involuntary responses to higher-level subjective responses (Sanchez-Vives & Slater, 2005). As such, presence is not one state of perception, but operates on a variety of perceptual levels of both conscious and subconscious experiences by the user.

In presence research immersion is differentiated from presence, with immersion being more hardware oriented and quantitatively measureable, while presence is more qualitative and experiential (Slater, Linakis, Usoh, & Kooper, 1995). It is clear that presence and immersion are related concepts, both impacting the experience of landscape visualizations to a large degree. Related to presence, *Flow experience* has been identified as a significant factor in learning and human computer interaction, and in immersive learning environments has been validated as a measure for task effectiveness (van Schaik, Martin, & Vallance, 2011).

Landscape visualizations are fundamentally made up of basic landscape elements that are rendered in 3D to approximate the visual qualities of a landscape. The basic landscape elements that are usually included in visualizations are terrain, vegetation, built form and water (e.g. Figure 4) and can be expanded to incorporate animals (including people) and atmosphere (Ervin, 2001). As discussed in section 2.1 these elements individually and collectively inform landscape preference, and as such are the focus of the research presented here.

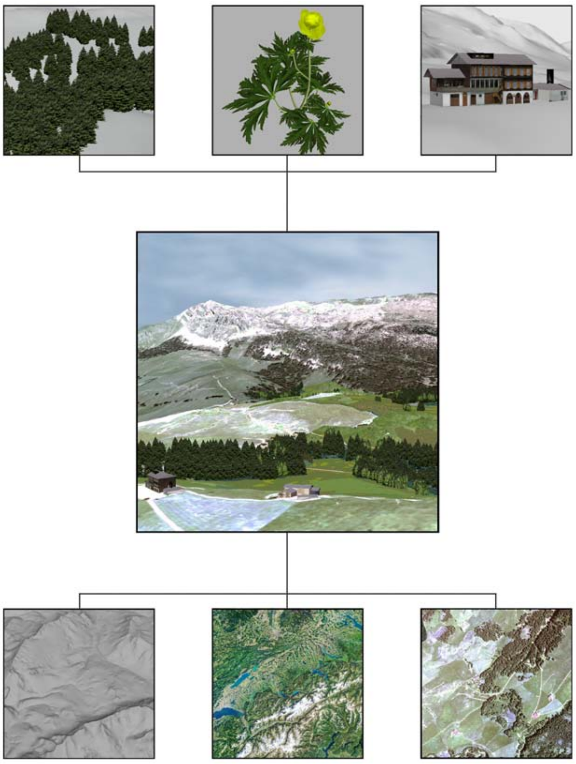


Figure 4: Landscape visualization basic elements: terrain, vegetation, built form and water (Lange et al., 2003)

2.3 Visualization application

Visualization of landscape offers many advantages over traditional methods of spatial representation, particularly when communicating complex spatial arrangements to those untrained in spatial design disciplines in some situations (Bishop, 2005; Kwartler, 2005). Public participation has been mandated by various declarations and conventions (Rio declaration 1992 principle 10 public participation; European landscape convention 5c, Aarhus convention). In contrast to top-down mandates there have been situations where the public, through collaboration with visualization professionals, have initiated a process of public participation using visualizations when planning professionals were reluctant to engage (Lindquist, 2007). Visualizations have been successfully used across a variety of landscapes and purposes including negotiating compromises between views and building height (Danahy, 2005); assessing urban green space qualities (Lange, Hehl-Lange, & Mambretti, 2004); scenario based assessment (Lange, et al., 2008); and evaluating perceptions of clear-cutting on mountains (Palmer, 2008) and indicators of perceived naturalness (Ode, Fry, Tveit, Messager, & Miller, 2009).

The case for using visualization over other methods for evaluating landscape preference has been demonstrated; one study indicated that landscape preference (scenic beauty judgment) is impacted by the media used; verbal and visual presentation of information show a difference in preference, the results supporting the use of visual presentation methods (Tahvanainen, Tyrväinen, Ihalainen, Vuorela, & Kolehmainen, 2001). Landscape visualizations have shown to correlate closely with on site experience using preference scores (Bishop & Rohrmann, 2003), though it has been demonstrated that they need to be reasonably realistic to be successful surrogates for real life experience (Daniel & Meitner, 2001; Lange, 2001). Immersive visualization, which allows a viewer to experience looking around and moving about in virtual space, has been presented as a superior method for conveying landscape experience with real-time 3d models when compared to conventional non-immersive methods (Danahy, 2001). An example of an immersive visualization environment is illustrated in Figure 5.

Figure 5: Immersive visualization environment

Visualization application has evolved beyond representing a landscape, to applying interactive features to visualizations to enhance public participation (Schroth, Lange, & Schmid, 2005); integrating visual and non-visual indicators with visualizations (Wissen, Schroth, Lange, & Schmid, 2008) as well as investigating the contribution of visualization to transdisciplinary knowledge generation (Schroth, Hayek, Lange, Sheppard, & Schmid, 2011). Recent studies have proposed the integration of visualizations and agent models to assist with complex multi-criteria decision making (Bishop, Stock, & Williams, 2009).

The types of landscape elements that should be selected for visualizations has been presented, arguing for elements that are specific and important to a user group with participants made up of that user group (Williams, Ford, Bishop, Loiterton, & Hickey, 2007). In addition, decision-making based on alternative future scenarios has been shown to benefit from the ability to compare effects of underlying systems using multiple panoramic views (Smith, Bishop, Williams, & Ford, 2012).

For applications in urban planning and design there has been identified a need for minimum standards for visualization preparation and presentation. Drawing on multidisciplinary research from architecture, landscape architecture, resource management, transportation engineering amongst others, the authors elaborate and discuss the need for the “use of a ‘null alternative’ scenarios, perceptual effectiveness of video based formats and collaborative technology development” (Lewis, Casello, & Groulx, 2012).

In the context of land-use policy decision making in relation to climate change researchers investigated data visualization options (Bishop, Pettit, Sheth, & Sharma, 2013). The project identified the issue that stakeholders responsible for policy decisions may not be experts in all aspects of climate change and would need climate change data communicated to them in an easy to understand way. In order to evaluate the best visualization options to use the researchers developed a framework and applied it in the context of climate change data visualization, finding in general that interactive software tools were favoured over other types of visualizations.

2.4 Virtual globes

Virtual globe software such as Google Earth is growing in use and popularity at an exponential rate since its introduction in 2005 (Sheppard & Cizek, 2009). Owing to their ease of use, affordability and ubiquity virtual globes are a logical next phase in the way practitioners and researchers, and increasingly the public, interact with and create visualizations. Computer based visualization is a relatively new field with theories and frameworks still emerging. Sheppard and Cizek (2009) identify cartography/GIS and landscape visualization as two disciplines that have developed frameworks for understanding and evaluation of visualizations that are pertinent to virtual globes, with virtual globes' key benefits identified as being open access to visual information, interest and representativeness.

As of October 2011 Google Earth had been downloaded over one billion times since its release in 2005 (McClendon, 2011). Some time following its release researchers theorized the potential of Google Earth for visualizing wind farms (Wolk, 2008). Since then Google Earth has been used primarily for visual analysis of the earth's surface and has uncovered animal shaped mounds in Peru (Benfer, 2011), meteor craters in the Saharan desert (Folco et al., 2010). Google Earth has been used to convey non-visual scientific data (Tiede & Lang, 2010) and for disaster support through situation awareness (Tomaszewski, 2011). More recently California has released vehicle emission rates visualized via Google Earth (Mellen, 2012). Google Earth has also been used in conjunction with ArcGIS to identify and map spaces of food production in Chicago (Taylor & Lovell, 2012).

A 2008 position paper put fourth "the vision on the next generation Digital Earth and identifies priority research areas to support this vision" (Craglia et al., 2008, p. 146). The authors' vision involves multiple facets including interface, data aspects and applications, though to date there is limited empirical research conducted on the application aspects.

There has been some attention paid to Google Earth by empirical geospatial researchers; Van Lammeren et al. (2010) conducted an affective appraisal experiment of visualizing different non-visual data, using Google Earth as the frame, finding that 3D icons elicited the highest affective appraisals and positively influenced perception of environmental quality when compared to 2D icons or coloured raster cells. In another study, questionnaire and in-depth interviews were used to appraise the utility of Google Earth in a bottom up, community driven visioning process, finding users split in their evaluation of the virtual globe for data visualization and interaction (Schroth et al., 2011). The issue of quality in virtual globes has started to be addressed, with 'perceived quality' being one indicator that has been tested (Jones, Devillers, Bédard, & Schroth, 2012).

In anther study researchers customized Google Earth through KML scripting to incorporate additional data from GIS and 3D modelling sources (Harwood, Lovett, & Turner, 2012). After trialling the visualizations with the public they concluded that once past initial technical hurdles Google Earth "undoubtedly has great potential for supporting initiatives concerned with public participation in landscape planning, including aspects of Geodesign" (Harwood, et al., 2012, p. 262).

The use of virtual globes in general, and Google Earth in particular, for landscape visualization at the design scale rather than large scale planning has received less focus. The integration of Google Earth with Google Streetview provides a means for validating the visual accuracy of a manually constructed 3D model prior to contributing the 3D model to Google Earth (F. Taylor, 2012, June 8). Google is also introducing in its mobile and tablet versions of Google Earth 3D models of buildings and vegetation generated from 45 degree aerial photography (Mellen, 2012, June 6).

One study compared various web-based means for landscape architecture presentations via the world wide web, finding that at that time the technical limitations of Google Earth limited its use when compared to Quicktime VR and static online presentations (Lindquist, 2008). Some studies have indicated that Google Earth can be used for landscape design visualization (Honjo, Umeki, Wang, Yang, & Hsieh, 2011), with 3D modelling imported as KML files; though proven to be feasible, evaluation carried out was limited to a subjective comparison of Google Earth to VRML by the authors.

As indicated by Sheppard, "relatively few studies have addressed affective dimensions relevant to environmental and community decision-making" (Sheppard & Cizek, 2009, p. 2105). The majority of studies focus on elevated oblique aerial views, having been identified as providing framing that is similar to landscape painting and thus familiar (Dodge & Perkins, 2009). Google uses Street View to 'fill in' detail, but as pointed out by Schroth et al. (2011, p. 207-208) "It is still an open question how much cognitive load these diverse landscape impressions impose on the user and how different user groups can cope with that cognitive load". While there still remain unanswered questions relating to affective and cognitive impact of Google Earth on users, the utility of Google Earth for landscape and other visualization research will continue to increase, particularly as new levels of 3D imagery increasingly become available.

2.5 Visualization realism

Almost two decades ago realism was argued to be of critical importance in communicating landscape change (Bishop, 1994; Lange, 1994) and was justified by studies that demonstrated a correlation between the level of realism of a simulation and its effectiveness (e.g. Bishop & Hull, 1991; Decker, 1994; Lange, 1994, 2001; Oh, 1994; Zube, et al., 1987). However, at that time 3D landscape visualisations still lagged well behind the experience of the real-world (Lange, 2001). In the forest setting efficiency and realism has been one of the goals of landscape visualization (Karjalainen & Tyrväinen, 2002). Bishop & Lange (2005) offer that when the subject matter to be visualized can be represented with high levels of realism (e.g. aesthetic issues, flood risk, traffic volumes) that realism is appropriate. Lange (2001) conducted a study to assess the importance of detail in visualization at a planning scale, finding that very detailed 3D-object-data and texture information would be necessary to achieve a very high degree of realism.

Bishop and Rohrmann (2003) conducted a questionnaire to compare responses to simulated and real environments, finding that simulated environments still lag far behind the real experience, although compare favourably better for night-time comparisons. Another experiment indicated differences of landscape preference when using 3d walk through vs. still photos (Bishop, Wherrett, & Miller, 2001). The correlation between realism and validity has been discussed (Palmer & Hoffman, 2001). Perceived reality of still photographs compared to less realistic but dynamic walk-thorough representations have been shown to be very close in a garden setting (Lim, Honjo, & Umeki, 2006).

In the urban context visualizations have shown to be superior to on-site experience for communicating some design ideas and tended to direct attention of the viewer, though proved inferior in conveying some types of visual data (Wergles & Muhar, 2009). In relation to realism the study brought up interesting issues where the very 'real' on-site experience did not necessarily improve participant design evaluation. For architectural design communication photorealistic computer generated photomontage and 3D renderings have been shown to be perceived as more realistic than watercolour or perspective drawings completed by hand, with the photomontage being more lifelike than the 3D rendering (Bates-Brkljac, 2012). One weakness of the study was that the 4 conditions did not depict the same view, therefore results could be challenged on a methodological basis.

Another study aimed to determine the effect of stylistic rendering differences on the perceived realism and preference for environmental visualizations, comparing a range of renderings from ‘neutral/restrained’ to ‘stylistic/unrestrained’ (Lewis, 2012), finding that presentation style had a significant impact on rating of preference, realism and confidence in those visualizations. However, the inclusion of different renderings of people in one view or another, and other confounding variables, make the results difficult to generalize.

The definition of realism in visualization research, and how it is measured, can differ between studies. Lange (2001, citing Hall, 1990, p. 19) offers a useful starting point, proposing a comprehensive definition of realism via three criteria: ‘generating the same stimulus as the real environment’; ‘generating the same perceptual response as the real environment’; and ‘creating the impression of realism’. Williams et al. (2007) point out that “creating the impression of realism is not at all the same as ‘generating the same perceptual response as a real scene (Williams, et al., 2007, p. 214) and, citing McQuillan (1998) state that ‘real’ and ‘realistic’ (i.e. apparent realism) must be distinguished.

While apparent realism may contribute to the effectiveness of a visualization, it is “not a safe guide to accuracy or response equivalence of visualizations…though visualization research often seems to focus on it.” (Sheppard & Cizek, 2009, p. 2107). Some criticize digitally generated visualizations citing what others would refer to as their benefits, that is the perception of precision and accuracy of computer images, which can “make an unresolved idea look polished and complete, discouraging further consideration” (Grubbs, 2008). Though anecdotal, it points to bias within the landscape profession that needs to be addressed with empirical studies. Previous studies have noted that a high degree of realism must exist for the environmental context of the study if anyone with knowledge of the local area is viewing the visualization (Appleton & Lovett, 2005; Karjalainen & Tyrväinen, 2002). Appleton and Lovett (2005) also indicate an issue raised by overly realistic scenarios in that participant stakeholders may think that the realistic visualization will necessarily be constructed exactly as shown, a concern echoed by McQuillan (1998) in the forestry context with a desire to “acknowledge the difference between the realistic and the real”. The issue of realism and apparent authenticity has also been raised in dynamic visualizations for coastal erosion (I. Brown et al., 2006).

Some recent studies have sought to address the issue of accuracy in visualizations by accepting lack of realism and focusing on what will suffice for visualization. Appleton and Lovett (2003) sought to define a ‘less real’ level of realism that was still deemed sufficient enough so as to not represent overly realistic visualizations in rural planning projects, though the study did not find this sufficient level. One weakness of the study was the lack of variation of vegetation, as their own results indicated foreground vegetation, along with the appearance of the ground surface, had significant effects on ratings. In addition, the study used a double-barrelled question (To what extent do you feel that the style *and* content of this image allow you to imagine the future landscape that is being considered?) that could further complicate analysis.

A related study sought to determine the required Level of Detail (LOD) of a visualization, finding that there was no significant relationship between LOD and assessed value of the landscape (Hofschreuder, 2004), though for individual criteria (i.e. harmony and openness) there was a significant difference based on LOD. Finally, using concepts from cartography and semiotics, Messager Belveze and Miller (2005) conducted a study to compare, among other variables, how well varying levels of realism (i.e. photorealism; realism; iconic; diagrammatic) represented a real landscape. Not surprisingly, the results indicate diagrammatic representation rated weakest, realistic better and photorealistic closest to reality.

Another study evaluated perceptual responses to varying LOD (i.e. shaded solids; medium detail photo textures, high detail photo textures) in visualizations for a suburban scene (Barbarash, 2012). Similar to findings of previous studies (e.g. Lange, 2001) photorealistic textures rated higher than flat shaded visualizations, and the communication of “project content” was lower for flat shaded visualizations as well. In addition, the study suggests that laypeople would be willing to accept a lower LOD in the visualization, depending on the content depicted. One weakness of the study, as with preceding studies, was the treatment of an entire image with the same LOD, thus omitting the possibility to isolate the variable responsible for the variance. There is a clear need to further explore abstraction and uncertainty in visualization, which the next section engages with.

The basic landscape elements in a visualization (i.e. terrain, vegetation and built form, Figure 4, p. 18) contribute differently to perceived realism, as does the relative distance of view from these elements. For example, research has shown that foreground scenes are rated more realistic than middleground or background scenes at the same level of detail (Lange, 2001). In addition, detailed foreground objects increase realism ratings (Appleton & Lovett 2003; Bergen et al. 1995). The inclusion of texture maps on both terrain and built form can greatly increase perceived realism when compared to simple geometry (Appleton & Lovett 2003; Barbarash, 2012; Lange, 2001; Oh, 1994), and the landscape elements that most affect perceived realism are built form and vegetation (Bishop & Rohrmann 2003).

2.6 Abstraction in visualizations

2.6.1 Visualizing abstract information

The concrete visualization of abstract or non-visual information is common in data visualization, information visualization, scientific visualization and, increasingly, landscape visualization. From information science the effectiveness of visualization and how to measure it has been presented (Zhu, 2007). Trumbo (1999) asserts that scientific communication relies on visualization of scientific data and concepts to aid in clarifying and illustrating, and to engage the public. In spatial information science the combination of geographic information and abstract scientific data combines the real-world and abstract concepts allowing for multivariate analysis (Gahegan, 1998). Combining graphical representation of numeric values with 3D landscape models has the opportunity to “provide a mechanism for the effective synthesis and graphical analysis of geographic information” (Bleisch, Dykes, & Nebiker, 2008, p. 216). The study of geomorphology has been shown to benefit from combining scientific data with 3D models of the earth’s surface and subsequently using multiple elevation surfaces and cutting planes to perform detailed analysis (Mitasova, Harmon, Weaver, Lyons, & Overton, 2012).

More recently frameworks for appropriately incorporating into virtual environments representations of quantitative data have been developed (Bleisch, 2011). In landscape visualization Bishop and Lange contend that “there are clearly environmental management impacts which either cannot be represented realistically (non-visual pollution, regions of influence) or are more easily interpreted by a more schematic form” (Bishop & Lange, 2005, p. 29). In this context they reference studies that engage with abstraction of different information and types; accurate geometric terrain modelling with abstract cover (Lovett, 2005); semi-realistic modelling combined with abstract icons (Krause, 2001); and making visual some invisible aspects of animal patterns (Hehl-Lange, 2001). They finish with the conclusion that numerous examples exist of different ways of representing abstraction, and that there is a lack of research on what is the most effective abstraction method for a given project type.

Other research has focused on visualizing the impact on landscape of climate change by analysing abstract data and in turn used to produce scenarios of future landscapes (Dockerty, Lovett, Appleton, Bone, & Sünnenberg, 2006; Dockerty, et al., 2005; Sheppard, 2005a), though some have critiqued this practice and raised important research questions (Nicholson-Cole, 2005). Other research takes an informative approach, using accurately calculated carbon footprints that are projected for different scenarios, then visualizing this while taking account of the multidimensional dataset (Petsch, Guhathakurta, Heischbourg, Müller, & Hagen, 2011). There is less literature on the deliberate abstraction of physical features of future scenarios that are fuzzy or undefined (e.g. at the early stage of the design process), which will be elaborated in the next section.

2.6.2 Abstracting uncertain reality (fuzziness)

Incomplete or unknown data is common in many scientific and professional disciplines. As a result, methods and techniques have been developed that attempt to draw conclusions and make useful such data in the form of fuzzy modelling. Fuzzy modelling has been used in GIS when traditional data, defined by explicit true or false properties, is ill defined or unavailable (Fisher, 1996). Conventionally geomorphologic landforms have been considered as “Boolean objects” (i.e. belonging to one landscape type or another), however, studies have indicated that due to issues with classifying boundaries it is more suitable to view them as fuzzy objects (Dinesh, 2007). Abstraction in relation to LOD as a necessary component of landscape visualization has long been a part of the visualization research agenda, with software addressing

LOD to allow for more efficient visualizations (Bergen, McGaughey, & Fridley, 1998). More sophisticated simplification algorithms in the realm of city models for vast urban landscapes have been developed with a focus on maintaining urban legibility by maintaining façade boundaries, landmarks and skylines (Chang et al., 2006; Chang et al., 2008). Wissen Hayek (2011) used qualitative social-empirical methods to evaluate the benefit of abstract (e.g. illustrative maps draped over 3D terrain models) or realistic visualization types at different phases of planning, finding that the different strengths of each type of 3D visualization are necessary at different types of participatory workshops.

The majority of empirical perceptual studies to date have evaluated responses to LOD rather than abstraction as defined here, and those that have addressed abstraction (i.e. Daniel & Meitner, 2001) were not focusing on deliberate abstraction due to uncertainty or fuzziness. Uncertainty in the design and planning process can be at the macro scale (e.g. political instability casting doubt on future processes) or micro scale (e.g. funding for a specific design element within a new park). Fuzzy boundaries are now a necessary part of the planning process in the UK; with the push for regional devolution, the so-called new spatial planning "seeks to alternatively augment, destabilize and overturn orthodox administrative categories and divisions of space….spatial planners have traditionally thought and practised with and through clearly bounded scales (national, regional, local), in this century the new spatial planning is imposing relationally inscribed concepts such as 'soft space' and 'fuzzy boundaries' into the lexicon of spatial planners“ (Heley, 2012, p. 1). From a human geography perspective the critique of abstraction has been revisited, arguing that abstraction be affirmed as a necessary element of lived experience (McCormack, 2012).

Uncertainty can enter the visualization process in various forms; early stages of design result in uncertainty and ambiguity, when a proposal is still being substantially developed. Ervin (2001) reminds us of the exploratory intent of (some types) of visualizations, viewing this fuzziness not as a problem, but an integral part of the process, and in turn embracing a variety of types of landscape models at these stages. In addition, Ervin (2004) identified four abstraction levels with respect to visualizations: diagrammatic; evocative; illustrative; and realistic, each serving its own purpose at different (or overlapping) stages of design. In the urban design realm abstraction has been presented as a necessary element, to be balanced with, and differentiated from, realism and accuracy (Pietsch, 2000). Beyond early design stages, uncertainty can arise in planning and landscape assessment from lack of existing data, or a lack of concrete knowledge to inform the creation of future scenarios. While some informal mechanisms exist to address uncertainty, more formal procedures would benefit the design and planning process in general.

Solutions offered to addressing uncertainty in visualizations have included non-visual queues, (e.g. a professional regulating body, or verbally explaining that the model is made with real-world units), however, there is little in the way of consensus from their participants. Participants in a study by Appleton and Lovett (2005) suggested a visual distinction by making “existing or proposed elements ‘fuzzy’ or monochrome, but it was also acknowledged that such a technique might also be confusing to the viewer” and, based on experience of Sheppard (1983), recommend “visual representation of uncertainty should be considered with care, given its many different sources and levels.” (Appleton & Lovett, 2005, p. 331). These issues and research agendas in landscape visualization point to the need for research engagement with abstraction in visualizations, both from visualizing abstract or non-realistic data and abstracting realism when designs are not fully formulated at early design stages.

2.6.3 Level of detail vs. abstraction

As with previous studies on realism, the techniques employed by Appleton and Lovett, Hofschreuder, and Messager et al. for varying realism is considered here to be more a function of LOD rather than abstraction, be it varied by comparing actual photographs and computer generated images (Bergen, Ulbricht, Fridley, & Ganter, 1995); photographs, sketches and computer generated images (Killeen & Buhyoff, 1983); photographs and computer generated images (Lange, 2001); computer generated images (wire frame; surface model; photorealistic model) and photographs (Oh, 1994); or computer generated line drawings at three levels of detail (Tips & Savasdisara, 1986). All dealt with variance that could be classified as a LOD problem than that of deliberate abstraction, details of which are listed in Table 4.

LOD can be a function of underlying accuracy of data or limitations/possibilities provided by computer hardware and software and is typically associated with distance of view within the scene. LOD is defined here as lower realism due to a ‘less detailed version of reality’, such as the absence of photorealistic texture on a building, or fewer or no leaves on a tree (e.g. Figure 6).

Table 4: Reality, abstraction and LOD perception studies

				3D digital model			Stimulus variance	
	Real site	Photograph	Sketch	Wireframe	Shaded solid	Photo-realistic	Abstraction	LOD
Appleton & Lovett, 2003						x		x
Barbarash, 2008					x	x		x
Bergen et al., 1995		x				x		x***
Bishop & Rohrmann, 2003	x					x		x
Bishop, Wherrett & Miller, 2001		x				x		x***
Daniel & Meitner, 2001		x					x	
Hofschreuder, 2004						x		x
Killeen & Buhyoff, 1983		x	x	x				x
Lange, 2001		x			x	x		x
Lim, Honjo & Umeki, 2006		x				x		x****
Messager Belveze & Miller, 2005					x	x		x
Oh, 1994		x		x	x	x		x
Tips & Savasdisara, 1986				x*				x
Wergles & Muhar, 2009	x					x		x***
Williams et al., 2007	x					x		x**

* line drawings at three levels of detail
** as a function of distance
*** as a function of comparing to real-world
**** comparing real-world, visualization walk-through

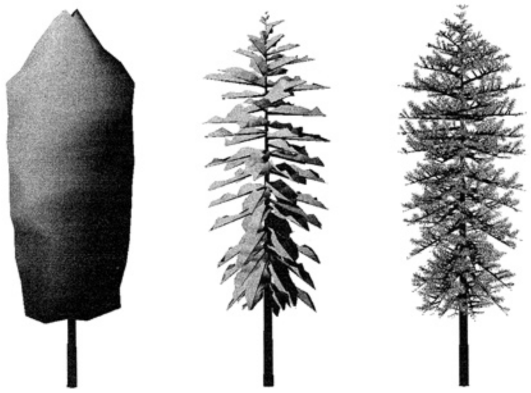
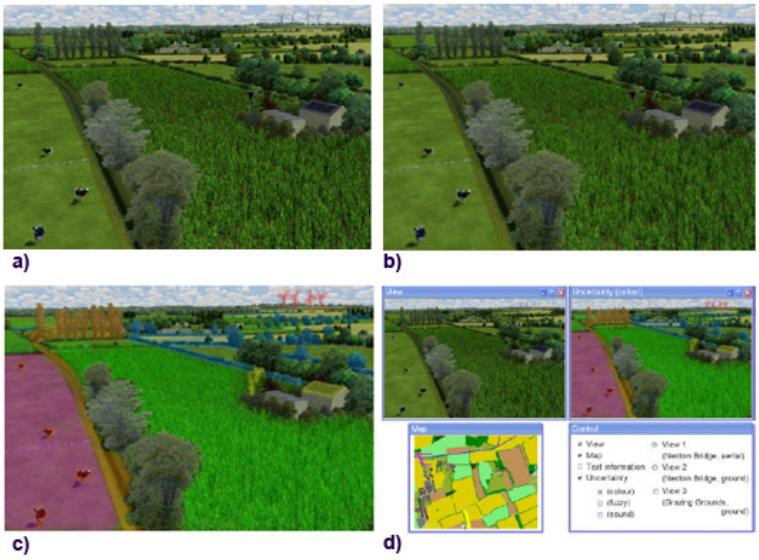


Figure 6: Level of Detail (LOD) variance for vegetation (Bergen et al., 1998)

Abstraction is defined as the deliberate modifying of (what someday could be) reality, such as blurring, colour modification, or transparency (e.g. Figure 7 - Figure 10, following pages). Methods for addressing uncertainty in landscape planning and design have been proposed. Within the context of a visualization based study in the UK, Appleton et al. (2004) propose methods to potentially address uncertainty within the visualization (e.g. blurring the scene or element within it) as well as through alternative methods (e.g. accompanying written information or the ability to compare multiple alternatives, Figure 7).

The desire to clarify the concrete or fuzziness of proposed landscape change via abstracting visuals elements was brought up by users in a related study, though in the same study the authors warn that abstracting an entire image is necessary to avoid the "lowest common denominator" effect where an image is only rated as realistic as its least realistic element (Appleton & Lovett, 2003). They conclude that there are certainly issues to address when evaluating the role of abstraction in visualizations, but that this should not deter further investigation.



☑ View
☑ Map
☐ Text information
☑ Uncertainty
● (colour)
○ (fuzzy)
○ (sound)
● View 1 (Necton Bridge, aerial)
○ View 2 (Necton Bridge, ground)
○ View 3 (Grazing Grounds, ground)

Figure 7: Examples of representing uncertainty techniques: a: "Original", b: "Blurring", c: "Colour", d: "Alternative comparison" (Appleton et al., 2005)

In their paper, Rekittke and Paar (2005) proposed six theories for graphic reduction (abstraction) and present methods of applying these to digital representations of vegetation (Figure 8). Their theories propose, broadly, that the level of realism should correlate to the level of concreteness of the design at a given phase, differentiate between reality and fiction, and provide visual clarity. Their graphic reduction techniques aim to not draw on subjective artistic or creative outputs of the person preparing the visualization, but “as an unstylized minimization of detail” (Rekittke & Paar, 2005, p. 218).

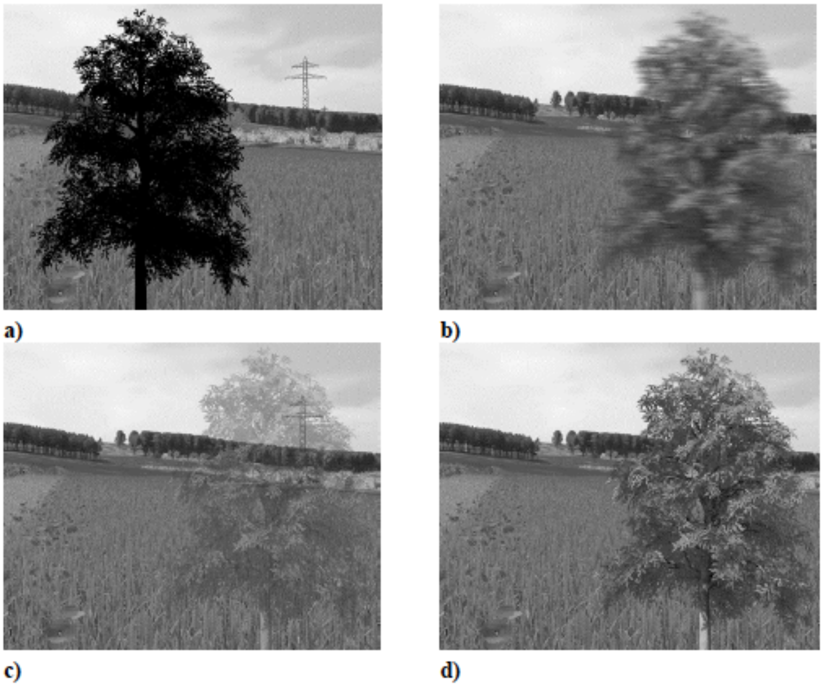
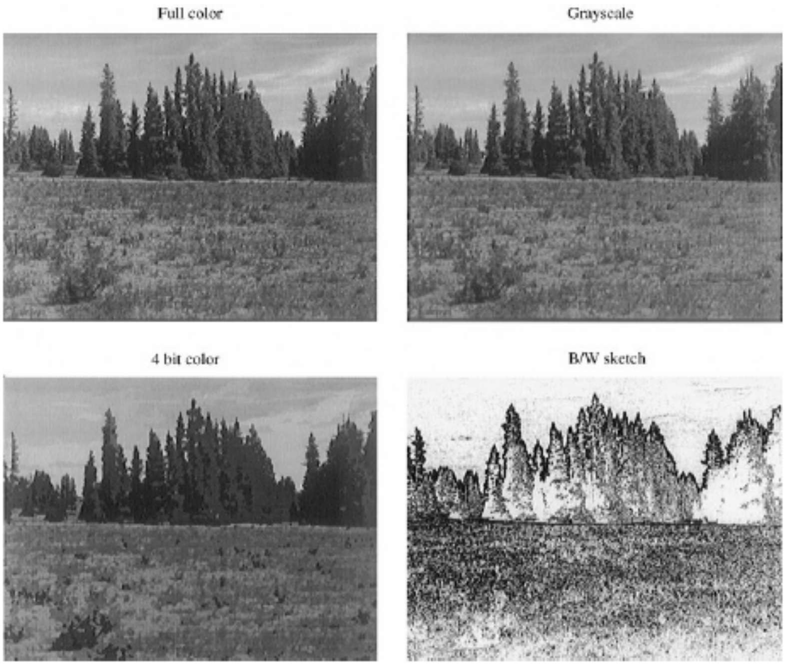


Figure 8: Examples of graphic reduction techniques: a: "Silhouette", b: "Blur", c: "Transparent", d: "Grayscale/Perfect" (Rekittke & Paar, 2005)

Studies that empirically evaluate perceptual responses to abstraction, rather than LOD, for landscape visualizations are relatively few, though there are some. One study that focused on the abstraction of visuals rather than a necessarily lower LOD indicated that between four variations of the realism of a photograph (i.e. Full colour, grayscale, 4 bit colour, black and white sketch, Figure 9) that only the full colour image could produce valid responses (Daniel & Meitner, 2001). The authors indicate that only high levels of photorealism would be appropriate for landscape quality assessment. While this did test for what is defined here as abstraction, the entire photograph was subjected to the abstraction technique and as a result did not examine responses to abstracting specific elements or features within a scene, which a visualization based study could provide. (e.g. the context could be more realistic). Additionally, the aim of the study was to evaluate responses to abstracted visuals, rather than specifically addressing uncertainty or ambiguity.



Full color

Grayscale

4 bit color

B/W sketch

Figure 9: Illustration of four visualization conditions studied (Daniel & Meitner, 2001)

While not a perceptually based, one empirical study investigated a method for quantifying levels of abstraction in landscape graphics at various phases of the design process using computer technology, with an aim of informing graphic guidelines for using abstraction with clients (Feser, 2002). Using a computer-generated visualization the study abstracted the entire image using an Adobe Photoshop filter (i.e. Cut Out) followed by two more (i.e. Stylize, Find Edges), Figure 10. The study did not evaluate perceptual responses but mathematically determined the level of abstraction of each image using techniques from information theory. Though the application of the study remains to be seen, it is one of few examples relating to deliberate abstraction and provides interesting starting point for discussion.

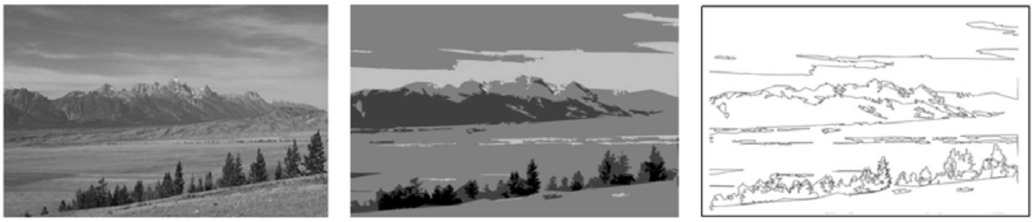


Figure 10: Levels of abstraction: top (original image); middle (cut out filter); and bottom (stylize filter) (Feser 2002)

The various abstraction methods that have been proposed by the authors for specific design and planning phases have been integrated here and are presented in Table 5.

Table 5: Approaches to representing uncertainty in landscape visualization

Method	Description/Source	Design/planning phase
Level of detail	Deliberately creating low-detail visualisations (or elements within them) (Appleton et al., 2004) 4 bit colour (Daniel & Meitner, 2001 'Cut out' filter (Feser, 2002) Using 'Stikkies' placed in the scene (Rekittke & Paar, 2005)	Design development (Feser, 2002)
Silhouette; B/W 'sketch'	Rough model allowing impression size, spatial effect (Rekittke & Paar, 2005)	Drawing board phase (Rekittke & Paar, 2005)
	(Feser, 2002 and Daniel & Meitner, 2001)	Site analysis, conceptual design (Feser, 2002)
Blurring	Details included in colour with a 'lack of focus' indicating flexibility of position (Rekittke & Paar, 2005) (Appleton et al., 2004)	Rough location (Rekittke & Paar, 2005)
Transparency/ Opacity	Full colour, high level of detail, elements behind visible (Rekittke & Paar, 2005)	Fine tuning location (Rekittke & Paar, 2005)
Altering colour	Altering colour, either by adding false colour or desaturating (greying out) (Appleton et al., 2004) Provisionally fixed location with high resolution and level of detail (Rekittke & Paar, 2005), (Daniel & Meitner, 2001)	Preliminary fixing (Rekittke & Paar, 2005)
Photorealistic	Represented as a lifelike possibility, end of planning process (Rekittke & Paar, 2005)	Final design (Rekittke & Paar, 2005) Final renderings (Feser, 2002)
Alternatives	Providing a range of possibilities (Appleton et al., 2004)	
Text	Written information, either on labels within the image or accompanying text (Appleton et al., 2004)	
Sound	Appleton et al., 2004	

Being developed in the computer science domain in parallel to this work were abstraction techniques that are illustrative and non photorealistic, in the form of stylizing filters relating to analogue techniques (e.g. hatching) (Coconu, Colditz, Hege,

& Deussen, 2005), which have been proposed as being good for presenting certain types of information, though have yet to be empirically evaluated.

As indicated, achieving high degrees of visual realism is a complex undertaking, and points to the need to evaluate alternative methods of increasing the sense of reality of visualizations, particularly when engaging in deliberate abstraction. Even when technology is able to achieve a high level of visual realism it has been argued that this can lead to ‘kitsch’ and is in need of applying some level of abstraction to avoid this (Kingery-Page & Hahn, 2012). The use of visual means of abstraction offers one potential for representing uncertainty in the design and planning process. An emerging and related area of research in relation to abstraction and addressing uncertainty is the use of multimodal stimuli, which this research directly addresses. There is a clear need to address deliberate abstraction in landscape visualizations. One logical lead on from this is how can the abstracted visual concept be supported or augmented to allow for or maintain an adequate level of experience of landscape? The next section outlines one such method to achieve this: the use of sound.

2.7 Enriching 3D landscape visualization: Multimodal perception

Based on the long history of visually representing existing and proposed landscapes, the rationale for favouring design investigation via visual means over other senses has been presented by Lange and Bishop (2005). However, other senses can have a significant impact on perception, wellbeing and interaction with our environment. For examples, studies have demonstrated that while walking in a wooded area can significantly raise natural killer immune cells, follow-up research indicates that the smell of a wooded environment alone can reduce amounts of stress hormones and boost immune cell activity (Li et al., 2009). In the human geography domain the argument, theoretically and conceptually, for a more experiential approach to urban experience has been proposed, calling for a *new humanism* to supersede the *anti/post-humanism* agenda (Simonsen, 2013).

2.7.1 Multimodalities and experience

The interaction of the senses and impact on behaviour and perception has received attention in numerous studies. In a recent study investigating olfactory stimuli researchers introduced the smell of orange, seawater and peppermint into a dance club. The scents were shown to enhance dancing activity (physical response) and improve the overall evaluation by participants of the evening, music and mood (perceptual response) (Schifferstein, Talke, & Oudshoorn, 2011). The ability to determine that our own body parts 'belong' to us is known to be impacted by at least the interaction of vision, touch and receptors in the muscles that signal to the brain (Walsh, Moseley, Taylor, & Gandevia, 2011). Tactile sensations generated by sensors have been developed that provide the perception of movement coined Surround Haptics (Israr & Poupyrev, 2010; Israr et al., 2011), with systems developed that combine tactile, acoustic and visual stimuli to support relaxation (Dijk & Weffers-Albu, 2010). A thorough review of the neurobiological processes underlying multimodal integration has been discussed by Calvert (2001) analysing studies that cover various modalities, techniques, paradigms, stimulus types and brain regions.

In the context of multimedia studies for learning multimodalities have proven beneficial. Having participants interacting via physical movement with visual representations of scientific data in the form of graphs has a significant effect on the ability of students to relate the graphs to movement than through visuals alone (Anastopoulou, Sharples, & Baber, 2011). If modalities are congruent and related to the task then they can support effective learning by combining e.g. sound and vision modalities (e.g. Gaver, Smith, & O'Shea, 1991). The impact of olfactory sensation on urban experience has been presented (Tan, 2013), in the context of cigarette smoking and it's effect on other people.

2.7.2 Sound and vision

Infants learn to calibrate their relationship with aural and visual stimuli in the first weeks of life, allowing them to use intersensory redundancy to hone their spatial and development skills (Bahrick & Lickliter, 2009). In a classic psychological study on the interaction of sound and vision, under experimental conditions, the McGurk effect (McGurk & Macdonald, 1976) can be observed; participants watch a face on a screen and see the lips say 'ga' while hearing 'ba', yet they report that they hear 'da'. This not only demonstrates the difficulty in isolating modalities but also the potential to change perception with multimodal information. In consumer oriented research it has been shown that a moderate level of ambient sound vs a low level increases performance on creativity tasks and likelihood of purchasing certain products (Mehta, Zhu, & Cheema, 2012). The same study demonstrated that high levels of ambient sound had a negative impact.

In their study of environmental sounds, Abe et al. (2006) demonstrated a significant difference between factor ratings for sounds listened to alone, accompanied by verbal information and sounds accompanied by visual information. In addition, contextual information, including sound and the sequence taken through a landscape, has been shown to have a significant effect on the evaluation of landscape preference when comparing real experience with photographs in a lab setting (Kroh & Gimblett, 1992). Another study investigated spatial navigation by visually impaired people in the public realm, concluding that there is a need to enhance sound and other sensory spatial cues to enable spatial navigation (Parkin & Smithies, 2012). The research presented here aims to extend prior findings by focusing on the use of sound with virtual landscapes.

2.8 Summary of landscape visualization literature review

3D landscape visualizations have shown to be effective for communicating relatively complex spatial propositions to diverse audiences, though are not currently perceived as matching the experience of the real world. Increased perception of realism would contribute to validating landscape preference ratings and other subjective judgments, and could potentially lessen the amount of visual detail required to simulate reality. The studies detailed in section 2.7 identify the most promising area for enhancing perception of 3D landscape visualizations: sound. The next section will provide an overview of soundscape concepts and their relationship to landscape and visualization.

3 LITERATURE REVIEW: SOUNDSCAPE FOR LANDSCAPE PLANNING AND DESIGN

In order to contextualize the research presented this chapter aims to review concepts, theories and research on soundscape, and the interaction of soundscape and landscape. Section 3.1 provides an introduction to soundscape and a definition, and distinguishes it from environmental noise studies. Section 3.2 characterizes soundscape, while section 3.3 discusses research on soundscape perception and preference, which leads to section 3.4 providing a brief overview of psychoacoustic concepts. Section 3.5 presents research on the interaction of soundscape and landscape in physical terms as well as their respective impact on the perception of each other. Section 3.6 provides details specifically on urban park soundscapes, the setting for current research, followed by a discussion of concepts for soundscape planning and design in Section 3.7. Section 3.8 presents sound and virtual environment research, leading to more specific details of sound and landscape visualization research in section 3.9. Section 3.10 presents a summary of chapter 3, along with concepts elaborated for including sound with landscape visualization. Finally section 3.11 presents a summary of the literature review and justification of the research.

3.1 Soundscape definition

Soundscape has emerged as a field of study that promises important and timely connections to landscape and visualization research. Soundscape was initially proposed as a concept in order to consider the total acoustic environment over time, space and across cultures (Schafer, 1977). Soundscape has been defined by various disciplines including music, architecture, and psychology. One definition from physical geography origins defines it as the “overall sonic environment of an area, ranging in size from a room to a region” (Porteous & Mastin, 1985, p. 19). This definition does not acknowledge human perception, which other disciplines are adamant the definition include. The most frequently cited definition is from the Handbook for Acoustic Ecology: “An environment of sound with emphasis on the way it is perceived and understood by the individual or by a society. It thus depends on the relationship between the individual and any such environment. The term may refer to actual environments or to abstract constructions, such as musical compositions and tape montages, particularly when considered as an artificial environment” (Truax, 1999). More recently the ISO/TC43/SC1/WG54 working group propose for their ISO standard that soundscape is "the perceived sound environment in context by an individual, a group, or a society" (Kang, 2010). The next section will use environmental noise as a point of departure for defining and characterizing soundscape research.

Interest by government and policymakers is increasing in the area of soundscape, though to date mostly in a more narrow view of the regulation and abatement of sound in the form of environmental noise from road traffic, aircraft, railway and machinery and that impact on health and safety (Directive 2002/49/EC). Sound studies in the form of noise annoyance evaluation have been the norm for research into sound quality, in both natural and urban environments. In natural areas such as National Parks there have been a variety of studies. In New Zealand 69% of users surveyed reported being annoyed by scenic flights over the park with 91% reporting noticing the noise (Cessford, 1999). In the United States similar findings were presented for three different National Parks (Miller, 1999) as well as wilderness recreation areas (Fidell et al., 1996). Other studies have focused on noise in local recreational areas (Krog & Engdahl, 2005) and glacier regions (Sutton, 1999). Soundscape research seeks a more holistic frame of reference for studying sound and its perception, and as such moves beyond noise evaluation. This is elaborated in the following sections.

3.2 Soundscape characterization

Differing from environmental noise studies, soundscape research aims to examine the 'acoustic environment primarily where the sounds present produce outcomes that enhance, enable, or facilitate, human enjoyment, health, well-being or activity.' (Brown, Kang, & Gjestland, 2011, p. 391). Soundscape is a perceptual construct and as such exists through human perception of the acoustic environment of a place, which also makes it context dependent (Brown, et al., 2011). However, relying in part on the human hearing system poses challenges for soundscape research, as some aspects of hearing are only still being understood. For example, the "cocktail party effect", or how humans can selectively hear one person within the context of many voices, has only recently been explained (Mesgarani & Chang, 2012).

From a (natural) landscape focus a unifying theory of soundscape ecology has been proposed, linking soundscape and landscape ecology concepts more closely and outlining a research agenda in the field (Pijanowski et al., 2011). More broadly defining the acoustic environment of focus, Brown et al. (2011) propose a taxonomy for soundscape studies that categorizes both indoor and outdoor soundscapes, further classified into urban, rural, wilderness and underwater acoustic environments for focus.

The cartographic representation of soundscapes has been proposed, moving beyond annoyance focused noise maps to include quantitative and qualitative features, with a case study of a rural landscape used as proof of concept (Papadimitriou, Mazaris, Kallimanis, & Pantis, 2009). In addition, distance based assessment has been developed that, while less accurate than noise level measurements, offer a rapid and cost effective method of predicting quiet areas in countryside (Votsi, Drakou, Mazaris, Kallimanis, & Pantis, 2012).

In a literature review, as part of their study to describe indicators for quiet rural soundscape, De Coensel and Botteldooren (2006) identify the main factors relating to soundscape evaluation across all environment types as: 1. Pleasantness/loudness; 2. Temporal structure; 3. Familiarity with or fit of sound; 4. Spatial characteristics of sound; and 5. Spectrum or timbre of sound. However, in their study “fit”, or meaning of the sound, was identified as being most significant in a rural context. Another study correlated with the results of De Coensel and Bottledooren, finding that human preference scores correlated not with common acoustical and psychoacoustical metrics, but with the absence or presence of wanted or unwanted sounds (Lam, Brown, Marafa, & Chau, 2010).

One empirical study correlates sound quality with the ecological quality of green space; Irvine et al. (2009) indicate that increasing the ecological quality of urban green spaces can enhance access to quiet natural places through specific design and planning. Targeted design and planning of this sort requires tools and methods that can provide evaluation and assessment beyond the visually oriented approaches more common used.

Soundscape research has typically focused on urban environments (e.g. Kang & Zhang, 2010; Yang & Kang, 2003, 2005b; Zhang & Kang, 2007) and has also focused on rural (e.g. De Coensel & Botteldooren, 2006; Matsinos et al., 2008; Papadimitriou, et al., 2009) and natural environments (e.g. Downing & Hobbs, 2005; Kull, 2006).

3.3 Soundscape perception and preference

One important variable in soundscape research is sound quality, which in the realm of product design has been defined as “the adequacy of a sound in the context of a specific technical goal and/or task” (Zhang & Kang, 2007, p. 69, citing Blauert & Jekosch, 1997). There are three main aspects of sound quality: stimulus response compatibility, pleasantness of sound, and identifiably of sounds or sound sources (Zhang & Kang, 2007, citing Guski, 1997; Zeitler & Hellbrück, 1999).

Empirical studies have demonstrated a correlation of the intensity of sound pressure level (SPL) as measured in A-weighted decibels (dB) to subjective evaluation (Yang & Kang, 2005a). However, an increase in acoustic comfort can not necessarily be achieved by simply reducing the sound level in urban spaces (Yang & Kang, 2005b). Empirical studies have also identified important soundscape preferences for natural over mechanical sounds (Porteous & Mastin, 1985). In addition, studies suggest that cultural background and long term environmental experience play important roles in people’s sound preference (Yang & Kang, 2003) as well as age based preferences of mechanical sounds by younger people (Yang & Kang, 2005b). This is in line with previous studies on noise sensitivity that show considerable individual variation and ability to adapt to noise (e.g. Weinstein, 1978).

In urban plazas there has been extensive research carried out on user experience at the University of Sheffield. Over the course of one year (i.e. four seasons) 9200 interviews were conducted in 14 urban public spaces across Europe, while simultaneously recording objective measurements of sounds in those spaces (Yang & Kang, 2005a, 2005b). The results suggest that subjective evaluations relates well with the mean Leq provided it does not go above 73 dBA. In addition, the background sound level was found to be a contextually important for evaluation of soundscape.

In an overall view of findings from a large interdisciplinary soundscape study it was shown that cognitive effects (e.g. meaning of sounds and soundscape) and how information is conveyed (e.g. behaviour of people) shapes soundscape perception (Davies et al., 2013). Further, the way that people describe soundscapes had three clusters: sound sources, sound descriptors and soundscape descriptors. Qualitative methods (soundwalks and focus groups) showed that emotional response to soundscapes had two principle dimensions, calmness and vibrancy, with vibrancy having itself two aspects, organisation of sounds and changes over time.

In addition to acoustic factors, there are also a number of non-acoustic factors that impact soundscape perception from an environmental noise viewpoint. The non-acoustical factors are numerous, including perceived predictability, personal beliefs, home ownership status and trust (Flindell & Stallen, 1999). In a study to determine water sounds that could mask road traffic noise it was shown that visual and acoustic characteristics affect perceptual responses, and that the psychoacoustic attribute of Sharpness was a dominant factor for urban soundscape perception (Jeon, Lee, You, & Kang, 2012b).

In an urban context sounds that were rated as pleasant or unpleasant engaged an additional neural circuit including the right amygdala when compared to neutral sounds as measured by fMRI and vector cardiogram (Irwin, Hall, Peters, & Plack, 2011). In a related study urban sound judgments were found to not be explained by acoustic or psychoacoustic variables, contradicting some previous studies (Hall, Irwin, Edmondson-Jones, Phillips, & Poxon, 2013).

3.4 Psychoacoustics

In an attempt to merge qualitative characteristics of sound quality with objective measures psychoacoustics was developed. Psychoacoustics allow for an objective focus on quality of soundscape beyond the measure of sound pressure level, which are important for soundscape research (Genuit & Fiebig, 2006). Psychoacoustics moves beyond the absolute measure of A-weighted SPL as measured by a sound level metre, to “differentiate sound perception due to its non-linearity and adaptivity as well as its signal processing characteristics, paying attention to further factors than only the averaged intensity of the sound event” (Genuit & Fiebig, 2006, p. 953).

Psychoacoustics have been used to categorize urban public spaces acoustically using clustering methods, which used a hybrid of SPL and psychoacoustic characteristics (Rychtáriková & Vermeir, 2009, 2011). While some researchers have indicated that the perceived quality of soundscapes is likely extremely individualized and influenced by past history, personal preference and other factors (Hall, et al., 2013), psychoacoustics give a good indication of perceptual responses beyond SPL (Rychtarikova, Vermeir, & Domecka, 2008).

3.5 Soundscape-landscape interaction

The interaction of the physical landscape and soundscape, both in qualitative and quantitative aspects, has become an area of research focus. The impact of the landscape on soundscape has been identified (Matsinos, et al., 2008), showing that temporal sound variability can be attributed to anthropogenic activities and biological processes, while spatial sound variability primarily was shaped by landscape attributes. They identified the main landscape characteristics affecting the perception of environmental sounds as: 1. Topography; 2. Vegetation; and 3. Sound proximity. In another study, foreground and background sounds were shown to have different relationships to the landscape, with spatial patterns of background sounds correlating somewhat with visually perceived landscape features, while foreground sounds did not correlate with landscape features or background sounds (Mazaris, Kallimanis, Chatzigianidis, Papadimitriou, & Pantis, 2009). Further, background or ambient sounds have shown to be more common in soundscape description than foreground or event sounds (Raimbault & Dubois, 2005). In the urban environment it has been demonstrated that the average sound level decreases with an increase in human population and building density, owing to a decrease in vehicle speed in city centres compared to motorways (Salomons & Berghauser Pont, 2012). In subsequent modelling the shape of building blocks was shown to have a large effect on sound level.

3.5.1 Impact of landscape on soundscape perception

Almost 10 years ago Mace, Bell and Loomis (2004) called for more field based psychological research for a complete understanding on the influence of visual surroundings and quietness in a National Park setting. Another study in Italy used photographs of 6 landscapes and 6 sounds recorded binaurally to elicit perceptual responses from participants, finding that LAeq alone was not adequate to base soundscape preference on (Arras, Massacci, & Pittaluga, 2003). Another study supports the complexity of aural-visual interaction on perception, demonstrating an up to 5 dB(A) perceived reduction in SPL from screening of vehicles from view, and a similar effect when shown different images (Jang, Shin, Song, & Kook, 2008).

In an urban park setting a study analysed the effects of the visual landscape on the perception of soundscape in five urban park environments, finding that the landscape had a significant effect on the experience of individual sounds rather than preference for those sounds (Liu, Kang, Luo, & Behm, 2013). Further analysis revealed that the amount of buildings, landscape and sky in panoramic photographs had a significant effect on soundscape perception (Liu, Kang, Behm, & Luo, 2014).

3.5.2 Impact of sound on landscape perception

The interaction of audio and visual stimuli in landscape perception and preference studies has received some focus over the past 30 years. Anderson, Mulligan, Goodman and Regen (1983) presented that the interaction of visual and acoustic characteristics had a significant impact on responses to a setting, both in situ and via photography and description. The significance of sound in environmental evaluation has been reported (Carles, et al., 1999; Carles, Bernáldez, & de Lucio, 1992), suggesting the importance of sound both negatively and positively in observer appreciation of a given environment evaluated via photographs. A reciprocal relationship has also been reported; Cox (2008) empirically evaluated the impact of visual stimuli on sound appreciation, finding that visuals alter the perception of the “horribleness of awful sounds”. Hetherington, Daniel and Brown (1993) describe the importance of both motion and sound for influencing judgement of dynamic landscapes. More recently it has been shown that sound alters visual perception of tranquil spaces (Pheasant, Fisher, Watts, Whitaker, & Horoshenkov, 2010), findings that are supported by physiological (fMRI) evidence (Hunter et al., 2010).

In a natural park setting aircraft noise has been shown to have a negative impact on responses to scenic beauty, preference, naturalness and solitude at both low (40dB) and high (80dB) levels (Mace, Bell, & Loomis, 1999). The study only tested for a control (no sound) vs two levels of aircraft sound, though a follow up study that included a natural sound had the same results (Mace, Bell, Loomis, & Hass, 2003). These results were further extended to indicate that the presence of any anthropogenic sound negatively impacted participants ratings, and that the inclusion of natural sounds had no impact on ratings (Benfield, Bell, Troup, & Soderstrom, 2010). However the generalizability of these findings is somewhat limited as the presence of anthropogenic sounds have been shown to be more disturbing in a setting such as a natural park (Tarrant, Haas, & Manfredo, 1995).

In landscape perception studies there has been a shift from identifying the influences of multimodal stimuli, to a call for action. The validity of computer based landscape visualizations as garnering perceptions that would be equivalent to those based on direct experience with the real world has been called into question (Daniel & Meitner, 2001). More recently Scott et al. (2009) criticised expert-led approaches to evaluating landscape perception as well as the primarily visual-based approaches used to date. This is supported by environmental psychology findings 30 years ago that the dominance of visual cues can vary widely by the individual (Gifford & Ng, 1982). Posner et al. (1976) have argued that when vision provides inadequate information the other senses increase to make up for it. Their interdisciplinary study utilized real-world walks to capture participants responses in real-time on pre-planned trips, elucidating landscape experience as a personal and complex relationship complicated by both sensory and socioeconomic issues. In another study the importance of sensory experiences in the urban realm is argued for, but caution that such experiences need to "address more fully the diversity and paradoxes produced by different forms of mobility through, and perceptual memories of, built environments" (Degen & Rose, 2012, p. 3271).

3.6 Urban park soundscape

In a 2006 study in Sweden the soundscape of both suburban and urban parks were compared to evaluate how closely they fit within proposed national guidelines that 80% of visitors perceived the sound environment as 'good' (Nilsson & Berglund, 2006). The soundscape was dominated in suburban parks by natural sounds and urban parks by vehicular traffic. The suburban green areas fell within the 80% target, while the urban parks did not. Measured equivalent sound levels were found to range from 42 to 50 dBA in the suburban green areas, and from 49 to 60 dBA in the city parks ($L_{Aeq15min}$). The authors conclude that the target can only be reached if traffic noise in both environments is below 50 dBA. In a separate study in Italy, comparing noise in urban parks and rural areas, researchers concluded that a sounds congruence with an expectation in a given place directly influenced annoyance ratings of that sound (Brambilla & Maffei, 2006).

In an urban park context a study was conducted in Hong Kong to evaluated perceptions of noise (Wong, Lam, & Hui, 2004). Sound levels ranged from 55 – 70 dBA while responses indicated that 24% of those interviewed classified the park as noisy. The authors suggest this is context dependent, and that in Hong Kong users did not expect a quiet park. In another study on urban parks two user groups were compared, active and static, with 25% of respondents indicating they were annoyed at 56.1 dBA for static users and 61.3 dBA for active users (Morinaga, Aono, & Kuwano, 2004). The findings support different annoyance levels based on activity. Soundscape analysis has also employed soundwalks, both on site and recorded for laboratory stimuli to determine subjective responses to tranquillity (Licitra, Chiari, Menichini, & Ascari, 2012).

In another study on urban parks 595 valid responses were analysed from users in four parks in Hong Kong (Tse et al., 2012). With SPL measuring 60-64 dBA (LAeq) 55% of respondents rated the acoustic environment as comfortable or very comfortable, though interestingly 81% considered the park environment on the whole acceptable or very acceptable. There has also been laboratory based studies to determine the best water sounds to mask noise (Jeon, Lee, You, & Kang, 2012a), with the results verified in situ (Axelsson, Nilsson, Hellström, & Lundén, 2014). In addition, artificial neural network models are being used to predict subjective comfort evaluations for visual and aural responses in urban open spaces (Yu, Kang, & Liu, 2012).

3.7 Soundscape planning and design

Landscape architects and planners have, in recent years, turned their attention to design and planning incorporating audio. In the garden context natural sound has been identified as important from aesthetic, pragmatic, and environmental perspectives (Dawson, 1988). Auditory concepts for design and planning have been outlined, with the importance for those that engage with landscape to consider the soundscape argued from a sustainability standpoint (Hedfors & Berg, 2003). In their 2003 study Hedfors and Berg identify concepts of intensity and clarity as important aspects of the soundscape, defining intensity as a measureable quantity (i.e. dB) while clarity (i.e. on a clear-crowded scale) requires subjective evaluation to identify any prominent sounds impacting evaluation (Hedfors & Berg, 2003). These concepts have been expanded to a toolkit for professionals to use (Hedfors, 2003b) and an entire methodology (Hedfors, 2003a). More recently there has been a renewed focus on soundscape design for landscape architecture practice, with results from the studio offered as proof of concept (Fowler, 2013).

In the area of landscape planning and management there have been advocates for audio design (Brown & Muhar, 2004) as well as auditory planning (Brown, 2004). More recently, the soundscape approach has been applied to early stage urban planning (De Coensel, et al., 2010) as well as frameworks for future research and practical needs outlined (Kang, 2010). The importance of silence in the planning process, both literally (e.g. in terms of space), and conceptually (e.g. providing a mental space for many voices to be heard), has been presented (Van Assche & Costaglioli, 2012). Exploratory design studios have also been conducted using students to analyse and generate ideas around this concept (Fowler, 2013). With proposals for incorporating sound into the design and planning process, and tested methods of visualization in this process, there is a lack of research on how visualization and auralization interact that this thesis seeks to contribute to.

3.8 Sound and virtual environments

Soundscape research has engaged with virtual environment research, with perceptually based audio rendering available (e.g. Tsingos, et al., 2004) as well as more physically accurate techniques emerging (e.g. Richmond, et al., 2010). The importance of the interaction of sound, vision, and other modalities to increase sense of immersion in virtual environments has been discussed (Laurel, 1991). Sound has been shown to enhance navigation in virtual maze environments, and even without visual stimuli provided important immersive qualities and navigational aids (Chandrasekera, Yoon, & D'Souza, 2011). It has been reported that spatialized sound provides an important cue within virtual environments which greatly increases the sense of presence (Blauert, 1997). The sense of presence in a virtual environment has been shown to be enhanced by the incorporation of spatialized audio (Hendrix & Barfield, 1996), while the sense of realism of the virtual environment did not increase. The reason was theorized as a problem with participants understanding the definition of ‘realistic’, focusing solely on the visual aspects.

Dinh et al. (1999) report that non-spatialized audio, and other sensory inputs, increase the perceived level of presence and reality, as well as memory, in a virtual office environment. Interestingly the level of visual fidelity had little impact on participant’s ratings. Davis et al. (1999) report that the use of ambient sound not only increases a sense of presence but enhances the subjective 3D quality of the visual display. In addition they report that recall and recognition of visual objects and the objects location within a virtual environment is improved with audio, especially if that audio is high fidelity. The impact on subjective quality has been verified by further empirical research by Storms and Zyda (2000) who also suggest that realism in a virtual environment is a function of audio and visual fidelity in relation to each other. Another experiment indicated that non-attenuated audio was detrimental when subjects were involved in a task trying to locate the sound source within a 3D virtual environment (Bormann, 2005). In addition, there is evidence that the perception of reality in a virtual environment is not only multimodal, but ‘cross-sensory’, that is, the audio and visual signals interact and have a significant effect on each other and participant perception (Bormann, 2008).

Within the context of creating photorealistic virtual environments sound has been identified as a significant addition in increasing presence when compared to unimodal visual information (Serafin, 2004). In a related project it was reported that sound alone could create a sense of place in a virtually recreated environment (Turner, McGregor, Turner, & Carroll, 2003). Both projects had the goal of recreating a sense of place via photorealistic environments, while acknowledging that realistic soundscape may not necessarily be required to contribute to realism. Along with haptic and graphic sensory inputs, sound has also shown to be critical to the perception of realism when walking in a virtual environment (Marchal et al., 2013). Sound has also been used in the creation of 3D virtual environments for children with visual disabilities, where 3D sound provided immersion and spatial indications, and was found through usability testing to be fundamental to interaction with the virtual space (Sanchez & Saenz, 2006).

3.8.1 Sound and serious gaming

Audio augmentation of visualizations for landscape planning and design could draw parallels to sound in video games, where some functional aspects are similar and some differing. In video games sound has been identified to have five functions: Action-oriented; atmospheric; orienting; control-related; and identifying (Jørgensen, 2006). Sound has been included in serious games for crisis management training to create a more realistic training environment with a focus on voice communication (Rudinsky, Hvannberg, Helgason, & Petursson, 2012). Psychophysiological studies have been carried out to evaluate the impact of sound on immersion in first person shooter games (Grimshaw, Lindley, & Nacke, 2008). In their study 4 different sound conditions were investigated, with subjective survey responses analyzed alongside EEG, EMG and eye tracing results. Their findings indicated a statistically significant affect of sound on immersion when compared to no sound. Interestingly, though inconclusive and not statistically significant, their objective measures contradicted the subjective responses.

One main difference between definitions of, and factors contributing to, immersion in video games vs landscape planning and design is that of narrative. In video games a player is engaged with a goal within the game and de facto interaction with the virtual environment and agents. The level of both social realism and perceptual realism have been identified in games to be factors that influence the sense of immersion

(McMahan, 2003). Similarly Carr (2006) has identified a distinction between psychological and perceptual definitions of immersion. In landscape planning and design there is rarely a social or gameplay component to a visualization, thus realism or immersion rely primarily on perceptual factors of level of detail and photorealism.

3.9 Sound and landscape visualization

3.9.1 Sound and GIS

The potential for the use of sound with Geographic Information Systems (GIS) has been presented, with important contributions identified as “sound as vocal narration, a mimetic symbol, a redundant variable, a means of detecting anomalies, a means of reducing visual distraction, a cue to reordered data, an alternative to visual patterns, an alarm or monitor, a means of adding non-visual data dimensions to interactive visual displays and for representing locations in a sound space.” (Krygier, 1994, pp. 149-150). One of the first uses of sound with geographic information was done by Fisher (1994), where sound was used to represent uncertainty in satellite imagery, a concept referred to as sonification. In addition, GIS tools have been developed to compute estimates of accurate sound levels in the landscape (Kampanis & Flouri, 2003). More recently a sonification tool has been developed for commercial GIS software allowing sound to represent uncertainty in data visualization (Bearman & Fisher, 2011). Early studies of the tool indicate that sonification provides greater understanding of the data for the user when compared to visually representing data alone (Bearman & Lovett, 2010).

3.9.2 Sound and virtual globes

Using the Google Maps API developers have created “mashup” websites that overlay Google Map imagery with sound recordings of places and events (e.g. http://aporee.org/maps/). Sound can already be incorporated into Google Earth, in the form of a pre-recorded narrated tour through 3D space (e.g. http://earth.google.com/outreach/tutorial_kmltours.html). A 3D sound plugin has also been developed, allowing geolocated sound in Google Earth (http://www.planetinaction.com/sound/), though it has been discontinued as a standalone spatial sound plugin and is now integrated within the Google Earth Diorama project (http://www.planetinaction.com/diorama/).

3.9.3 Multimodal environmental simulation

Combining sound with landscape visualization has been proposed (e.g. Appleton, et al., 2004; Loiterton & Bishop, 2005), though relatively few realized projects have been reported, and empirical research on perceptual dimensions lacking. In one of the few studies that investigated perceptual aspects of combing sound and visualization the interaction was shown to enhance perceived visualization realism, and promote attention and recognition, with the authors concluding that the correct sound could be more important than getting visual elements totally realistic (Rohrmann & Bishop, 2002). More recently methods have been proposed to integrate bird survey data, including bird song, into a real-time 3D simulation (Morgan, Gill, Lange, & Dallimer, 2012), allowing a user to walk around in a 3D landscape model and hear bird song based on actual survey data collected for the site.

Wind farm evaluation has been the focus of other research into the sensory effect of combing aural and visual stimuli, and use bespoke software (Bishop & Stock, 2010) or game engines (Manyoky et al., 2012) to add audio to 3D visualizations. In addition, a concept has been presented for a visual-acoustic simulation system that uses realistic soundscape modelling with GIS-based 3D landscape visualization models (Marchal, et al., 2013). The project incorporates sophisticated auralization tools for emission synthesis (Pieren, Heutschi, Müller, Manyoky, & Eggenschwiler, 2014) as well as propagation filtering and vegetation noise synthesis (Heutschi et al., 2014). While the visualization capabilities of the tool were adequate, the authors concluded that their chosen simulation environment, CryENGINE (Crytek, 2013) was at the time lacking functionality for sufficient auralization.

3.9.4 Future soundscape scenarios

For soundscape analysis of the physical environment accurate computer based models can be used to calculate sound distribution, and can be divided into two categories: microscale and macroscale (Kang, 2006). Microscale models usually rely on simulation techniques to accurately calculate sound fields for smaller urban areas, while macroscale models use statistical methods and algorithms to map sound impacts, usually based on SPL (Kang, 2006). Such techniques are very accurate, and have been combined with artificial neural network modelling in an attempt to predict soundscape quality evaluations of potential users of urban open spaces (Yu & Kang, 2009). Due to the complexity of urban environments a general model was not feasible, but the authors report for individual sites the modelling was quite accurate.

For perceptual studies of audio-visual interaction the generation of sounds, rather than statistical outputs or maps, is necessary. The generation of an unrealized future soundscape with the intent of playback for evaluation poses interesting research and methodological questions, whether to be analysed on its own, or to augment abstract or realistic visualizations of an equally unrealized future scenario. Visualizations make visible future scenarios, focusing primarily on the perceptual visual impact of alternatives. For the acoustic equivalent there are a number of methods that can be used, ranging from relying on pre-recorded sounds, and the editing of them, to automatic generation of sounds, each of which can be viewed as varying the abstraction of the sound.

3.9.5 Soundscape abstraction

Relying on recorded sounds to create a future soundscape scenario can be viewed as analogous to visual scenario design techniques, and while different, pose similar research questions in relation to the level of reality required or desired when representing uncertainty. At the most realistic level a recording of another place, unmodified, could be played back to portray a comparable soundscape. This technique has been used in the majority of laboratory-based studies investigating perceptual responses to landscape and sound, as well as the impact of sound on landscape preference (e.g. Anderson, et al., 1983; Carles, et al., 1999).

Recorded sounds can be edited to remove or enhance sonic aspects. Recorded sounds can also be mixed together to create a new sound. Studies using this method have investigated responses to noise in parks and rural areas (e.g. Brambilla & Maffei, 2006). However, relying on recorded sounds has been criticized as not offering enough diversity for specific applications (e.g. ambient sounds in movies), and as a result audio synthesis methods based on analogue and more currently digital oscillators have been developed. These methods synthesize sound based on algorithms that can produce sounds using abstract synthesis algorithms, synthesis from scratch, or synthesis from existing sounds (Misra & Cook, 2009). It is the later (synthesis from existing sounds) that the authors propose work well for sound textures and soundscapes.

Recent methods for synthesizing sound have used methods that semi-automatically retrieve sounds from a database and mix those sounds into ambient background sound (Cano et al., 2004). This method has been advanced by providing dynamic rather than static sound files (Birchfield, Mattar, & Sundaram, 2005), and extended to use community-provided, unstructured sound databases (Finney & Janer, 2010). Using crowdsourced sounds via online databases there is the potential to automatically generate an acoustic environment using various algorithms. This has been done with the Freesound.org database, with automatically generated soundscapes used to augment Google Streetview imagery (Finney & Janer, 2010). Methods for identifying, cataloguing and the subsequent retrieval of environmental sounds from databases are being developed (e.g. Wichern, Jiachen, Thornburg, Mechtley, & Spanias, 2010), which would aid researchers relying such databases for their research.

Another option is to focus not on the entire soundscape, but one element (e.g. foreground or background). In this vein, a method has been outlined by Schwarz (2011) for the automatic generation, and use, of sound textures. Sound texture is differentiated from the overall soundscape as it is comprised of "many micro-events, but whose features are stable on a larger time-scale, such as rain, fire, wind, water, traffic noise or crowd sounds (Schwarz, 2011, p. 221). Sound textures are important part of in the cinema, multimedia, games and installations, and offer a promising technique for inclusion in audio-visual interaction studies as they provide a more neutral ambient or background sound than environmental recordings. The various approaches to auralizing sound for visualizations are presented in Table 6.

Table 6: Approaches to auralizing sound for visualization

Method	Description/Source
Reality	Recording of real environment (e.g. Anderson, et al., 1983; Carles, et al., 1999)
Remixing	Concatenative: editing a sound to create a new sound based only on aspects of the original sound varied in time (Misra et al., 2009) Subtractive: editing and/or remixing a recording of a real environment to remove or enhance sonic aspects (e.g. Serafin, 2004) Additive: combining recordings of real environments to create a new sound (e.g. Brambilla & Maffei, 2006)
Synthesizing	Semi-automatic generation of ambient sounds (e.g. Cano et al., 2004) Using probabilistic models to create soundscapes that are responsive and diverse (Birchfield et al.,2005) Using algorithms to automatically generate an acoustic environment (e.g. Finney & Janer, 2010)

3.10 Summary of soundscape literature review

As presented in this chapter there has been much interaction between landscape and soundscape research. Soundscape preference has been shown to be dependent upon both the pleasantness/loudness of the sound, and the congruency of the sound to environment. In addition, it has been shown that the physical landscape impacts soundscape perception, and vice versa, as well as the perceptual aspects of these interactions. Sound has been used in VE research to increase the sense of presence in a VE, and has been integrated with GIS and virtual globes to provide indications of non-visual data and to highlight issues of locational accuracy. Despite the promising technological advances there is little known about the perceptual impact of combining sound and 3D visualizations for landscape evaluation.

3.11 Literature review summary

As presented in Chapters 2 and 3, the literature review indicates a complicated and not fully understood relationship between sound, vision and landscape perception (both in reality and simulated via 3D virtual environments). A gap in the literature has been identified concerning the interaction of aural and visual stimuli for 3D landscape visualization and the impact on perception of this interaction. The combination of aural and visual methods can potentially engage a wider variety of users, both expert and layperson, than one sensory stimuli on its own. In addition, visualizations can still be considered to lag behind the experience of reality for visual simulations, and the effort required to model highly realistic landscapes is still a very time consuming and challenging task. In order to confront this challenge there is an interesting possibility of not focusing on visual detail and instead perceptually *filling in* detail with other sense modalities such as sound by focusing on experiential approaches to perception. This project explores multimodality for landscape design and planning using psychology-based measures of user experience in an audio augmented virtual environment. The research reported here investigates experiential aspects of landscape, soundscape, visualizations and auralizations.

3.12 Multisensory environmental simulation framework

Informed by the literature review in the previous two chapters is the proposal of a preliminary multisensory environmental simulation framework. This framework integrates visual abstraction techniques for specific design phases (Table 5, section 2.6) and auralization techniques for 3D landscape visualizations (Table 6, section 3.9). Sound is hypothesized to have a significant effect on the perception of 3D landscape visualizations, which will vary by sound type and visualization element. The congruency of aural-visual combinations has been shown in previous aural-visual studies to have a large effect on realism and preference ratings. As a result, the framework proposed here recommends using congruent and realistic sounds for early stages of design in order to increase perceived realism, transitioning to more abstract sounds as designs develop, become more concrete and visualizations more realistic. This would facilitate maintaining relative realism ratings without negatively effecting preference ratings. The framework is illustrated in Figure 11.

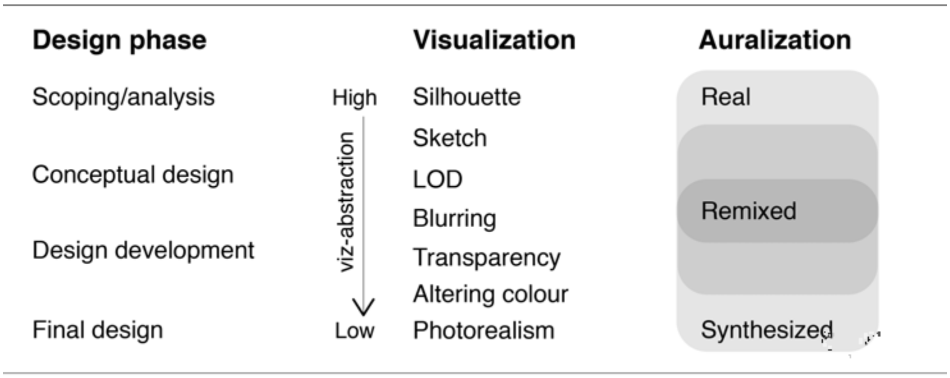


Figure 11: Multisensory environmental simulation framework

The framework is developed to be flexible and can be informed by, and adapted for, particular multisensory contexts. For example, specific project requirements (e.g. wind farm siting and evaluation) have resulted in research being carried out on auralization techniques for particular sounds, e.g. wind turbine noise (Heutschi, et al., 2014; Pieren, et al., 2014). As other techniques for auralization are identified and developed they can be applied within the proposed framework for other simulation needs, and different project contexts. In order to inform and support this framework the exploratory research presented here aims to provide evidence of the interaction of fundamental visualization elements (i.e. terrain, vegetation and built form) with fundamental sound types (i.e. anthropogenic, mechanical and natural). The next chapter outlines the research hypotheses in detail for the experiment conducted.

4 RESEARCH HYPOTHESES

The literature review indicates that there is no empirical evidence on the effect of the interaction of combining 3D visualization landscape elements and sound on the perception of virtual landscapes. The interdisciplinary research reported here connects the fields of landscape visualization, soundscape, environmental psychology and psychoacoustics to contribute to the body of knowledge on multimodal environmental simulation. The research questions and related hypotheses are described below.

4.1 Research question 1: How do different landscape elements in visualizations (i.e. terrain, vegetation and built form) interact with different sounds to alter perceived realism of, and preference for, 3D landscape visualizations?

Sound characteristic hypotheses

- **Sound preference**: Natural sounds will be rated highest for preference, followed by anthropogenic then mechanical sounds (e.g. Porteous & Mastin, 1985; Yang & Kang, 2003)
- **Sound loudness**: Mechanical sounds will be rated highest for loudness, followed by anthropogenic then natural sounds

Realism and preference hypotheses

- **Visualization realism**: Visualizations with geometric features are perceived as more *realistic* than those without (e.g. Appleton & Lovett 2003; Lange, 2001)
- **Visualization preference**: Visualizations with vegetation will be more preferred than those with built form (e.g. Kaplan, Kaplan, & Wendt, 1972)
- **Sound-congruency**: Congruent aural-visual combinations will increase perceived realism and preference more than incongruent combinations (e.g. Carles et al., 1999; Zhang & Kang, 2007)

4.2 Research question 2: Do different user characteristics interact with combined aural-visual stimuli to alter perception of realism and preference for 3D landscape visualizations?

Hypotheses

- **Gender**: Realism and preference ratings will not vary according to participant gender
- **Age**: Realism and preference ratings for non-natural aural/visual combinations will be ranked more favourably by younger people (e.g. Yang & Kang, 2005b; Balling & Falk, 1982)
- **First language**: Realism and preference ratings will not vary by participant first language (i.e. English or not)
- **Cultural background**: Realism and preference ratings will vary by cultural background (e.g. Yang & Kang, 2003)
- **Expert**: Realism and preference ratings will vary by layperson/expert distinction (e.g. Lange, 2001)
- **Familiarity with 3D computer graphics**: Realism and preference ratings will vary based on participants familiarity with computer graphics
- **Experience with 3D computer graphics in design and planning**: Realism and preference ratings will vary based on participants experience with computer graphics in design and planning context
- **Site familiarity**: Ratings will vary for local vs. non-local participants for realism (e.g. Appleton & Lovett, 2005; Karjalainen & Tyrvainen, 2002; Lange, 2001; Messager Belveze & Miller, 2005) and preference (e.g. Kaplan & Kaplan, 1989)
- **Noise sensitivity**: Realism and preference ratings will vary based on noise sensitivity

4.3 Research question 3: How effective is the Internet for aural-visual data collection compared to a laboratory setting?

Hypotheses

- **Audio hardware**: Audio hardware quality will not significantly impact realism or preference ratings for aural-visual combinations
- **Video hardware**: Monitor size will not significantly impact realism or preference ratings for aural-visual combinations
- **Experiment condition**: Results for the dependent variables will not significantly differ between the lab and online experimental condition

5 STUDY SITE: ST. JAMES'S PARK, LONDON, UK

A physical site was needed in order to satisfy specific variables arising out of the literature review that would be investigated in the experiment (e.g. effect of site familiarity on realism and preference responses). Section 5.1 of this chapter describes the process of identification and selection of the study site used in the main experiment and the criteria for selection, both in terms of physical characteristics and the technological influences on this selection. Section 5.2 describes the study site by its location, history, climate, vegetation, management, user demographics and physical character. Section 5.3 of this chapter describes the processes of identifying, sourcing and selecting the sounds used for the experiment from the study site.

5.1 Study site: Selection

Previous research projects have investigated bespoke 3D visualizations that were custom made for a specific study (e.g. Lange, 2001). The research project reported here aimed to assess the perception of more widespread tools used by a variety of spatial and scientific researchers and practitioners. Google Earth was identified in previous research as being relatively ubiquitous (section 2.4) and was the focus of the study presented here. As a result, the study area selection was informed by physical aspects (e.g. accessibility, suitability of the environment) as well as technological aspects (e.g. landscape elements available in Google Earth). These are elaborated in the next sections.

5.1.1 Physical considerations

The investigation of the impact of the interaction of various visual landscape elements (built form, vegetation and terrain) necessitated a focus on a site that contained a variety of those elements, which focused site selection on open space in general, and parks in particular. In addition, the sound element of the study aimed to evaluate the contribution to perceived visualization realism and landscape preference of real sounds, and as such an accessible site (e.g. located within the United Kingdom) was deemed necessary to allow for visiting the physical location to enable measuring and recording the soundscape of that environment.

The site chosen aims to contribute to understanding of perceptions of an important landscape typology of public space, the Public/Central Park (Carr, Francis, Rivlin, &

Stone, 1995; Garvin, Berens, & Leinberger, 1998). While there have been calls for looser definitions of open space (Thompson, 2002), these existing categories are useful to compare the current research to previously undertaken research. Further, it was determined that a site that had other data available (e.g. visitor numbers, user satisfaction surveys) would be beneficial in order to contribute to analysis and further inform the project. Finally, the site had to have a sufficiently high level of detail in both vegetative and built form in Google Earth, which is elaborated in section 5.1.2.1.

5.1.2 Technological considerations

As discussed in section 2.2, the development of landscape visualization hardware, software and data sources has evolved dramatically over the past 25 years. Early mainframe-based wireframe rendering of static forests scenes has given way to photorealistic cities available, for free, on desktops, laptops, and mobile devices via Google Earth. The proliferation of Google Earth and its widespread accessibility require further research, especially as it begins to be used by planners, designers, scientists and the public for critical evaluation.

The risks of using virtual globes such as Goole Earth for landscape visualization have been identified, with uncertainty, credibility and bias in interpreting imagery being raised as some of the main challenges (Sheppard & Cizek, 2009). The current study situates itself within this context, providing exploratory results on both perceived realism and landscape preference using imagery from Google Earth, as well as results on multimodal interactions of sound and visualizations that impact virtual globe responses specifically. In addition there is the opportunity to extrapolate results for other visualization mediums and technology.

5.1.2.1 Level of Detail of Landscape Elements in Google Earth

The level of detail available in Google Earth varies greatly depending upon geographic location. Google Earth has relatively high detail imagery available with photorealistic buildings and trees, though this is dependent upon location, with the majority of detailed sites located in the USA. Many large US cities have photorealistic buildings and trees modelled and textured to a high level of detail (e.g. Chicago, Figure 12).

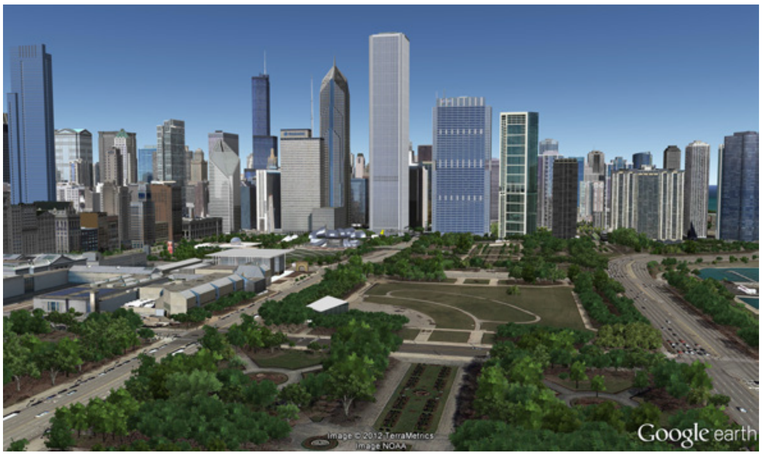


Figure 12: Google Earth view of Chicago, IL, USA; July 2 2012
(© Google Earth)

5.1.2.2 The United Kingdom in Google Earth

The United Kingdom is represented in Google Earth with much less high quality 3D coverage than in the USA, with only central London and some larger cities having relatively consistent photorealistic buildings (e.g. Birmingham, UK, Figure 13). For example, Manchester, the 3rd largest metropolitan area in the UK, has inconsistent built form and very little vegetation (e.g. Figure 14). For both photorealistic built form and vegetation there are some cities that have a varied amount (e.g. Glasgow, Figure 15). At the time of planning the experiment (Summer 2012) only Hyde Park and St. James's Park, located in London, were found to have photorealistic trees consistently, with only St. James's Park having both consistent buildings and vegetation, as illustrated in Figure 16.

Figure 13: Google Earth view of Birmingham, UK; July 2, 2012
(© Google Earth)

Figure 14: Google Earth view of Manchester, UK; 2 July 2012 (© Google Earth)

Figure 15: Google Earth view of Glasgow; 2 July 2012 (© Google Earth)

Figure 16: Google Earth view of Hyde Park with St. James's Park in background; 2 July 2012 (© Google Earth)

Using Google Earth sites were narrowed down to those located in the UK and with a relatively high level of detail of textured buildings and vegetation available. The study site was selected based on availability of varying textured objects in Google Earth (i.e. terrain, vegetation, trees). In addition, the site was required to have sufficient built context around it to be able to provide views without large gaps between built form that do not actually exist. Applying all the selection criteria the only site that met needs of the study within the UK was St. James's Park, located in London as it had: (a) photorealistic vegetation within the park; (b) photorealistic built form surrounding the park for context; (c) relatively high detail in the terrain image mapping; and (d) rigorous surveys and counts on visitor numbers and user satisfaction.

5.2 Study site: Description

5.2.1 Location

St. James's Park is one of the eight Royal Parks of London – St. James's, The Green, Hyde, The Regent's and Primrose Hill, Greenwich, Richmond, Bushy and Hampton Court Parks and Kensington Gardens - and is located in the City of Westminster (Figure 17). The park covers 23 hectares (57 acres). It is bounded by Buckingham palace, The Mall and St. James's Palace, Horse Guards and Birdcage Walk. It includes a small lake with meandering paths and a bridge (Figure 18)

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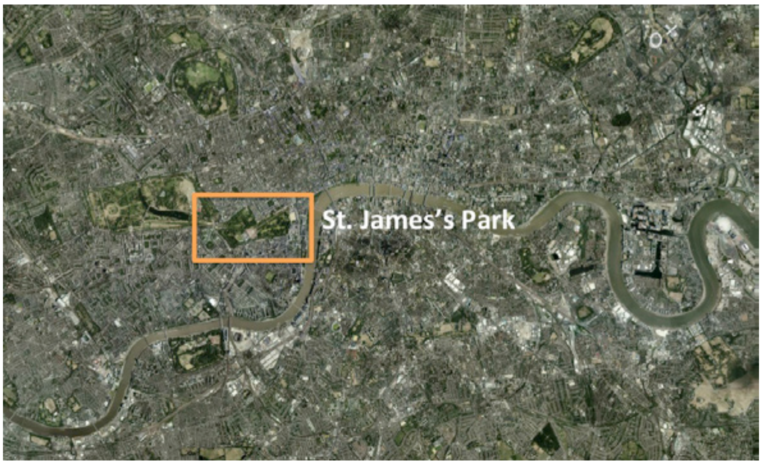

Figure 17: St. James's Park location, London, UK (© Google Earth)

Figure 18: St. James's Park aerial view with context (© Google Earth)

5.2.2 History

Originally a swampy area with the River Tyburn running through it, King Henry VIII acquired the land in 1536 for deer hunting and built a hunting lodge that eventually became St. James's Palace. Later King James I drained and landscaped the area to keep animals. The parks first design in 1660 under the orders of Charles II is believed to be by French garden designer André Mollet and was inspired by the gardens of France (). The park at this time was depicted in 18th century art (). In the 1820's John Nash redesigned the park in a more natural style that was completed n 1827. The park as it is today is very much unchanged from the Nash plan.

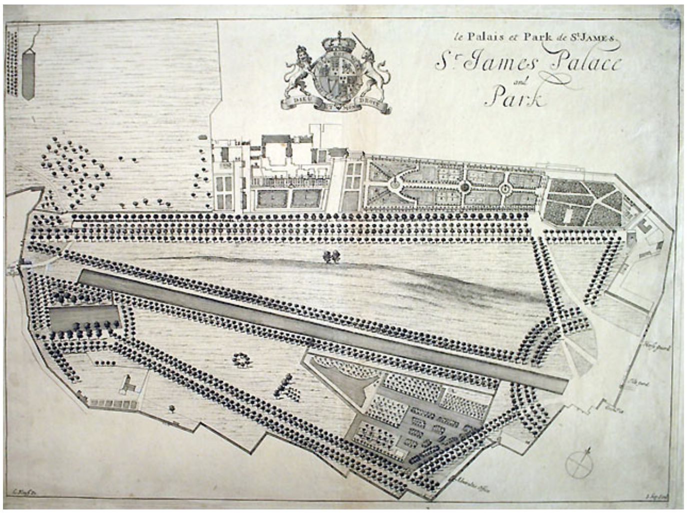

Figure 19: André Mollet's design for St. James's Park, 1660 (pd)

Figure 20: *St. James's Park and The Mall, after 1745*
by Joseph Nickolls, 1771-72 (pd)

5.2.3 Climate

Located in the south of England London is affected by continental weather influences that can produce cold winters and relatively hot, humid summers. According to the UK Met Office (The Met Office, 2012) the average temperature in central London is 9 °C, with January being the coldest month (minimum temperature averages 3°C) and July the warmest month (22.5°C average maximum temperature, while December has the least sunshine hours and June the most. Rainfall for London averages less than 650 mm per year, which is close to the driest parts of the UK (400 mm per year in eastern England) and far less than the rainiest (4000 mm per year in the western Scottish Highlands). There is very little snow on average with less than 3 days per year having snow lying on the ground. Wind is not as much of a factor for central London as it is for more westerly lying areas, however, January is the windiest month on average while June is the least.

5.2.4 Flora and fauna

St. James's Park provides important habitat within central London for a variety of animals. While it is impacted by the presence of humans all year round, the large trees in general, and water feature in particular, provide habitat for a variety of birds and mammals. The park is home to pelicans, 15 different species of waterfowl, foxes Wood Mice and Brown Rats, as well as Grey Squirrels (The Royal Parks, 2012). Plane trees (*Platanus* × *acerifolia*) make up the majority of trees in the park along with Scarlet Oak (*Quercus coccinea*) and the Black Mulberry Tree (*Morus nigra*). Figure 21 illustrates typical vegetation within the park.

Figure 21: Vegetation within St. James's Park

5.2.5 Management

The parks are managed by the Secretary of State for Culture, Olympics, Media and Sport on behalf of the Queen and by virtue of the 1851 Crown Lands Act the Crown transferred the duties and the parks to the Commission of Works and Buildings, now DCMS (The Royal Parks Agency, 2012).

5.2.6 User demographics

The park is a highly active place that is activated by people through all seasons. Being in a popular tourist location the user attracted to the park is primarily from outside of the UK, stay in the park for a relatively short average duration of 1 hour and can be expected during peak hours (i.e. 1100-0700) (Gabrieli & Wilson, 2010). Given the daily fluctuations in numbers of people and activities, the visual qualities and soundscape fluctuate a great deal over the duration of a day.

St. James's Park was the most frequently visited of the Royal Parks in a study conducted in 1995 with 5.5 million visitors. By 2007 Hyde Park had overtaken St. James's Park as the most frequented Royal Park with 7.1 million visitors in 2006-07 compared to 4.7 million in 1995, St. James's Park was visited by 6.4 million visitors coming in second, with Green Park a close third at 6.3 million visitors (Hitchcock, Curson, & Parravicini, 2007). This puts the top three most visited Royal Parks ahead of other top tourism attractions in the UK, Blackpool Pleasure Beach being the top with 5 730 000 visitors in 2006. The report indicates that approximately 15% of the parks use occurs in off-peak times (e.g. early morning and evening). The most frequented season is summer with visitor numbers of 1 124 818 recorded in June 2007 and 657 805 in July 2007. Recorded numbers via a Steady State Count between January and July 2007 are listed in Table 7.

Table 7: Visitor Figures for St. James's Park, Steady State Count January-July 2007, from Hitchcock, Curson, & Parravicini, 2007

Date	Visitor Numbers
January 2007	263,019
February 2007	153,078
March 2007	452,210
April 2007	604,086
May 2007	374,076
June 2007	1,124,818
July 2007	657,805

According to on-site surveys carried out for The Royal Parks, visitors to St. James's Park have an average age of 40 years, slightly below the average of 43 years for visitors to all nine[1] Royal Parks interviewed in 2009, with gender almost evenly split, though slightly more females (Gabrieli & Wilson, 2010). St. James's Park, along with the other more centrally located Royal Parks (i.e. Green, Hyde, Kensington) had a significantly higher number of visitors from outside the UK than the non-central parks, and a significantly lower percentage from London than Regent's, Primrose or Richmond Park. St. James's Park had a significant number of first time visitors, a high journey length to get there, and relatively low average length of visit. As rated by users the best performing aspects of the park were: 1. Ease of getting around, 2. Ease of access, 3. Upkeep and quality of the natural environment and 4. General tidiness and cleanliness. By far the lowest rated aspects were the toilet facilities. Key action areas that came out of the study for St. James's Park were to improve facilities for children.

5.2.7 Physical character

St. James's Park is characterized by formal paths and walkways that meander through mature trees. In summer with full leaves on trees there are very few viewpoints that include any of the surrounding buildings. Located adjacent to Buckingham Palace the park is very popular with tourists and tour groups. In the early morning (e.g. 07:00) human activity is low, with joggers and people feeding birds the sole occupiers. At these times wildlife is very active, particularly geese. During the day much of the activity within the park owes itself to tourism, with visitors mostly receding by 19:00. The park is shown at 07:00, 12:00 and 17:00 in Figure 22. The park was observed to

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[1] In the 2006-07 Steady State Count visitor number survey Primrose Hill and Regent's Park were treated as one entity. In the 2009 In-Park questionnaires Regent's Park and Primrose Hill have been separated into two entities.

be virtually empty after dark, though still technically open. The site has five primary visual conditions: (a) Spaces enclosed with vegetation; (b) Open spaces; (c) Spaces enclosed by a combination of vegetation and built form; (d) Meandering pathways and (e) Expansive views around the periphery of St. James's Park Lake.

Figure 22: Views along paths in St. James's Park at 7:00, 12:00 and 17:00

5.3 Study site: Acoustic environment

5.3.1 Analysis methodology

Landscape representations in general, both digital and analogue, tend to depict summer scenes (Lange & Bishop, 2005). While the practice is open to criticism in a wider context, the summer soundscape was focused on for the study to be congruous with the landscape visualization in Google Earth. In addition, when compared to other seasons, the study site is visited far more in the summer than in the other seasons (Gabrieli & Wilson, 2010). Sounds were recorded digitally in hi-fidelity (48 kHz sampling rate, 24-bit resolution) with an Edirol R-44 4-channel portable recorder using 1 channel (mono) and a mono microphone while simultaneously measuring LAeq with a 01dB Solo Sound Level Meter (SLM). The recorder had both the "Low cut" setting and the limiter switched on to compensate for potential wind noise on site. The apparatus is shown in Figure 23.

Figure 23: Field recording and sound level measuring apparatus

The SLM was calibrated using a 01dB Cal 01 SL calibrator that played a 94 dB 1000 hz tone. The same calibrator was used to record a 10 s segment at the beginning of each recording to enable calibration in the lab with psychoacoustic analysis software. Recordings were 2-minutes in duration, with the addition of 10 s of calibration sound and another 5-10 s to remove the calibrator in order to fit the microphone wind guard, resulting in recordings that were between 140 s and 150 s. 6 sites were recorded within the park, with a seventh site on the periphery of the park added for a comparison of sound level (Figure 24), each recorded and measured at 4 times (0700, 1200, 1700 and 2200) over two days, 17-18 July 2012. The sites were chosen after an initial walk-through of the entire park and were evenly distributed along a common route through the park. Any prominent sound sources differentiated from ambient sound during recordings were noted.

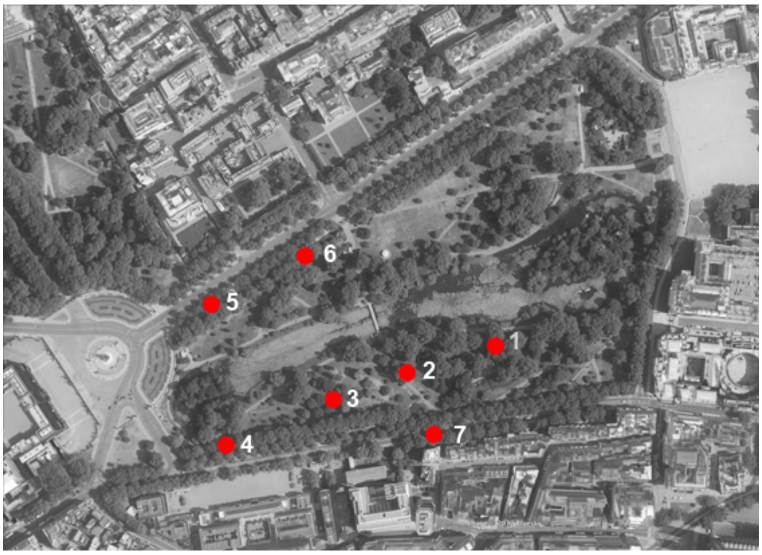

Figure 24: Recording and measurement locations in St. James's Park, 17-18 July 2012 (base image © Google Earth)

5.3.2 Results

5.3.2.1 Sound pressure level

The ambient sound within the park measured at Leq ranged from 50.9 dB(A) to 61.4 dB(A), with Lmin 48 dB(A) and Lmax 70 dB(A). The site on the periphery of the park was located along Birdcage Walk adjacent to a frequently used road, and ranged from 68.8 dB(A) to 70.7 dB(A) for Leq, with Lmin measured 51.7 dB(A) and Lmax 78.3 dB(A). The mean and standard deviation for the measured locations are presented in Table 8; the mean and standard by time of day are presented in Table 9. The SPL by location and time is illustrated in Figure 25.

Table 8: mean Leq (dBA) and standard deviation (SD) by location in St. James's Park

Location	Mean Leq	SD
1	56.5	2.18
2	55.9	0.49
3	55.9	1.38
4	59.9	1.99
5	55.2	1.84
6	54.5	2.64
7	69.8	0.78

Table 9: mean Leq (dBA) and standard deviation (SD) by time

	Location 1-6		Location 7	
Time	**Mean Leq**	**SD**	**Leq**	**SD**
7:00	56.7	2.15	70.7	4.3
12:00	57.5	2.29	69.9	4.3
17:00	57.15	1.86	69.9	4.8
22:00	54.05	2.24	68.8	5.8

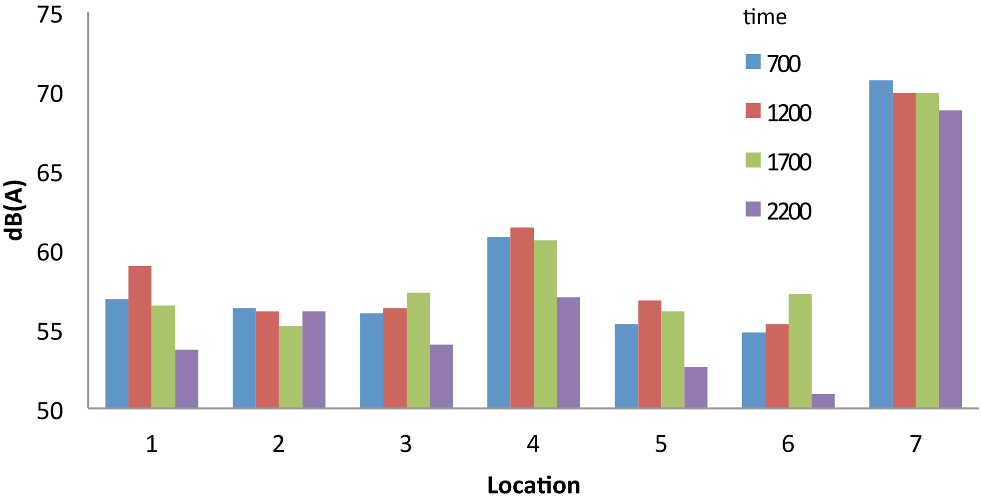

Figure 25: St. James's Park SPL by location and time

5.3.2.2 Psychoacoustic metrics

In addition to measured sound pressure level, psychoacoustic metrics were analysed (see section 3.3 for an overview of psychoacoustics). Psychoacoustic analysis was conducted using HEAD Analyzer ArtemiS 11.0.200 software (Head Acoustics, 2012). Sounds recorded on site were manually calibrated individually within the software using a recorded reference tone (94 dB at 1000 Hz tone) output by the 01dB Cal 01 SL calibrator, adjusting the SPL of each 10 s calibration segment to 94 dB at 1000 Hz. Four psychoacoustic metrics were chosen to evaluate the soundscape of the park as they are well known and have been used in multiple studies previously (e.g. Hall, et al., 2013; Jeon, et al., 2012a):

- Sharpness (acum scale) is a measure of the spectral shape, referring to the proportion of high frequency energy relative to the total energy (Zwicker & Fastl, 1999). For the present dataset[2] mean sharpness was 2.00 (SD=0.18).

- Fluctuation strength (vacil scale) is the sound quality perceived when loudness fluctuations are audible (Hall, et al., 2013). For the present dataset[2] mean fluctuation strength was 0.01 (SD=0.003)

- Loudness (sone scale) is the perceptual intensity of the sound (Zwicker & Fastl, 1999), where high frequency sounds are perceived louder than low frequency when presented at the same dB SPL. For the present dataset[2] mean loudness was 29.8 (SD=3.72).

- Roughness (asper scale) is related with rapid amplitude modulations that are too fast to be perceived as a loudness fluctuation and too slow to be perceived as a spectral variation (Zwicker & Fastl, 1999). For the present dataset[2] mean roughness was 2.83 (SD=0.22).

Loudness and sharpness were calculated according to ISO 532 FFT, fluctuation strength was calculated at a resolution of 1/1 Bark and roughness the default software configuration (i.e. there were no adjustable parameters). The overall values for the psychoacoustic characteristics are shown in Figure 26 - Figure 29. The overall values for psychoacoustic characteristics as well as SPL are shown in Table 52 in Appendix 13.1.

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[2] Mean and SD calculations exclude location 7.

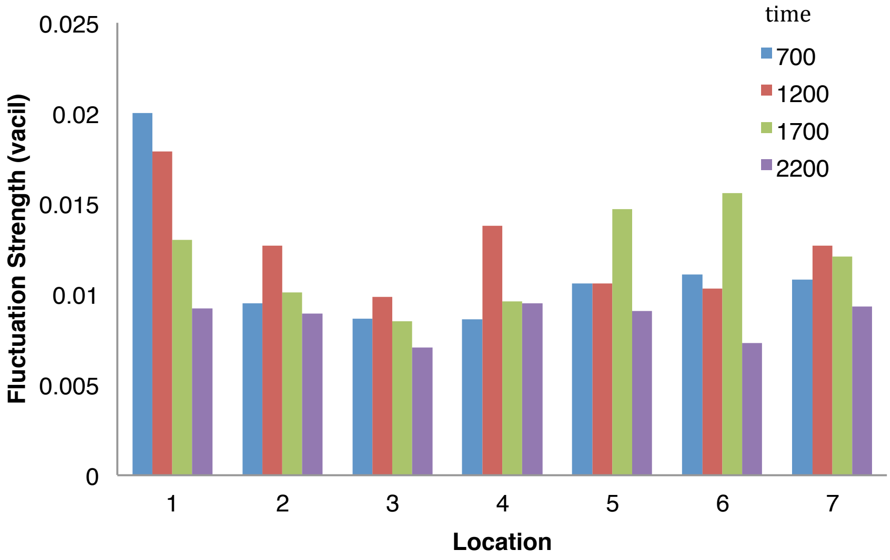

Figure 26: St. James's Park measured fluctuation strength

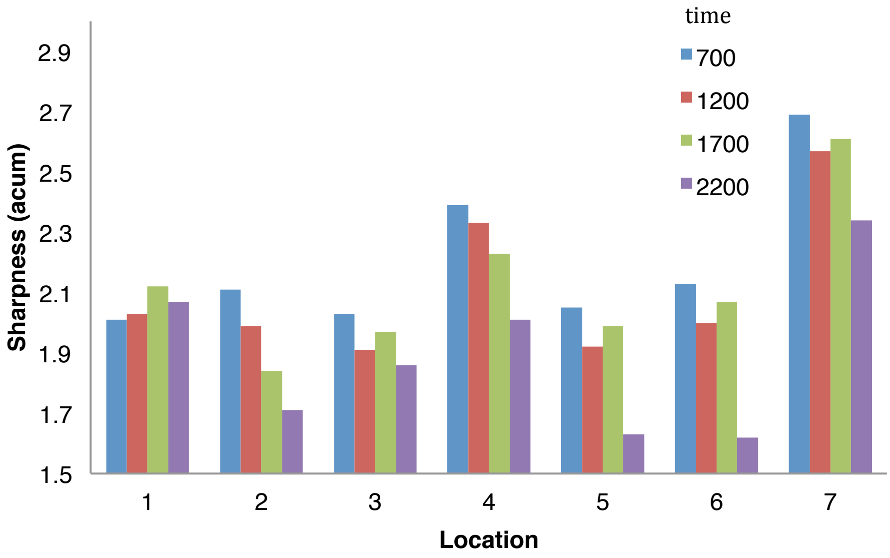

Figure 27: St. James's Park measured sharpness

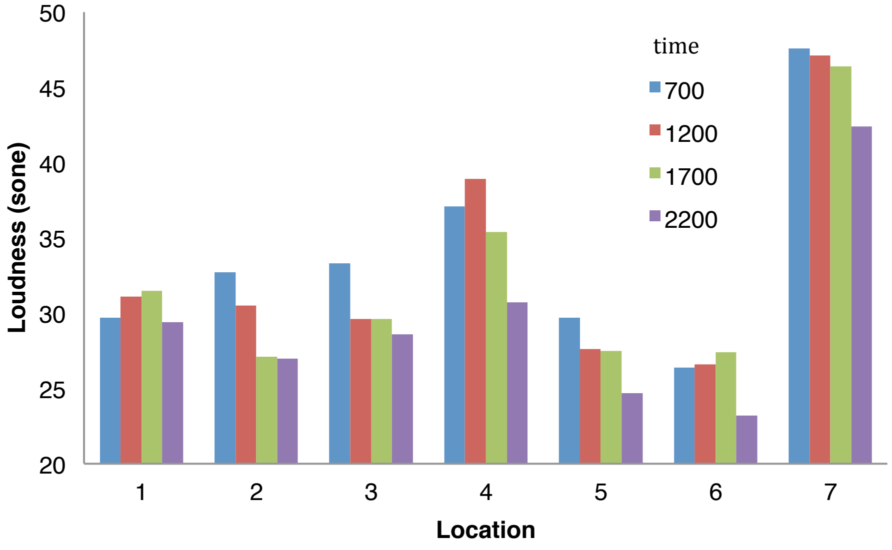

Figure 28: St. James's Park measured loudness

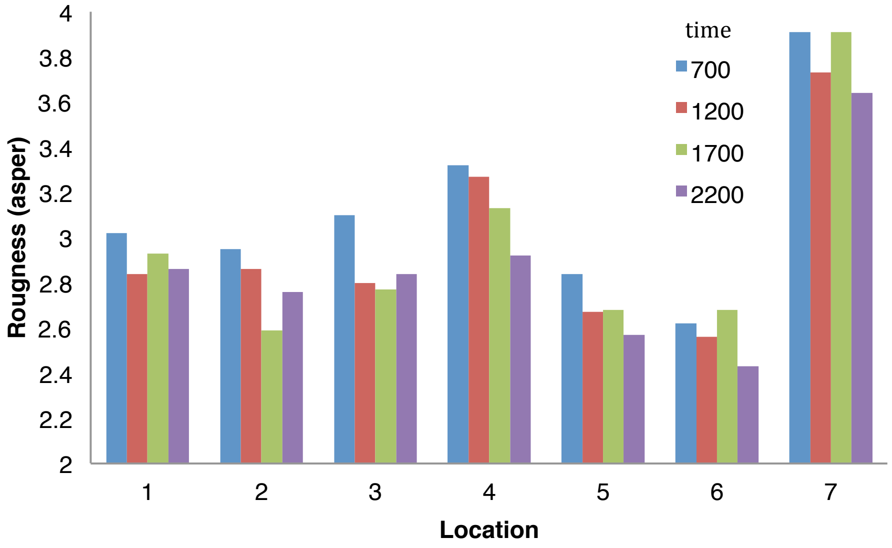

Figure 29: St. James's Park measured roughness

5.3.2.3 Sound component identification at the sample sites

Audible sound components at each site were identified from the recordings for each 2-minute duration by the researcher, who had training and experience in soundwalks (e.g. Adams et al., 2008; Semidor, 2006). The identification of sound source is important, as relying purely on objective measures of soundscape analysis does not explain the varied ambient soundscape, especially in cities (Raimbault, Lavandier, & Bréngier, 2003). In addition, the percentage of explained variance of perceptual responses to sound increase when including the meaning of sound sources (Lavandier, Defr, & ville, 2006). The methodology was identical to that followed in section 6.3.4.5. Though the distinction of primary and background could be ambiguous, in this study the distinction was clear as has been demonstrated in other studies for both urban sites (Yang & Kang, 2005a) or non-urban (Lam, et al., 2010). As a guide sounds were classified into broad categories: natural (e.g. bird song); human (e.g. voices); and technological (e.g. traffic). The overall distribution of sound components over all samples is illustrated in Figure 30.

5.3.3 Discussion

Emerging from the SPL and psychoacoustic metrics was a clear indication of the fluctuation of the soundscape for St. James's Park over the duration of the day. The overall sound as measured by psychoacoustic metrics provided relatively mixed values in the morning (07:00) to the lowest values in the evening (22:00). The overall lowest values, except for fluctuation strength, were recorded at location 6 at 22:00; fluctuation strength was lowest at location 3 at 22:00; the highest values for sharpness and roughness were at location 4 at 07:00; and highest loudness at location 4 at 12:00, and fluctuation strength at location 1 at 07:00. Overall sharpness, fluctuation strength and loudness was higher in the morning and at midday, slightly lower in the early evening and significantly lower late at night. This more or less matched the SPL measurements during the same time period.

In relation to the sound source identification the primary sound source is traffic with 28 total occurrences, with birds and speech the next most prominent primary sound at 22 and 14 occurrences respectively. Birds slightly overtake traffic as secondary or background sounds with speech dropping: traffic 9; birds 10; and speech 6 secondary occurrences. Though never a primary sound, crosswalk beeping frequently occurred (10 times), as did children (8) aircraft (3) and vehicles reversing (2). Other machinery, a lawnmower, bells, sirens and dog barking all occurred once throughout the samples. In this instance traffic accounted for 30.43 % of all sound sources. If the other technological/mechanical sound sources are added to the traffic sources the total occurrences amounts to 51.09% of sounds, compared to 25.0 % for natural sounds and 23.91% for anthropogenic sounds.

Location 7, used to compare sound level within the park to those outside of the park, could skew the results as it was located directly adjacent (i.e. 3 metres) from a busy road. If location 7 is removed from the analysis traffic, birds and speech accounted for 28.92%, 25.30% and 14.46% respectively, followed by crosswalk beeping (8) children (8), aircraft (3), vehicles reversing (2) and one each of machinery, lawnmower, bells, sirens and dog bark. Adding the technological sounds to traffic results in 49.40% attributed to mechanical sound sources, only slightly lower than when location 7 was included. The overall distribution of sound components, without location 7, over all samples is illustrated in Figure 31.

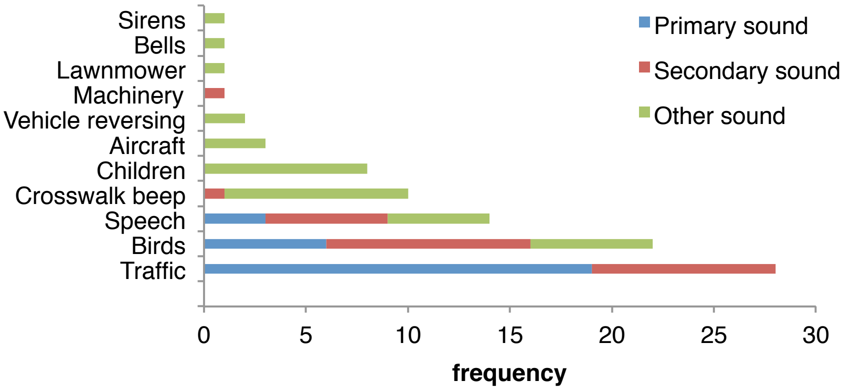

Figure 30: Sound component sources for St. James's Park, overall (frequency over 24 hours)

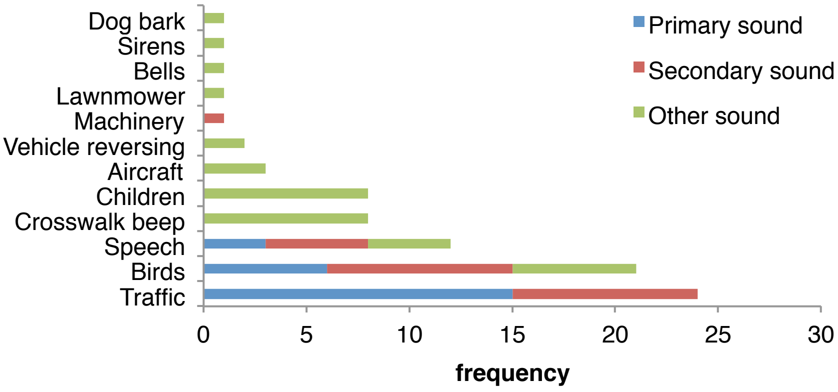

Figure 31: Sound component sources for St. James’s Park, location 7 removed

6 EXPERIMENTAL METHOD

The research reported here investigates the impact on landscape preference and representational realism of landscape visualizations as depicted in Google Earth at three levels of detail, and the extent to which auditory-visual interaction influences preference for landscape and judgements of realism of representations for three different sounds. Section 6.3 details the materials for the experiment (questionnaire development, experiment variables, experiment images, experiment sounds, online survey design and pilot study results) followed by the experiment apparatus in section 6.4. Section 6.5 provides the procedure followed for both online and laboratory-based participants. Section 6.6 discusses the participant sampling technique as well as participant characteristics in general. Section 6.7 details measurements and statistical analysis used, including data processing and evaluation of outliers and normality. Section 6.8 provides conclusions for the method chapter.

6.1 Introduction

The way that the brain integrates multimodal sensory inputs is becoming a much-researched topic. Many different approaches to investigating the impact of multisensory integration have been used including behavioural, neuroanatomical, and neuroimaging studies (Calvert & Thesen, 2004). A thorough overview of objective measurement methods is provided by Watkins et. al (2006). Multimodal analysis is expanding, and is a relatively new technique being used in interactive digital media (O'Halloran, Podlasov, Chua, & Marissa, 2012). For robust methods previous studies have often tried to combine subjective and objective measures. As the research reported here was exploratory in nature, and to offer comparability with previous landscape perception studies, self-reported methods analysed by statistical analysis was chosen for the experiment.

6.2 Ethics

Following protocol set out by the University of Sheffield for any experiment using human subjects the proposed research underwent ethics review. A faculty member from the Department of Landscape at the University of Sheffield reviewed the research proposal, and all suggested revisions were completed prior to ethics approval being granted.

6.3 Materials

6.3.1 Questionnaire development

6.3.1.1 Concept operationalization

The study that makes up this thesis is based on a survey that investigates responses to varying landscape elements in visualizations (terrain, built form and vegetation) and responses with and without sound to those visualizations. Based on the hypotheses developed (section 4, page 53) key concepts and related variables were developed for the experiment and survey, which are illustrated in Table 10.

Table 10: Concepts and variables in the experiment survey

Hypothesis	Key concept/s	Variables
Audio hardware effect	Audio hardware used	Respondents self-reported audio hardware
Video hardware effect	Monitor size/type used	Respondents self-reported video hardware
Experiment condition	Experiment setting	Laboratory vs internet condition
Realism landscape element	Landscape element visualized	Realism
Preference landscape element	Landscape element visualized	Preference
Sound-loudness effect	Sound loudness	Respondents loudness rating of the sound
Sound-preference effect	Sound preference	Respondents preference rating of the sound
Sound-congruency effect	Fit of sound with visual material	Content of visual material compared to sound
Expert effect	Expert vs. layperson	Occupational title
Familiarity-site	Spatial familiarity	Recognition Interaction frequency
Experience-computer graphics	Computer graphic use	Familiarity
Experience-visualizations	Visualization experience	Experience with visualizations
Sound type	Sound category	Sound preference
Sound sensitivity	Noise annoyance	Noise annoyance
Age effect	Age cohort	Age
Gender effect	Participant gender	Gender
Cultural effect	Cultural group	Country spent most time in

6.3.1.2 Visualization-sound effectiveness indicators

The study used two indicators to assess the impact of varying landscape elements in visualizations (terrain, built form and vegetation) while varying sound types (no sound, traffic, speech, nature) realism and affective appraisal:

i. *Realism*: a high level of perceived realism in a visualization correlates to a valid representation of real landscapes (e.g. Lange, 2001). As the validity of the visualizations with varying landscape elements, and with or without sound, are in question level of realism is a factor.

ii. *Preference*: The affective dimension, an emotion based response, is particularly of value relating to the impact of sound (e.g. Bradley & Lang, 2000; Hume & Ahtamad, 2011).

The indicators needed were sought to be indicative for both responses to varying landscape elements in visualizations as well as the interaction of visualization and sound. As such, broad terminology (realism and preference) was a criterion for the indicators. While preference research has relied on qualitative paradigms e.g. (Lewis, 2010), in the urban environment a small majority used quantitative methods, surveys in particular (Matsuoka & Kaplan, 2008). To be comparable with previous research on realism and preference (e.g. Chapter 2), a largely quantitative paradigm was adopted.

There has been agreement shown between expert planners and stakeholders in the forestry context using visualizations (Sheppard & Meitner, 2005). In other contexts there is evidence that familiarity and expert vs non-expert designation can impact ratings of visualizations (Lange, 2001). As such, the study aimed to investigate responses of local vs non-local, as well as expert vs non-expert, in the urban and natural context.

6.3.1.3 Defining familiarity

The importance of familiarity on recall tasks in both interior and exterior environments has been shown to be significant (Mainardi Peron, Baroni, Job, & Salmaso, 1990). Familiarity can be measured by Experience Use History (EUH), which “refers to the amount of past experience, usually measured in terms of total visits, total years of use and frequency per year of participation with an activity and/or resource at a specific site and/or other sites (Hammitt, Backlund, & Bixler, 2004, p. 358)”. Other EUH studies focus on an activity frequency over amount of time, which correlated to differing interests and habits (Choi, Loomis, & Ditton, 1994; Ditton, Loomis, & Choi, 1992).

Familiarity has been conceptualized as consisting of *place name recognition; visual recognition,* i.e. the ability to recognize a place; *locational knowledge,* i.e. to know where a place is; and *interaction* with the place (Gale, Golledge, Halperin, & Couclelis, 1990). They found that the first three correlated highly when aggregated, indicating that they are collinear and measured the same thing, with “interaction” as the second variable. The authors describe this as the “factual/cognitive” vs “behavioral” components of spatial familiarity, supporting the “declarative-procedural knowledge distinction widely assumed in cognitive science. The authors recommend a two-valued rating based on each of these components. Operationalizing the concept within the context of place bonding, Hammitt et al. (2006) present familiarity as one of five aspects of place bonding which can be measured via two questions: 1. I recognize most of the campus scenes; 2. I am quite familiar with most of these places.

In the context of assessing recreation demand and identifying choice sets for survey material researchers have reported defining ‘Familiar’ as “a more difficult task than we had anticipated” (Parsons, Massey, & Tomasi, 1999, p. 306). In the end the authors opted for past trip information as a proxy for familiarity. While this addresses the ‘behavioural’ component of familiarity identified by Gale et al., it omits the ‘factual/cognitive’ element. Hicks and Strand (2000) address familiarity as a direct question including a definition of familiarity[3]. Similar studies have presented users with a map and list of sites to identify sites they think about in relation to fishing destination (Peters, Adamowicz, & Boxall, 1995). For the purpose of the research reported here a two value rating for spatial familiarity was adopted as recommended by Gale et al. using a direct question and definition of familiarity as well as frequency of visits. Participants were presented with an aerial photograph of St. James’s Park and a ground level image (Figure 32) and asked the following two questions:

- *Are you familiar with St. James's Park?*
  (By 'familiar', we mean that you know something about the park either by having been there or you know about it through some other source)
  Options: not at all, a little, moderately, quite a bit, very much
- *Approximately how often do you visit St. James's Park?*
  Options: Most days, about once a week, At least once a month, Every 2 or 3 months, 2 or 3 times a year, less frequently, have not visited

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[3] Wording of Hicks et al. 2000 question: “Please give me the letter that appears beside the name of each beach on this card that you (and your family) are familiar with. By 'familiar', I mean that you know something about the beach either by having been there or you have heard about it through some other source”

Figure 32: St. James's Park familiarity images, aerial photograph (© Google Earth) and eye level view

6.3.1.4 Noise sensitivity

Previous studies have indicated that noise sensitivity can influence non-sound reactions, though other studies have contradicted this (Miedema & Vos, 2003), and therefore this was investigated as a variable. In addition noise sensitivity has been shown to lead to greater reported annoyance (Jakovljevic & Belojevic, 2001). Some studies use long surveys to assess noise sensitivity (e.g. Anderson, 1971; Weinstein, 1978; Zimmer & Ellermeier, 1998). While valid and accurate for measuring noise sensitivity, surveys of this length put a large burden on the participants when used in the field or as part of larger survey (e.g. the Weinstein Noise Sensitivity Survey (NSS) has 21 questions; Zimmer and Ellermeier's has 52). While single item questions have been used and have been shown to somewhat correlate ($r = 0.60$) with the Weinstein NSS questions (Heinonen-Guzejev, 2008)[4], other research has demonstrated that single item noise surveys are not an acceptable substitute for lengthier alternatives (Zimmer & Ellermeier, 1999). The Weinstein NSS has been the most used and widely researched since its development in the 1970's. In order to develop a shorter but equally valid NSS for field work, Benfield et al. (2012) developed a 5 item survey[5] that they showed was "structurally identical to the original with comparable levels of internal consistency and temporal stability (and)…highly correlated with the original NSS"

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[4] From Heinonen-Guzejev, 2008: Noise sensitivity was investigated using the question: "People experience noise in different ways. Do you experience noise generally as very disturbing, quite disturbing, not especially disturbing, not at all disturbing or can't say?" Noise sensitivity was determined from the answers in the following way: Subjects answering "very disturbing" and "quite disturbing" were classified as noise sensitive, and subjects answering "not especially disturbing" and "not at all disturbing" were classified as not noise sensitive.

[5] The five questions used in the survey were: "I am sensitive to noise"; "I find it hard to relax in a place that's noisy."; "I get mad at people who make noise that keeps me from falling asleep or getting work done."; "I get annoyed when my neighbors are noisy."; "I get used to most noises without much difficulty.". The last item is reverse scored.

(Benfield, et al., 2012, p. 13). While placing slightly more burden on the participants than a single item question, the validity and data collected was deemed an appropriate trade off.

6.3.1.5 Development of the rating scale

Realism and preference rating scales

Previous studies were used to inform the development of the rating scale for realism and preference used in the current study. While no standardized method exists for rating visualization realism, previous research has used some relating and overlapping methods, largely relying on questionnaires using rating scales. Only one study directly asked participants to report directly on the realism of the stimuli (Lange, 2001), where participants grouped printed images according to the degree of realism (i.e. very low, low, medium, high, very high).

In an early study participants ranked computer generated line drawings of landscapes at three levels of detail in terms of the level of detail of the photos (i.e. most detailed, intermediate detail, lest detailed) followed by preference ratings for each (Tips & Savasdisara, 1986). Similarly another study had participants rate the relative scenic beauty of four landscapes represented at varying levels of detail (i.e. low to high) and analysed the conjoint validity of the scenic beauty rating by correlation with rating based on high resolution full colour representations (Daniel & Meitner, 2001). In another study a combination of methods was used including semantic differential, direct questions (i.e. confidence in the simulations and attractiveness, ranked on a 5-point descriptive scale of very X, somewhat X, neutral, somewhat Y, very Y) (Oh, 1994).

In the context of attempting to define the sufficient level of realism for visualizations, Appleton et al (Appleton, et al., 2004) asked participants “To what extent do you feel that the style and content of this image allow you to imagine the future landscape that is being considered?”, respondents used a 9-point scale (i.e. 1 indicating they could not imagine the future landscape at all, 9 indicating they could imagine it very easily). They then compared a visualization to a real photograph and asked participants to indicate how real the visualization was when compared to the photograph using the 9-point scale (i.e. 9 indicating that the image was as realistic as the photograph and 1 being used if the respondent felt the visualization was not at all realistic).

In the forest context, one study addressed the validity of visualizations as surrogates for real experience by having participants view a real site and refer to a printed hard copy of the visualization, then asked to rate the accuracy of the simulation (i.e. on a five point scale, ranging from 1 = not at all accurate to 5 = very accurate). A further study aimed to assess the difference in stylistic effects of software on the perceived realism and preference for a view (Lewis, 2012) used a 5-point scale and asked participants to indicate the perceived realism, preference for and credibility of each image.

In computer science direct questioning of participants by asking them to select which is a real picture of an environment and a simulated environment has been used to gauge realism (Meyer, Rushmeier, Cohen, Greenberg, & Torrance, 1986). Related to realism is the notion of presence, and with advances in virtual reality researchers have also developed sophisticated standardized presence questionnaires e.g. (Witmer & Singer, 1998). However such questionnaires have so far failed to pass the ‘reality test’, whereby the presence scores should be higher for real experiences than for virtual ones (Usoh, Catena, Arman, & Slater, 2000). The authors conclude that such questionnaires are useful when comparing subjects within the same type of virtual environment, though more limited across environments.

There has been some research specifically using landscape preference-rating tools for environments similar to that used in the current study (e.g. park or open space within an urban context). In research aimed at improving collection of attitudes towards urban green spaces a survey was developed, informed by qualitative and GIS data (Balram & Dragićević, 2005). The survey used a 5-point scale and was validated, with the analysis showing that attitudes towards urban green space rely on two factors, behaviour and usefulness. In a study to assess the important of urban nature for peoples well being a combination of direct questions with supplied answers (e.g. Which feeling does nature evoke in you?; Freedom, Luck, Adventure, Happiness, etc.) and a 5-point scale for emotional well being (e.g. How important are these feeling for your daily well being?; 1, not important at all; 5, essential) was used (Chiesura, 2004).

In a UK based study aimed at assessing public attitudes towards naturalistic vs formal green space in the urban environment, methods used included open ended, pre-coded and scale format questions (Özgüner & Kendle, 2006). Different features were rated against each other as well as direct questioning about preference for one site vs. the other.

Other aesthetic preference research has used interviews and observations e.g. (Berg, 2004), contingent valuation, i.e. willingness to pay e.g. (Jim & Chen, 2006), user satisfaction e.g. (Oguz, 2000), open ended questions, e.g. what do you like about/dislike about X e.g. (Gobster, 1995), visual and verbal manipulations of potential answers, e.g. forcing selection of one of two options for transit oriented vs. auto-oriented development (Vogt & Marans, 2004), and variations on different rating scales: visual analogue scales, e.g. Dislike very much – Like very much (Jorgensen, Hitchmough, & Calvert, 2002) or strongly like – strongly dislike (Todorova, Asakawa, & Aikoh, 2004); 5-point numeric only scales, e.g. 1 denoting low preference, 5 denoting high preference (Sullivan & Lovell, 2006); continuous graphic scales, e.g. Not satisfied – Very Satisfied (Ellis, Lee, & Kweon, 2006) and direct questioning, e.g. How do you like the above landscape?, Not at all – very much (Lange, et al., 2008).

For the study presented here the presence questionnaire was deemed unsuitable owing to the length, more complicated analysis and questionable validity, and semantic differential was deemed too lengthy for the stimulus set used. Direct questioning was selected as it has been shown to produce valid and reliable results and directly measures the desired effect, and is relatively efficient. For realism ratings the 5-point scale is by far the most common method, with the adjective ‘very’ or ‘not at all’ as the lowest rating point on one end and ‘very’ as the highest point on the other end (e.g. Lange, 2001; Oh, 1994; Williams, et al., 2007). The 5-point scale is also used extensively in aesthetic preference research as indicated above. The rating scale also needed to be consistent between the realism and preference question types, therefore verbal labels were used; the development is outlined in the next section.

Previous studies have noted that a high degree of realism must exist for the environmental context of the study if anyone with knowledge of the local area is viewing the visualization (Appleton & Lovett, 2005; Karjalainen & Tyrväinen, 2002). Familiarity with computer graphics in general, and visualizations in particular, have shown to influence realism ratings (Appleton & Lovett, 2003). Site familiarity can have a significant influence on preference (Kaplan & Kaplan, 1989) as well as affecting judgments of realism in visualizations (Lange, 2001). To isolate site familiarity as a variable previous studies have used artificial sites (e.g. Ode, et al., 2009), though this project aims to investigate familiarity as a variable, alongside variables of local and non-local and expert-layperson, therefore a real site was deemed necessary.

Previous research has used a local/non-local distinction for familiarity with a study site (e.g. Lange, 2001). In the context of St. James's Park, this distinction is potentially less informative as the most recent demographic survey of park visitors reported that only 43% of visitors lived in London, while 52% reported visiting at least 1-3 times per month (Gabrieli & Wilson, 2010)[6]. As a result, familiarity as a concept was more important than specific living location, and it was necessary to determine a means of operationalizing familiarity for experiment participants.

Verbal labels for the rating scale

In the development of the rating scale the aim was to use verbal labels for each question that were relatively equidistant, linguistically distinctive and comprehensible as well as contextually relatable (i.e. the label makes sense with the phrase of the question). 5-point scales should be labelled on all points when intended for use with both a general and student population (Weijters, Cabooter, & Schillewaert, 2010). While other studies have used grammatically balanced scales (e.g. tend to disagree – tend to agree) research has demonstrated that such language may not be perceived as conceptually opposite (Worcester & Burns, 1975). As a result, natural language was chosen as it is more familiar and linguistically more compatible with the questions being asked in the study. In addition, a comparison between likert-type scales and visual analogue scales found that they yielded similar results, though the authors recommend likert scales for their ease of administration and interpretation (Jaeschke, Singer, & Guyatt, 1990). The intensity qualifiers used in the study (i.e. the words used on the scale) were informed by a study conducted by Rohrmann (2007) that aimed to identify the best verbal labels for ratings scales, with the main considerations for choosing a word for each point level identified as:

1. Appropriate position on the dimension to be measured
2. Low ambiguity (i.e. low standard deviation in the scaling results)
3. Linguistic compatibility with the other words chosen for the scale
4. Sufficient familiarity of the expression
5. Reasonable likelihood of utilization when used in substantive research

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[6] Data averaged for visitors to the central Royal Parks in London.

In the Rohrmann study the extremes were very clear for intensity qualifiers in their categorization on a 10-point scale: ‘not at all’ (M=0.0) and ‘not’ (M=0.4) had lowest mean ratings; ‘extremely’ (M=9.6) and ‘completely (M=9.8) had highest mean ratings. The author recommends specific combinations for 5-point scales, based on the data collected, and a small add-on study. For Intensity the combinations are “not/a-little/moderately/quite-a-bit/very”. While this does not reflect the full spectrum of responses possible (e.g. as would something ranging from ‘not at all’ – ‘completely’) it addresses issues reported in other studies where participants are reluctant to select too extreme of a verbal label (Friedman & Amoo, 1999), which then in effect reduces the scale from a 5-point to a 3-point scale according to Rohrmann. In addition, using ‘very’ or ‘very much’ for the most extreme positive qualifier is in line with previous realism and preference research as reported above. Rohrmann further recommended a multimodal scale format (e.g. number labels, even frame spacing) to enhance psychometric quality and user-friendliness. As numeric scales can change the meaning of scale labels (N. Schwarz, Knäuper, Hippler, Noelle-Neumann, & Clark, 1991) even spacing and accurately ranked labels were chosen for the scale. There were 4 question conditions within the survey, 2 for the pre-test sound ratings, and 2 for each aural/visual stimuli combination:

Aural stimuli (pre-test):
1. How loud is this sound?
2. How much do you like this sound?

Aural/visual stimuli (main experiment):
1. How realistic is your experience of this environment?
2. How much do you like this environment?

Response options, based on recommendations by Rohrmann (2007):
How loud is this sound?
How much do you like this sound (environment)?
Not much; A little; Moderately; Quite a bit; Very
How realistic is your experience of this environment?
Not real; A little real; Moderately real; Quite a bit real; Very real

The recommendations by Rohrmann were adequate, however, there was awkward language (i.e. ‘Quite a bit loud’, ‘Quite a bit real’, and the hanging answer to ‘How much do you like this environment’ – Very). To address this the realism and loudness qualifiers were changed to the next closest adjective while being relatively equidistant and linguistically distinctive. The resulting verbal labels are shown in Table 11.

Table 11: Verbal scale label, Mean, sd and linguistic separation compared to recommended labels (adapted from Rohrmann, 2007)

Recommendations				**Realism/loudness**				**Preference**			
Verbal label	M	sd	LS*	Verbal label	M	sd	LS*	Verbal label	M	sd	LS*
not	0.4	0.6	-	not	0.4	0.6	-	not at all	0	0.2	
a little	2.5	1.2	2.1	slightly	2.5	1.3	2.1	a little	2.5	1.2	2.5
moderately	5	1.1	2.5	somewhat	4.5	1.6	2	moderately	5	1.1	2.5
quite a bit	6.5	1.5	1.5	quite	5.9	1.4	1.4	quite a bit	6.5	1.5	1.5
very	7.9	0.9	1.4	very	7.9	0.9	2	very much	8.7	0.8	2.2

M = mean
sd = standard deviation
LS = linguistic separation (subtracting the mean of that label from the label above

The original recommendations from Rohrmann ranged from mean ratings on 0-10 scale from 0.4 to 7.9, with standard deviation ranging from 0.6-1.5 and linguistic separation 1.4-2.5. For realism and loudness the range of means are the same, with maximum sd only slightly higher at 1.6, while the range of LS is reduced (a good thing). For Preference the range mean range is larger (0-8.7), sd (0.2-1.5) and LS 1.5-2.5. These are all within the range recommended meeting the requirements for verbal labels.

6.3.2 Experiment variables

The elements that have the most impact on the visual appearance of landscape in relation to visualizations are terrain, vegetation, animals and humans, water, built structures and atmosphere and light (Ervin, 2001). Little research has been conducted on the impact of people in visualizations, though the presence of wildlife can significantly impact responses (Hull & McCarthy, 1988). The visual representation variables chosen for this study were those that varied in Google Earth and have also been identified as having a significant impact on perception of visualizations in previous studies: terrain, built form (Lange, 2001); and foreground vegetation (Appleton & Lovett, 2003). The variation in visual condition, by the presence or absence of landscape elements, as well as the presence or absence of sound, defined the sample images used for the experiment (Table 12).

Table 12: Variation in the representation variables

Terrain	Buildings	Vegetation	Sound
Pure terrain	Not present	Not present	Not present
	Buildings with textures	Singles trees with texture	Present

6.3.3 Experiment images

While an interactive experience has proven to be superior to viewing an animation (Bishop & Dave, 2001), to control for the lack of participant experience with virtual environment interaction, and to isolate variables, still images were used as they have been validated in numerous experiments and have been shown to be reliable surrogates for real landscape experience.

The images chosen for the study were drawn from a database of 100 images taken from 3D eye-level views (i.e. foreground, 0-800 m, USDA Forest Service, 1974) within Google Earth on the study site. Eye-level views were focused on to provide congruence with sounds used in the study (i.e. sound recorded at ground level on site). In addition, eye-level views have been identified as being the most challenging to represent (Lange, 2001) and as such it was hypothesized that they would provide a wide range of responses based on varying landscape elements.

Viewpoints were selected according to the following criteria: (a) showing a representative cross-section of the site; and (b) varying in each image the visual amount of built form, terrain and vegetation. Three views representative of the site were chosen (open with vegetation, enclosed by vegetation, enclosed vegetation with some built form). Vegetation in Google Earth is achieved via 2D textures mapped to a vertical plane; as such overhead enclosure from vegetation was not possible. For the enclosed vegetation view a dense area of vegetation was chosen. The combination of elements contributing to the different visual conditions used in the experiment is illustrated in Figure 33.

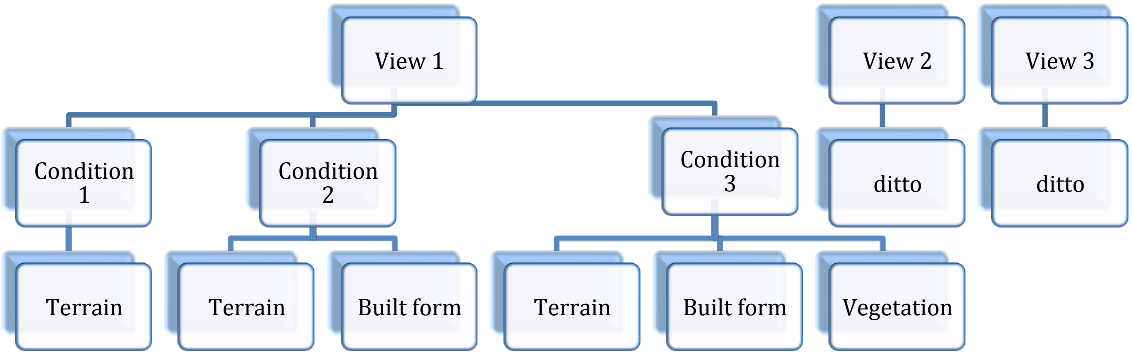

Figure 33: Experiment image combination, per view

The three viewpoints and the three visual conditions (terrain; terrain and built form; terrain, vegetation and some built form) are illustrated in Figure 34.

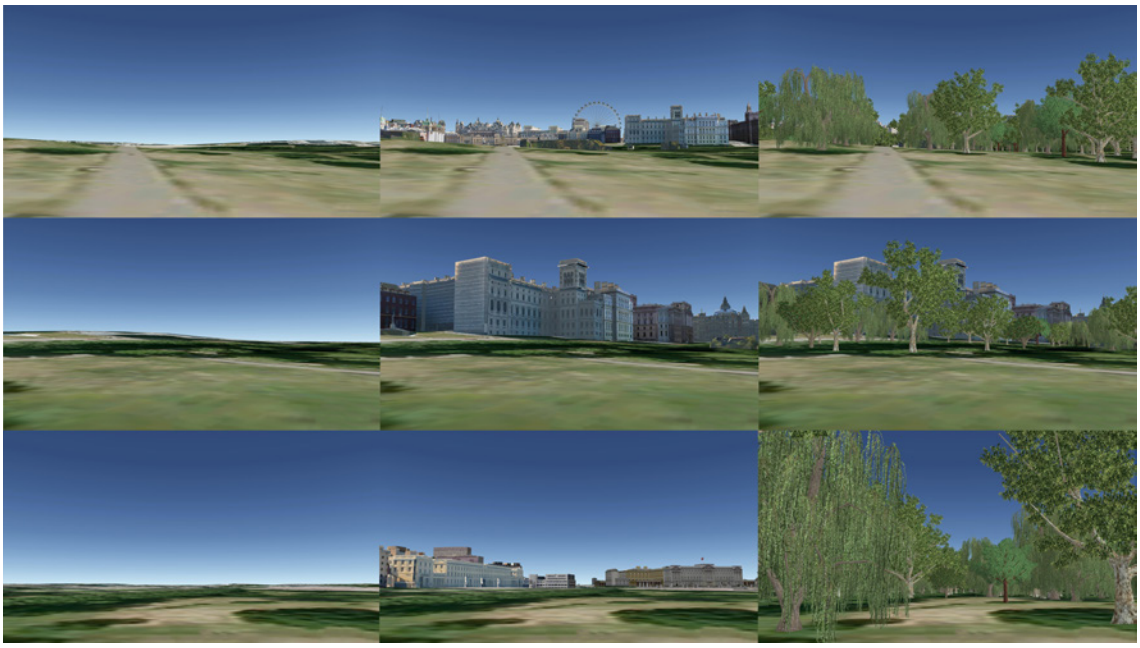

Figure 34: Views and landscape elements used in the research: view 1 (top row); view 2 (middle row); view 3 (bottom row); by condition (1, left column; 2, middle column; 3, right column) (© Google Earth)

Each view was exported from Google Earth Pro at a 1080p HDTV ratio, at a 4800 x 2700 pixel .jpg file. The .jpg file format compresses the image retaining most of the image quality of a scene while reducing the file size, unlike lossless formats that do not compress the original image (e.g. .tif). At the time of writing .jpg export from Google Earth was the only file type available for image exporting, with Google Earth Pro required for “Premium” image export of 4800 pixels on the longest edge. Google Earth uses an algorithm to export the high quality image similar to panoramic photo-stitching software, piecing together a large image from smaller screen shots. The pixel size allowed for high resolution printing at A4 size and 300 dpi, while also being scalable to fill a 1080p (1920x1080 pixel) monitor if needed.

Prior to exporting the images from Google Earth navigation aids on screen were turned off, as was the status bar so they would not appear in the final images. Adobe Photoshop CS5 was used to remove the Google Earth logo and copyright attribution watermark on each image using the ‘Content aware fill’ tool (permissions cleared by Google Earth content suppliers Bluesky, Getmapping PLC, Infoterra Ltd and TerraMetrics). In order for the images to remain identical the content aware fill was performed on one image from each view, then copied and pasted onto the remaining from that view. Images were then resized to 1080p (1920 x 1080 pixels) using Bicubic resampling, and saved as JPEG with a ‘10’ quality with a ‘Baseline (Standard)’ format, which produced final images that were visually indiscernible from the original quality images. For the final survey images were resized to 1024 x 576 pixels using Bicubic resampling and saved as high quality ‘Baseline (Standard)’ format to allow for fast loading. No image would have been viewable larger than 1024 x 576 pixels given the survey format.

6.3.4 Sound stimuli data sources

6.3.4.1 Introduction

This section describes a study designed to evaluate the suitability of an online sound database for sourcing sounds for the main experiment and using the online database to identify soundscape characteristics along an urban-rural continuum.

6.3.4.2 Data sources for sounds

As presented in the literature review sounds to accompany landscape visualization, and for the study, could be recorded in a real environment, sourced from an existing database, or synthesized. The advantage of synthesizing would be the control over events vs background ambience, and a greater ability to use abstract sound texture synthesis based on cinema and video game techniques. Such synthesis can be automatic, sourced from unstructured databases (Finney & Janer, 2010). The advantages of using recordings of a real environment include comparability within the experiment with a real vs remixed and texturized sound. Sounds for landscape preference and environmental psychology studies have primarily been sourced from onsite recordings (e.g. Carles, et al., 1999; Gifford & Ng, 1982; Mace, et al., 1999) as well as online databases (e.g. Benfield, et al., 2010). Sourcing sounds from online databases offers a convenience for the researchers and quite often offers large selection of sounds to choose from. To date many of these databases have been the jurisdiction of large institutions (e.g. the National Park Service in the United State, or the British Library in the UK) that rely on professionally recorded samples using high quality instrumentation. A new type of online database, sourced from the public (i.e. crowdsourced) offers an alternative to institutional databases and was the focus of the study reported here.

6.3.4.3 Crowdsourced data and sounds

Crowdsourced data is a relatively new phenomenon and can be attributed to the rise of social media and their applications, which can be used to collect and organize user contributions. It has been used in a range of contexts including disaster relief (Huiji, Barbier, & Goolsby, 2011), GIS data collection (Van Exel, Dias, & Fruijtier, 2010) and plant identification (Goëau et al., 2011) and to minimize risk in urban evacuations (Oxendine & Waters, 2014). The main issues reported with crowdsourced data are the weakness of the applications to support data collection and data quality (Barbier, Zafarani, Gao, Fung, & Liu, 2012).

As part of the larger research project reported here, a study was conducted to evaluate the efficacy of crowdsourced online sounds as the aural stimuli for the main experiment. The goal was to investigate the utility of a newly available online database made up of user-contributed sounds. To contextualize the soundscape of study the initial task was to identify soundscape characteristics across the urban-rural continuum via a literature review, and compare those characteristics with online, crowdsourced (i.e. user generated) databases of sounds. Soundscape characteristics that were identified via the literature review are discussed in section 3.5 and illustrated in Figure 35.

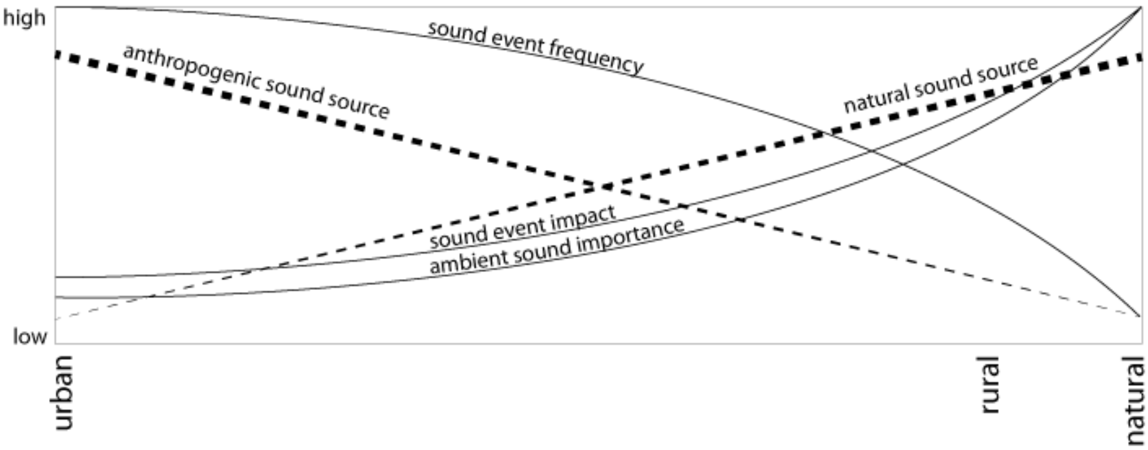

Figure 35: Soundscape characteristics along urban-natural environment continuum

UKSoundMap

Crowdsourced material was collected from sounds uploaded to the UKSoundMap (UKSoundMap, 2010, July, UKSM) between July 2010 and June 2011, the one-year duration the British Library accepted contributions. The UKSM uses Audioboo (Audioboo, n.d.), a website that describes itself as a “mobile & web platform that effortlessly allows you to record and share audio for your friends, family or the rest of the world to hear”. Users are able to record sounds via dedicated mobile phone applications, upload via email, record directly from a phone or upload recorded material from any source to the site directly. As is popular with web 2.0 applications Audioboo supports tagging and geolocating content, which can then be viewed on a Google Map of ‘boos’. To participate in the UKSM project a user tagged their recording using ‘uksm’, and the recording would automatically be referenced by, and located on, the UKSM from the Audioboo site.

6.3.4.4 UKSM Study area

The study area was selected using a 25 km transect along an urban-rural continuum (i.e. Sheffield Train Station to the western extent of the Peak District) including an area of 10 km adjacent to each side of that transect covering an area of 25 000 ha (Figure 36). The study area was chosen because: 1. It characterized a regular and representative urban to natural gradation within a relatively short (25 km) distance; 2. The popularity of the peak district resulted in a relatively numerous rural and natural uksm tagged content (when compared to other UK based areas); and 3. Researcher familiarity with the area provided useful background knowledge for the coding exercise (see section 6.3.4.6 for coding procedure). The study area land use types included urban housing, suburban housing, industry and commerce.

Figure 36: Site study area (base image © Google Earth)

6.3.4.5 UKSM analysis procedure

Data from the study area (N=69) were streamed over the Internet via the UKSoundMap site. Hardware used was a 13” Macbook Pro laptop connected to Creative XMod external USB soundcard relaying the signal to Sony MDR-NCS headphones. Listening was conducted in a carpeted room. The 69 recordings ranged in length from 14 s to 228 s.

6.3.4.6 UKSM sound coding

Coding, a process that categorizes data to facilitate analysis, was completed for the recordings within the sample area. Constant comparison, a coding approach from grounded theory was used, allowing categorization based on individual recordings, as well as the relationship of those sounds and recordings previously coded (Strauss, 1993). Grounded theory approach has been used for soundscape research in the past successfully (Schulte-Fortkamp & Fiebig, 2006).

In the first coding session data were initially listened to sequentially from west to east, or in the case of the study, rural to urban, without annotation or coding, in order establish an overall typology of sounds uploaded within the study area.

The second coding session followed the same order as the first (i.e. west to east) and, using both map placement, user supplied tags, and recording content, categorized data into a spatial framework of rural, suburban and urban.

The third coding session followed the same order as the first two (i.e. west to east) with specific attention paid to recorded content. In this session each sound recording was replayed one to four times, as necessary, in order to code all sound sources within the file. Sounds were classified into the primary sound and secondary sound(s). The coding categories are presented in Table 13.

Table 13: UKSM coding variables

Variable	Category	Source
point	Number: 1-69	Geographic location from east-west
location	Place name	Google map location
loc type	Location type: urban, suburban, rural,	Researcher defined
loc sec	Location type: town, on public transportation, park, indoors, market, plaza	Researcher defined, more specific location
title	Name of recording	User defined file name
user	Username	File metadata
duration	Seconds	File metadata
published d	Date published	File metadata
published t	Time published	File metadata
tags	User supplied tags	File metadata
sound(s)	Sound source: announcement birds children footsteps music traffic voices water wind	Researcher defined

6.3.4.7 UKSM analysis results

This section describes the results obtained from the coding methodology outlined in the previous section. The coding was organized into primary, secondary, tertiary and quaternary sound source for each location, with the primary sound sources compared to the other sound sources. The total sound sources collapsed across location is illustrated in Figure 37, with the sound sources separated by anthropogenic and non-anthropogenic sources shown in Figure 38. The data is shown by location and sound source for all three-location types (urban, suburban and rural) in Figure 39.

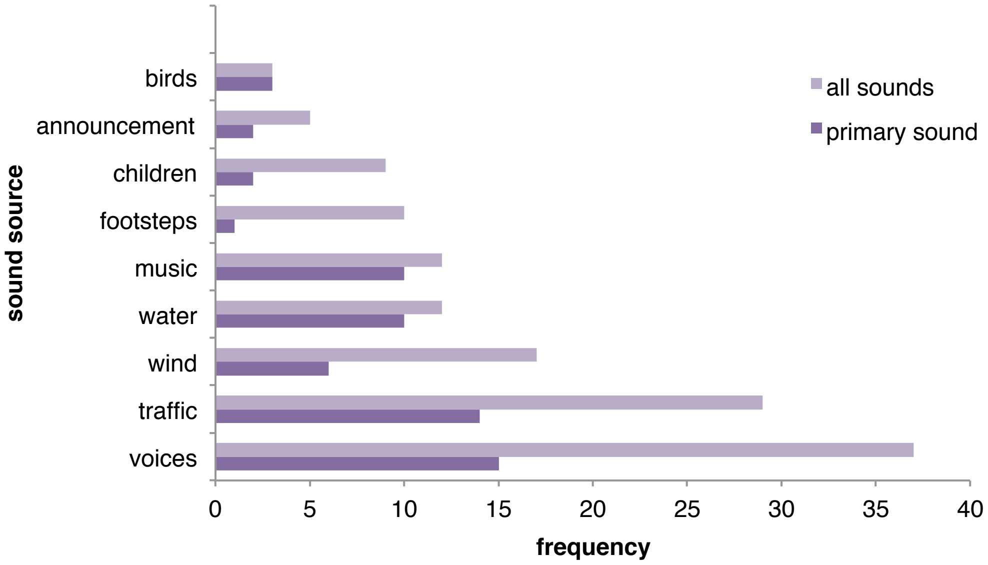

Figure 37: Sound source frequency, all locations

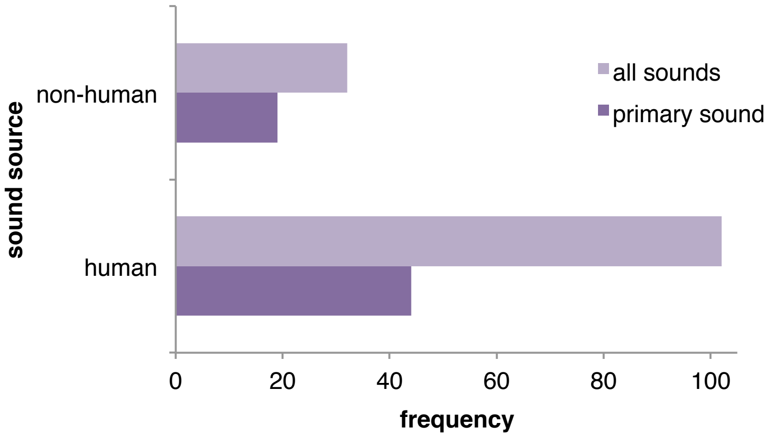

Figure 38: Anthropogenic vs non-anthropogenic sound source frequency, all locations

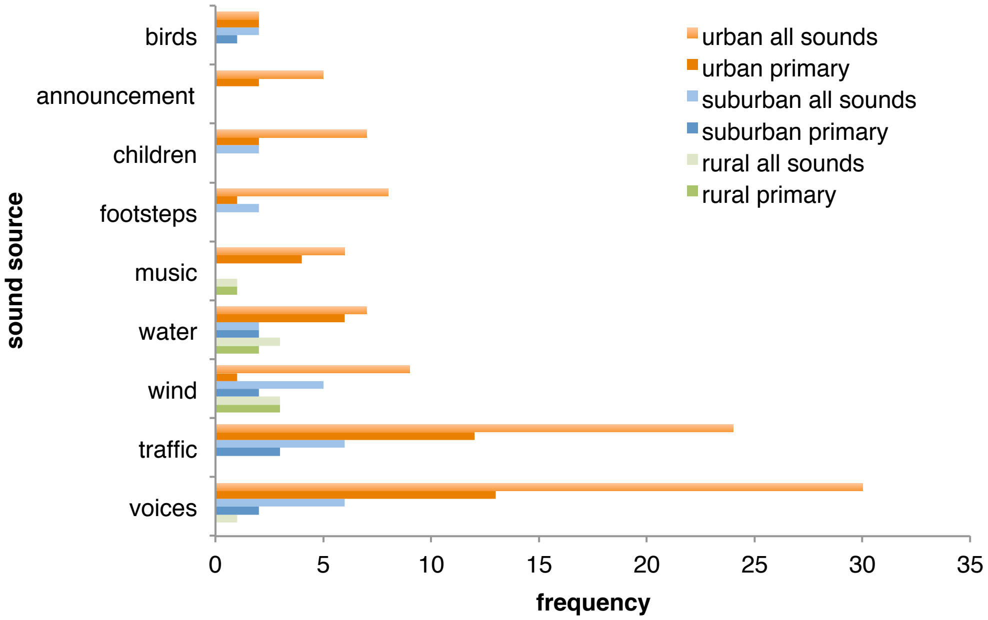

Figure 39: Sound source frequency by type, all locations

6.3.4.8 UKSM discussion

The results indicate that there are essential soundscape characteristics and that they are similar across all three environments (i.e. elements of natural, anthropogenic and mechanical sounds), and it is the relationship and frequency of sound that is of particular interest. For examples there is an inverse relationship of human vs non-human sound generation across the three environments, with more anthropogenic sound sources in the urban environment compared to the suburban and rural environments. This matches to crowdsourced activity in this instance as compared to the UKSoundMap. The results indicated that there was congruence between the literature review and the uploaded sounds for the UKSoundMap. In relation to sourcing sounds for experiment stimuli the quality and content of the sounds was not deemed adequate for the main experiment due to poor recording quality in general and recordings that were overly complicated with too many divergent sound sources. These findings are in line with other research using crowdsourced data, where others have concluded that there is much work required by the researcher to make data useable and meaningful (Barbier, et al., 2012). As the crowdsourced data was not sufficient as experimental stimuli it was decided to use sounds recorded on site for the aural stimulus in the experiment.

6.3.5 Experiment sounds

Moving beyond the online crowdsourced samples discussed above, a more conventional method of onsite recordings was eventually decided upon. The sounds used for the experiment were drawn on the 24 recordings recorded on site at St. James's Park (as outlined in section 5.3.1). This provided congruence of the sound-image combination, as previous studies have demonstrated that the "appraisal of a sound depended largely on the extent to which it matched with the setting in which it occurred" (Carles, et al., 1999). Sound sources were selected from the on site recordings, with the 4 recordings collected from outside the park along Birdcage Walk omitted as they would be incongruous with the park setting due to extremely dominant vehicle sounds. Each of the 6 locations on the site had recordings at 4 times (0700, 1200, 1700, 2200), resulting in a total of 24 sounds to select sound stimuli from.

In urban outdoor environments the ambient soundscape is complex and can defy conventional categorization between ambience and event (global point of view versus discrete listening) (Raimbault, et al., 2003). Moreover, sounds can prove complex perceptually, e.g. traffic can be indistinguishable from the sound of a fountain when no visual indicator is present. However, in some instances, the setting of a large park can have a soundscape similar to a rural environment, depending on the time of day. The rural soundscape has been attempted to be characterized and an indicator set developed for it (De Coensel & Botteldooren, 2006). Previous studies have indicated that natural sounds enhance sound evaluation while traffic and machinery negatively impact evaluations (see section 3.3 for an overview).

For outdoor urban areas acoustic indicators associated with overall sound level have been shown to describe a substantial amount of variance in perceived soundscape quality when averaged for an area ($r=-0.86$ for LA_{eq}, $N = 16$) (Nilsson, Botteldooren, & De Coensel, 2007). While LA_{50} had a slightly higher coefficient LAeq was used as the baseline to recreate conditions in the experimental lab setting. Other studies have demonstrated a significant effect of SPL on overall assessment of natural environments (Mace, et al., 1999) and that subjective evaluation of sound level relates well with the mean Leq (Yang & Kang, 2005a), though is dependent upon the sound source type. Psychoacoustic characteristics of sharpness have also shown to be a significant factor for soundscape evaluation (Jeon, et al., 2012a), though other studies have indicated that acoustic and psychoacoustic variables did not contribute significantly to judgments of pleasantness and vibrancy of soundscape (Hall, et al., 2013).

With these varied previous results this exploratory research selected the sound clips with the most extreme variability in qualities. From the soundscape analysis of St. James's Park (section 5.3.1) the recording location and time that could be viewed as having the most positive characteristics was easily identified at location 6 at 2200 with the lowest Leq (50.9 dBA), Lmax (52.2 dBA), sharpness (1.62 acum), fluctuation strength (0.007 vacil), loudness (23.2 sone) and roughness (2.43 asper) values. In addition, the primary sound source was birds, with a background or traffic.

The most negative sounds were narrowed down to two recordings, both at location 4 at either 07:00 or 12:00: Leq (07:00 60.8 dBA; 12:00 61.4 dBA), Lmax (07:00 64.6 dBA; 12:00 67.5 dBA), sharpness (07:00 2.39 acum; 12:00 2.33 acum), fluctuation strength (07:00 0.009 vacil; 12:00 0.014 vacil), loudness (07:00 37.1 sone; 12:00 38.9 sone) and roughness (07:00 3.32 asper; 12:00 3.27 asper). Ultimately location 4 at 07:00 was chosen as it had higher values for two metrics (sharpness and roughness) vs. one metric (loudness) at 12:00.

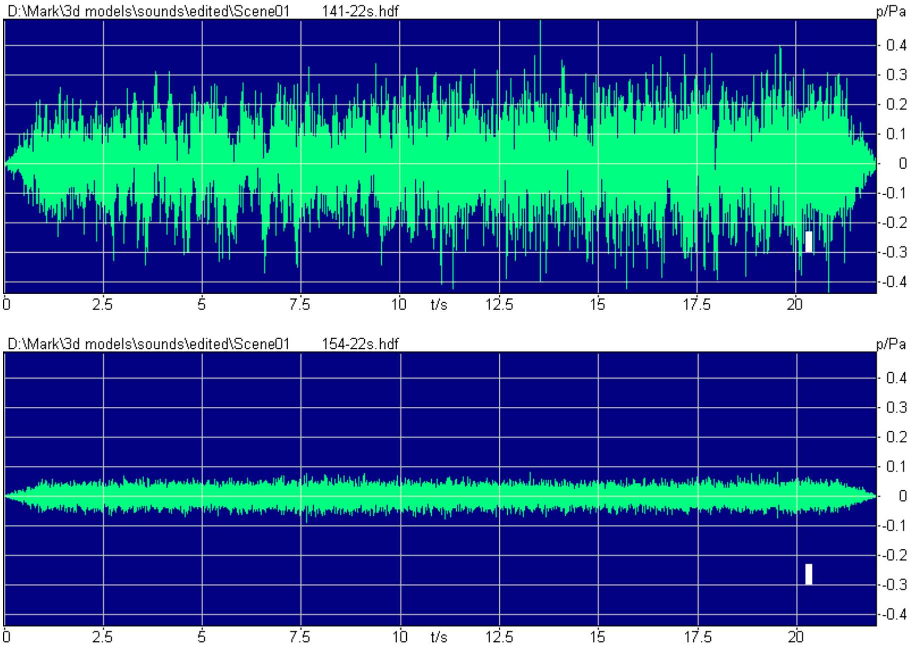

Figure 40: Roughness vs. time of sound stimuli for the mechanical sound (top) and natural sound (bottom)

With one primary sound source mechanical (traffic), and another natural (birds) a third source was selected to provide anthropogenic (speech) as the primary sound source (location 2 at 1200). Recordings containing speech tended towards the mean values for acoustic and psychoacoustic variables (see Table 52), which would provide another potential measure of the importance of these variables for reality and preference of visualizations.

6.3.5.1 Sound length

Relatively short samples (e.g. 6 s – 8s) have proven successful for gathering responses to acoustic effect in previous laboratory based studies (e.g. Bradley & Lang, 2000; Hall, et al., 2013) therefore recordings were edited to 8 s duration clips to be used for stimulus exposure. From each of the three 2-minute clips a segment of 8 seconds was selected based on a minimum of 5 listening tests per segment to identify a segment that had: 1. Relatively equal foreground to background sounds; 2. The fewest sound events that differentiated from the average soundscape. Using Adobe Soundbooth (Adobe, 2010), noise reduction was performed on the 8-second segments to enhance the foreground sound (100% Reduction; Reduced by 5 dB to the traffic and speech segments; 100% Reduction; Reduced by 10 dB to the bird segment). The 8-second segments were matched for loudness using the traffic segment as a baseline resulting in a 0.13 – 11.05 dB change (loc 5 +0.13 dB, speech segment +5.10 dB, bird segment +11.05 dB)[7] as well as a fourth sound that was used to set a comfortable listening level of the audio hardware (location 5 at 1700, +0.13 dB)[8]. All segments were edited to have a 400 ms lead in and lead out to avoid influencing responses via a sudden onset or ending to the sound. Finally the segments had 500 ms of silence added to the beginning of the file so that over slower Internet connections images would be fully loaded on screen before the sound played. Files were exported as 320 Kbps mp3 files that the online system could playback. 320 Kbps compression was chosen as adequate for the task, as previous studies have indicated that most listeners

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[7] In Adobe Soundbooth the ‘Match Volume’ tool provides two options: 1. matching the physical parameters (i.e. dB); or 2. matching perceived parameters (loudness) of one file to one or more other files.

[8] A recording from the site (location 5 @ 1738h) that exhibited characteristics of each of the three recordings used in the main experiment (i.e contained human, natural and mechanical sounds), was embedded in the survey. This site recording was edited to twice as long as the main experiment stimuli, 16 s, and matched to loudness to allow participants to adjust the volume of their audio device to what they evaluated to be a comfortable level.

cannot tell the difference between hi fidelity coded files (e.g. .wav) and anything above 128 Kbps (Böhne et al., 2011) and 320 Kbps is near lossless compression quality.

6.3.6 Online survey design

Virtual environments overcome the major challenges of cost and real-world dynamics inherent in evaluation based methodologies that use real landscapes, yet pose their own challenges. The ecological validity of the virtual reality experience will be controlled by comparing web-based responses to those acquired under controlled laboratory conditions. A culturally diverse and varied age group will be sampled to test against variances in landscape preference based on ethnicity, age, living environment and education level (e.g. Balling & Falk, 1982; Hull & Reveli, 1989; Lewis, 2010; Yu, 1995) as well as soundscape preference based on age, cultural background and environmental experience (e.g. Yang & Kang, 2003; Yang & Kang, 2005b).

Online experiments have advantages and disadvantages when compared to laboratory based experiments. Some advantages include the ability to recruit large, heterogeneous or specialist samples standardize procedures (Birnbaum, 2004), reduced demand on participants, automatic collection and formatting of procedures and data, and the potential increased generalizability of results (Reips, 2002). One of the main disadvantages is the high drop out rate (Roth, 2006). In the context of a problem solving experiment consistent results were attained when using online and lab methods, though online participants were less accurate than lab participants, and as with previous studies there was very high (95.5%) drop out rate (Dandurand, Shultz, & Onishi, 2008). In another study on stimulus ratings a different statistical conclusion was reached when using online or in person data (Barenboym, Wurm, & Cano, 2010).

Previous studies using Internet based surveys where visualizations are the focus found that almost 20 percent of participants commented on image size, brightness, clarity and download times (Laing, Davies, & Scott, 2005). However, these issues have been found in other studies to not significantly influence participant responses; other visualization studies have found correlation between internet and paper-based survey results (Lange, et al., 2008; Wherrett, 2000) and that colour resolution (Bishop, 1997) and monitor size (Wherrett, 2000) do not significantly influence responses. While some studies have indicated screen size can influence realism as measured by presence/immersiveness of a movie, the screen size difference were much larger than desktop monitors (i.e. 1.5m wide compared to 0.89m wide) (Troscianko, Meese, & Hinde, 2012), though another study found that display size did not influence distance perception in natural scenes (Riecke, Behbahani, & Shaw, 2009). Also, with current Internet download speeds and managing the file size of the images the remaining technical issues can be avoided. A recent study also indicated that scenic quality assessment was independent of technological and methodological configurations with little difference in landscape preference reported from different groups (Roth, 2006).

The study used the same internet based online platform for the survey, SurveyGizmo (SurveyGizmo, 2012) to deliver stimuli and collect responses from participants both in the laboratory and online. The online platform selection was informed by previous studies on internet survey providers (Wright, 2005). However, as the previous study was over seven years old at the time of evaluation an entirely new survey was required with a specific focus on sound and image stimuli combinations. At the time of evaluation (July 2012) SurveyGizmo offered the most robust tools for combining audio and video stimuli sources when compared to SurveyMonkey, KwikSurvey, Google Drive, Qualtrics and Limesurvey (which would need to be configured and hosted by the researcher). The features and pricing as of July 2012 for each are shown in Table 14.

Table 14: Online survey software comparison

Company Name/Product	Features*	Audio-video capabilities	Question randomization	Pricing	Service Limitations
Google Drive	Standard features	Video available	Yes (HTML coding required)	Free	Limited in survey sequencing, organization and output (e.g. lacking SPSS)
KwikSurvey	Standard features; educational discount; unlimited questions; full results export	Audio and video; YouTube based surveys	Yes, with subscription	Free basic subscription, $9.99/month student account	Survey housed on company server; student account allows storing 1000 responses
Limesurvey	Standard features	Audio video supported (difficult to implement)	Yes, with subscription	Free and open source	Researcher must setup and host website and database for surveys
Qualtrics	Standard features; advanced question types	Audio and video	Yes, with subscription	Not available on website	Upgrade required for many advanced features
SurveyGizmo	Standard features; educational discount; unlimited questions	Audio, video, combined audio-video	Yes, with subscription	Free; educational discount $49.99/year	Free limited to 350 responses/month; upgrade required for SPSS export
SurveyMonkey	Standard features; unlimited surveys	Audio, video, combined audio-video	Yes, with subscription	Fee basic subscription; $228 annually	limited to 10 questions and 100 responses per survey without payment

* standard features were considered the ability to include in the survey Text; Paragraph text; Multiple choice; Checkboxes; Choose from a list; Scale rank; Grid; Image; and Audio
Note: features and pricing as of July 2012

One of the challenges of the online survey platform was delivery of the stimuli randomized in different sections with non-randomized questions in between (i.e. demographic questions (not randomized); sound ratings (randomized); explanatory text; test ratings (randomized); explanatory text; main survey items (randomized). The survey needed to be separated into 3 different sections. At the end of each section the respondent would seamlessly be forwarded to the next section. Forwarding participants to the next section was a straightforward task given the capabilities of the software, however, the challenge was to link then link one respondents answers together, as no information is automatically collected or passed between surveys. A unique identifier (user id) was used, created by using the built-in random number generator (set to generate a random number of 6 digits), which then could be ‘pushed’ to the next survey using surveygizmo query string construction, then subsequently ‘captured and stored’ those values with a hidden variable on the receiving page. Figure 41 shows the three separate surveys used in the online survey sequence.

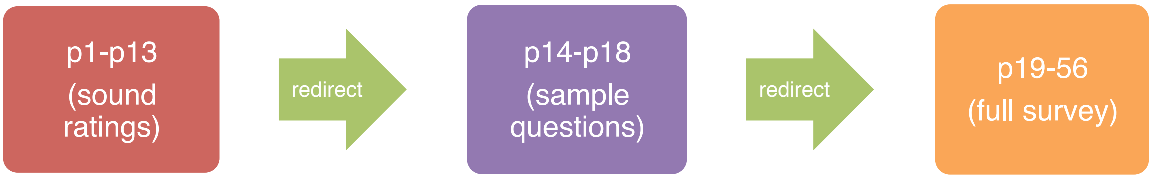


Figure 41: Separate surveys linked together for randomization

Another challenge was that the included audio player of the survey software would show even when the sound was set to play automatically when the page loaded, which distracted from focus on the survey task. Setting the sound player to a width of ‘0’ effectively hid the player from respondents, with the sound set to play immediately upon page loading. For the image stimuli that paired with sound condition 1 (i.e. no sound) in the initial instance the sound player was turned off. However, this resulted in a formatting change on the page as even when the sound player is set to be invisible there is still a space provided for it. Simply leaving a link to the sound file blank resulted in an error message on the page. In the end a link to a ‘fake’ mp3 file was provided (i.e. //fakemp3.mp3) containing no sound, which the survey software registered as a sound file forcing the same page formatting.

6.3.7 Pilot studies

Two forms of pilot studies were conducted to test the user interface and instructions: 1. Incremental prototyping and updating administered to 5 people in person; 2. a finalized online version incorporating feedback from the incremental prototyping and testing that was piloted online. 5 people were chosen for the prototyping as this number has been shown to be enough to identify 80% of usability issues (Virzi, 1992). The main aims of the pilot study were:

1. To test technical issues in the simultaneous delivery of audio and visual stimuli using the online survey (i.e. audio and image download speeds)
2. Evaluate question wording and the rating scales used
3. To generate initial data using the entire experiment apparatus

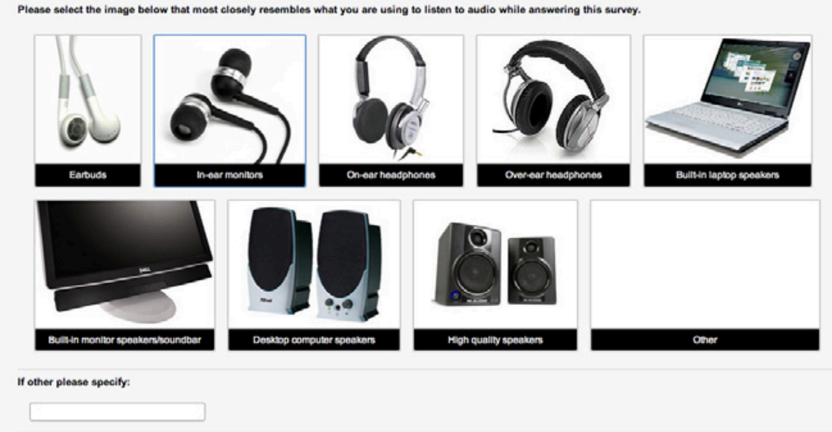
The procedures for the pilot followed those recommended by Peat, Mellis and Williams (2002) outlined in Table 15.

Table 15: Pilot study procedures to improve the internal validity of a questionnaire (from Peat et al. 2002)

Administer the questionnaire to pilot subjects in exactly the same way as it will be administered in the main study
Ask the subjects for feedback to identify ambiguities and difficult questions
Record the time taken to complete the questionnaire and decide whether it is reasonable
Discard all unnecessary, difficult or ambiguous questions
Assess whether each question gives an adequate range of responses
Establish that replies can be interpreted in terms of the information that is required
Check that all questions are answered
Re-word or re-scale any questions that are not answered as expected
Shorten, revise and, if possible, pilot again

6.3.7.1 Incremental prototyping

Incremental prototyping revealed two potential issues with the online survey concerning audio variables: user defined audio hardware and volume level setting. It was raised that while the language used to describe the variety of audio devices available spanned the potential options that would be used by most participants, there could be ambiguity in some terms (e.g. ‘on ear’ vs ‘over ear’ are common terms to describe headphones, though some participants may not be able to distinguish the difference). To address this potential confounding variable both descriptive and visual cues were used combining an image of the audio hardware paired with a verbal label (Figure 42).

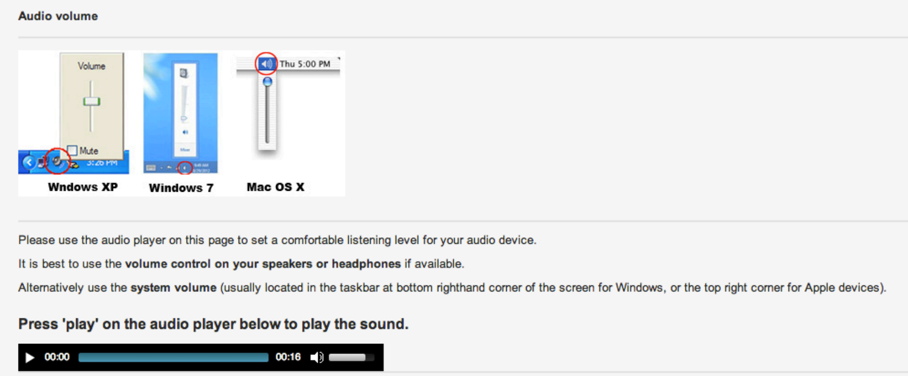


Please select the image below that most closely resembles what you are using to listen to audio while answering this survey.

If other please specify:

Figure 42: Online experiment audio hardware option

The second interface issue raised was participants potentially unable to adjust the volume using the system volume, rather than any built-in volume control on their audio device or web browser. To address this potential confounding variable verbal description combined with a screen shot of the three most ubiquitous system volume settings was provided (Figure 43).



Please use the audio player on this page to set a comfortable listening level for your audio device.

It is best to use the **volume control on your speakers or headphones** if available.

Alternatively use the **system volume** (usually located in the taskbar at bottom righthand corner of the screen for Windows, or the top right corner for Apple devices).

Press 'play' on the audio player below to play the sound.

Figure 43: System volume setting options and location for setting volume in the online survey

6.3.7.2 Pilot study participants

The survey was disseminated via email and Facebook to a mix of design and planning professionals and laypeople, all of whom were known to the researcher. This facilitated the targeting of a sample that would reflect the distribution of participants for final survey, with a mixture of design and planning professionals and laypeople, ranging in age from 25 to 71 (mean 41.14; SD 16.5, mode 28). A total of 35 respondents completed the entire online pilot study (12 female) with 18 partial responses recorded. Participants took between 8 mins and 45 minutes to complete the survey. Average time to complete the survey was 18 mins. A comment box was available on the final page of the online survey for open text responses. Respondents were also emailed following the their participation and asked to provide feedback on any ambiguities or difficult questions, and if they experienced any technical issues with the survey. Comments from the pilot study respondents are presented in Appendix 13.2

6.3.7.3 Pilot study results

Respondents did not indicate any technical issues with the delivery of the survey or with the wording of questions. The rating scales used were evaluated by comparing the mean responses to what was expected (relative to other experiments on preference and realism). Responses of the pilot study were in line with the expected format for visual-based realism and preference studies (e.g. Lange, 2001 for realism; Daniel et al., 2001 for preference). The rating scales incorporated responses across most of the spectrum possible, which validated the scales.

The final aim of the pilot study also involved exploratory analysis of the significance of the generated data. While the data proved neither normally distributed nor spherical this was expected for a small sample size. In addition, ANOVA was used, and is robust even when data is not normally distributed, and figures corrected by Greenhouse-Geisser transformations were used to compensate for lack of sphericity. The results indicated a significant effect and interactions for some of the data. The results were not used for further analysis but indicated that the experiment could obtain reliable responses.

6.4 Apparatus

6.4.1 Laboratory

The laboratory-based part of the experiment used a dual workstation setup. Each workstation was identical except for the audio playback hardware: a Dell Ultrasharp IPS (In Plane Switching) 2209WA monitor (56cm/22” panel size, spatial resolution 1680x1050 pixels WSXGA+ @ 60 Hz, 24 bit colour depth, 1000:1 contrast ratio, 300 cd/m2 brightness, calibrated with a web-based calibration tool by Lagom (www.lagom.nl)[9] connected by DVI-D to a Dell Optiplex PC running Windows 7 with Intel Core 2 Duo processor 2.8 Ghz, Nvidia GeForce 9600 GT graphics card with 512 GB Dedicated Video Memory. The LCD monitor and viewing environment adhered to the ISO 3664:2009 specifications for Graphic Technology and Photography Viewing Conditions (ISO, 2009).

Ambient light at each workstation was measured with a Precision Gold N09AQ 4 in 1 Environment Metre as 650 lux (+/- 50 lx), typical of an average office environment, though far higher than specified in ISO 3664:2009 i.e. 32-64 lux. Overhead lights were disabled directly over each workstation resulting in ambient illumination of 50 lux (+/- 0.7 lux) as measured at each LCD screen. Each monitor was calibrated with a Spyder4Elite Colorimeter by Datacolor (http://www.datacolor.com/en). Light output of each monitor was measured 155 (+/- 1) lumens. The monitor and resolution resulted in

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[9] The online calibration tool was run on each workstation to ensure the monitors were calibrated for colour and brightness. The Brightness 60; Contrast 50; Sharpness 40

an on-screen stimulus image size of 31.04 cm width x 17.46 cm height (12.22 inches x 6.875 inches; 880 x 495 pixels).

Workstation 1 had the ‘high quality’ audio hardware (Sennheiser HD 598 over-ear headphones). Workstation 2 had ‘low quality’ audio hardware (first generation Apple earbuds with no remote or mic). Both sets of audio hardware were connected to the PC via the motherboards integrated 1/8” (3.5mm) connector on the back. The Sennheiser headphones used a high quality gold plated ¼” to 1/8” (6.35mm to 3.5mm) adapter to connect to the audio port, the Apple earbuds used a high quality gold plated extension cable to compensate for the length of their built in cable. Both PC towers were placed on the ground under the desk so fan noise would be as minimally intrusive as possible. SPL of the room was 34.1 dB(A) (LCpk 68.9 dB) measured with a 01dB Solo SLM, ambient temperature was 20.3 degrees Celsius, relative humidity was 38.5%.

6.4.1.1 SPL matching

Matching the output from the online survey via the PC soundcard was necessary to ensure the SPL from each set of audio hardware were identical. To match the output SPL a Neumann KU 100 Dummy Head (Neumann, 2013) binaural microphone was used (e.g. Figure 44).

Figure 44: SPL matching using a Neumann KU 100 Dummy Head binaural microphone

Prior to matching the headphone levels each of the two internal microphones were tested to ensure they were calibrated with each other. The head was dismantled and a 01dB Cal 02 sound calibrator was used to playback a 94 dB 1 KHz reference tone directly into each of the microphones. Each signal was passed through an Edirol R-44

4-channel recorder (Edirol) to a laptop and recorded separately to a .wav file using Adobe Audition 3.0 (Adobe, 2012). The .wav file was then imported into dBBati (01dB) to analyse the SPL and frequency of the signal. Analysis indicated that the left channel was 80.7 dB(A), 79.8 dB and the right channel 80.7 dB(A), 79.9 dB, indicating that the microphones were indeed matched and calibrated with each other, with a 13.3 dB(A) difference from the reference tone. As SPL matching was the aim this was taken into account during subsequent measurement and analysis.

To match the SPL from each workstation a 60 s .wav file was generated in Adobe Audition of white noise and played back on the respective PC through the two different headphones. It was played back through the Neumann KU 100, recorded as .wav file in Adobe Audition 3.0 and analysed in dBBati to evaluate the SPL. Initially the volume was set to 100% through the windows volume settings. The Sennheiser measured channel 1 (left ear) at 78.4 dB(A), channel 2 79.1 db(A); the earbuds measured channel 1 (left ear) at 87.0 dB(A), channel 2 (right ear) at 85.6 dB(A). Reducing the overall volume on workstation 1 (Sennheiser) to 80 percent resulted in measured SPL of 73.4 dB(A) and 74.4 dB(A); 60 percent 68.9 dB(A) and 69.9 dB(A); 40% 64.1 dB(A) and 65.8 dB(A); 20% 54.5 dB(A) and 55.7 dB(A). The overall values are shown in Table 16.

Table 16: High quality/low quality headphone volume calibration values, measured in dB(A)

	Sennheiser HD 598		**Apple earbuds**	
PC volume	**Channel 1 (left)**	**Channel 2 (right)**	**Channel 1 (left)**	**Channel 2 (right)**
100	78.4	79.1	87.0	85.6
80	73.4	74.4	83.0	82.7
60	68.9	69.9	78.5	78.2
40 test 1	65.4 (57.1)	65.6 (57.7)		
40 test 2	65.4	65.6		
40 test 3	65.4	65.6		
25			66.1	65.2
23 test 1			65.5 (57.8)	65.7 (57.1)
23 test 2			65.4	65.7
23 test 3			65.4	65.7
22			64.6	63.8
20	54.5	55.7	63.4	63.2

As a comparison the Sennheiser headphones were connected to workstation 2 to compare the soundcards to each other. At 100% volume left channel was 77.8 dB(A) and 79.3 dB(A), which is very comparable to the 78.4 and 79.1 of workstation 1, therefore the difference in SPL could be attributed to differences between the headphones and earbuds rather than the PC configuration. The SPL of both audio hardware were set as close to 65 dB(A) to be as close to the average SPL measured on site. This was achieved by setting workstation 1 to a level of '40' and workstation 2 to an output level of '23'. Finally, the SPL of the wav files as transmitted via the online survey were compared to those on the local PC, and all measures within 1 dB(A) of each, considered acceptable tolerances for the experimental condition.

6.4.2 Online

The apparatus used for the online study varied by individual, the data collection of which relied on self-reporting in the demographic part of the online survey. Given the focus on sound and image combinations each participant was asked to report their monitor size and audio hardware that is illustrated in Table 17.

Table 17: Online experiment participant hardware (Display; Audio device)

Display size	Freq	%	Audio device	Freq	%
Monitor: 13"-21"	93	72.7	Built-in laptop speakers	37	28.9
Monitor: 22"-27"	21	16.4	Earbuds	22	17.2
Unsure	5	3.9	In-ear monitors	20	15.6
Monitor: less than 13"	4	3.1	Desktop computer speakers	17	13.3
iPad/tablet	3	2.3	On-ear headphones	10	7.8
Monitor: larger than 27"	2	1.6	Built-in monitor speakers/soundbar	9	7.0
Total	128	100	Over-ear headphones	9	7.0
			High quality speakers	2	1.6
			Other	2	1.6
			Total	128	100

6.5 Procedure

The study was conducted in two parts, the main differences being control over hardware delivery of the stimuli, with both using the same online experiment apparatus and materials. Part one delivered the stimuli for rating in a controlled environment allowing for a comparison of results between the two types of experimental conditions (laboratory based and internet based), with a specific focus on the delivery of sound (i.e. high quality headphones vs. low quality earbuds). Part two replicated the stimuli from part one via an Internet based experiment allowing for potentially targeted participants from London and internationally who may be familiar with the site, and to increase the potential number of respondents. Participants were recruited for both conditions via email, a copy of which is provided in Appendix 13.3.

6.5.1 Laboratory and online

For both the lab-based and online parts of the experiment participants were presented with the online survey, the flow of which is illustrated in Figure 45 and an example of the interface shown in Figure 46. Participants answered preliminary questions for data on demographics, site familiarity (Oh, 1994), audio and video hardware, and noise sensitivity (by answering 5 short question on noise sensitivity). Participants then rated the three sounds for the perceived level of loudness and their preference for that sound. Participants were then presented with 4 sample sets of stimuli (two image/sound conditions, two image only conditions) to familiarize themselves with the images (Lange, et al., 2008; Reips, 2002). This was followed by viewing on their own monitor one of the image/sound combinations, with an 8 s duration of sounds, followed by indicating for each on a 1-5 likert-type scale (Lange, et al., 2008) the perceived level of realism and their preference for each item of the stimulus set. To reduce dropout and the negative impact of dropout on the survey data six measures were used that were adapted from Roth (2006), which has been outlined in Table 18.

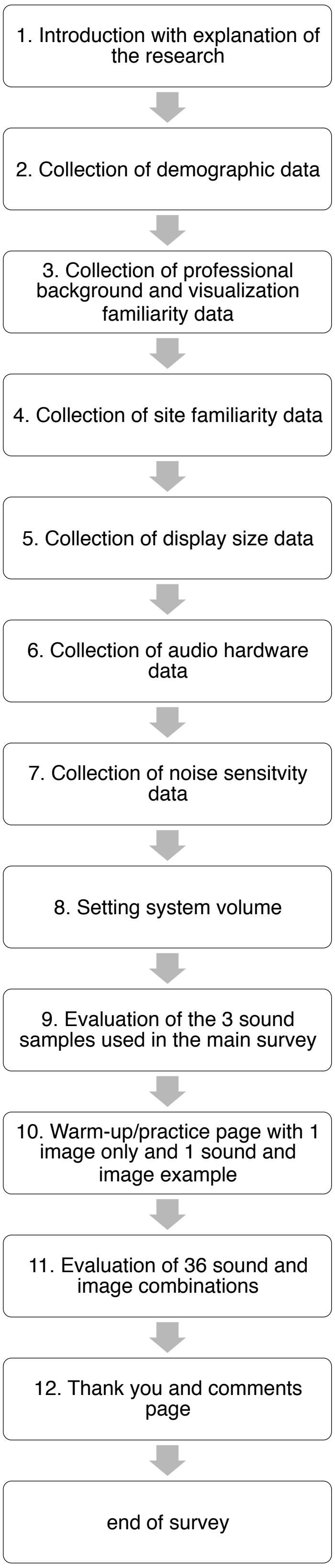

Figure 45: Flow diagram of the web questionnaire

How realistic is your experience of this environment?

not real ○ slightly real ○ somewhat real ○ quite real ○ very real ○

How much do you like this environment?

not at all ○ a little ○ moderately ○ quite a bit ○ very much ○

Figure 46: Example of the online survey

Table 18: Measures taken to reduce dropout and to reduce the negative impact of dropout (adapted from Roth, 2006)

Measure	Description
High-hurdle technique	The demographic data (personalization) were collected before the evaluation of the stimuli
Warm-up technique	The collection of personal data and practicing stimulus rating before the real experiment start ensures that the data collected in the experimental phase comes from the mostly highly committed participants
Incentive	Participants were given the opportunity to be entered in a draw for a gift certificate (£25 online, £50 laboratory participation)
No plug-ins	No plug-ins are needed for the user's PC, the survey works with all modern web browsers.
Two-item-one-screen design	Each rating takes place on a separate web page. The results are transferred and saved to database immediately after clicking the submit button. If the participant drops out, the former results and the point of time of dropout can be examined
Record of response time per page	The response time is recorded for each web page/each rating. If data quality suffers from interruptions of the experiment, this can be identified

Participants were randomly assigned stimuli combinations from the set; visual and sound-visual stimuli were presented according to a 3 (visual) x 4 (sound) factorial design that is shown in Table 19. The stimuli set included 3 visual conditions (terrain only; terrain and built form; terrain, vegetation and some built form) and 4 sound conditions (three sound conditions plus one *no sound* condition) across three different views for 36 different visual/sound combinations.

Table 19: Experimental condition, factorial design (per view x 3 views)

		visual stimuli		
		Condition 1	**Condition 2**	**Condition 3**
acoustic stimuli	**No Sound**			
	Sound 1			
	Sound 2			
	Sound 3			

6.5.2 Laboratory

The experimental procedure included reading an information sheet and signing a consent form (see Appendix 13.4). Participants were then randomly assigned to either the high quality headphone condition or the earbud condition (each participant selecting a piece of paper to allocate them to condition 1 or 2), then following written instructions on-screen. The laboratory was setup so that two participants could conduct the experiment at one time (one with the low quality headphones and one with the high quality headphones (e.g. Figure 47). In some cases two participants took part simultaneously, sometimes one participant, dependent upon how many participants attend a particular session.

The survey completed was identical to the online survey with the exception of a shorter introductory page (participants read a paper copy in the lab and signed a consent form), and the monitor and audio hardware information was automatically populated in the question set. The difference was in control of stimulus delivery (i.e. SPL of headphones and monitor size). Participants were seated 1 metre from the screen and first provided socio-demographic data prior to conducting the questionnaire. LAeq output levels in the headphones used in the lab were matched with those of the field recordings. Data collection was conducted by meeting participants in the laboratory to give general instructions.

Figure 47: Participants in the experiment in the laboratory setting

6.5.3 Online

The experimental procedure included reading the information sheet provided on the first page of the survey, then following written instructions on-screen. The Internet delivered part of the study required participants to use speakers or headphones for the delivery of audio stimuli, which was included in the pre-survey questions to control for any influence when compared to the laboratory condition. In addition, monitor size was also indicated by participants (if known) to evaluate any effect of image size on responses.

6.6 Participants

6.6.1 Participant sampling

Participants in the lab experiment were recruited by the University of Sheffield subject pool email list (students and staff) and by personal contacts, and were eligible to be entered in a draw to win a £50 voucher. Participants in the online experiment were recruited via Facebook and the University of Sheffield subject pool email list (students and staff). Participants in the lab were offered the opportunity to be entered into a draw to win a £25 voucher.

In both the lab-based and online versions of the experiment participants were asked to indicate their gender, age, whether English was their first language, country spent majority of life, professional background, familiarity with 3D computer graphics, experience of 3D computer graphics in design or planning context, site familiarity, monitor size, audio hardware, and noise sensitivity. All of these independent variables are directly tied to the research hypotheses and were included in the final analysis.

A total of 252 respondents participated in the experiment: 181 online (including 40 from the pilot study) and 71 in the lab. There were a total of 47 partial completions in the final experiment and 5 in the pilot study, for a total of 52 non-completions. These were discarded from further analysis. All 71 lab participants completed the full experiment resulting in a total of 200 participants completing the experiment (71 in the lab and 129 online, including 35 from the online pilot study). As a repeated measures design each participant was exposed to each of the 36-image/sound conditions with two questions for each combination (realism; preference), for a total of 72 questions in addition to technical (e.g. monitor type) and demographic information. One participant that completed the experiment online did not answer 44 of the 72 dependent variable questions (61.1%) and was not included in the final analysis resulting in 199 total responses. Three other participants failed to answer for different questions: view 1, condition 3, ‘nature’ sound; view 2, condition 2, ‘speech’ sound; and view 2, condition 2, ‘nature’ sound. As all other questions were answered these 3 were treated as missing values for analysis.

Inclusion criteria were the same for the online and lab based samples. Participants had to exhibit attentiveness by not having an excessively long duration on the main survey questions (i.e. the 36 sound/image combinations). A total time as going to be used but some participants had very long first or last page times (e.g. 580949 seconds) indicating that the survey had likely been opened and left active in a tab, as the corresponding main question times were within a 30 s window.

6.6.2 Participant characteristics

User characteristics were collected prior to the main experiment in the online survey through a series of direct questions. Section 6.3 provides detail of the development of the demographic variables. Details of user characteristics are provided in Table 20.

Table 20: User characteristics (lab, online, and total)

	Lab (n=71)	**Online** (n=128)	**Total** (n=199)
Gender			
Male	26 (36.6%)	59 (46.1%)	85 (42.7%)
Female	45 (63.4%)	69 (53.9%)	114 (57.3%)
Age groups			
15-24 years	33 (46.5%)	47 (36.7%)	80 (40.2%)
25-44 years	30 (42.3%)	54 (42.2%)	84 (42.2%)
45-64 years	8 (11.3%)	21 (16.4%)	29 (14.6%)
65+ years*	0	6 (4.7%)	6 (3.0%)
First language			
English	43 (60.6%)	94 (73.4%)	137 (68.8%)
Other	28 (39.4%)	33 (25.8%)	61 (30.7%)
Missing information	0	1 (0.8%)	1 (0.01%)
Country majority of life			
UK	32 (45.1%)	63 (49.2%)	95 (47.7%)
Canada	1 (1.4%)	19 (14.8%)	20 (10.1%)
United States	2 (2.8%)	11 (8.6%)	13 (6.5%)
China	5 (7.0%)	4 (3.1%)	9 (4.5%)
Mexico	4 (5.6%)	1 (0.8%)	5 (2.5%)
Professional background			
Other	30 (42.3%)	70 (54.7%)	100 (50.3%)
Arch	7 (9.9%)	14 (109%)	21 (10.6%)
Civil Engineering	0	3 (2.3%)	3 (1.5%)
Geography	4 (5.6%)	13 (10.2%)	17 (8.5%)
Horticulture	6 (8.5%)	1 (0.8%)	7 (3.5%)
LA	32 (45.1%)	16 (12.5%)	48 (24.1%)
Planning	6 (8.5%)	9 (7.0 %)	15 (7.5%)
Familiarity w/ 3D computer graphics			
Very much	12 (16.9%)	15 (11.7%)	27 (13.6%)
Quite a bit	11 (15.5%)	25 (19.5%)	36 (18.1%)
Moderately	12 (16.9%)	29 (22.7%)	41 (20.6%)
A little	30 (42.3%)	46 (35.9%)	76 (38.2%)
Not at all	6 (8.5%)	13 (10.2%)	19 (9.5%)
Experience w/ 3D graphics in design/planning			
No	38 (53.5%)	93 (72.7%)	131 (65.8%)
Yes	33 (46.5%)	35 (27.3%)	68 (34.2%)
Noise sensitivity			
Low	25 (35.2%)	41 (32.0%)	66 (33.2%)
Medium	38 (53.5%	71 (55.5%)	109 (54.8%)
High	8 (11.3%)	16 (12.5%)	24 (12.1%)
Site familiarity			
very much	2 (2.8%)	3 (2.3%)	5 (2.5%)
quite a bit	3 (4.2%)	4 (3.1%)	7 (3.5%)
moderately	14 (19.7%)	15 (11.7%)	29 (14.6%)
a little	21 (29.6%)	30 (23.4%)	51 (25.6%)
not at all	31 (43.7%)	76 (59.4%)	107 (53.8%)
Visited site			
Have not visited	38 (53.5%)	85 (66%)	123 (62.9%)
Less frequently	27 (38.0%)	36 (28.1%)	63 (31.7%)
2 or 3 times a year	4 (5.6%)	3 (2.3%)	7 (3.5%)
Once every 2 or 3 months	2 (2.8%)	2 (1.6%)	4 (2.0%)
At least once a month	0	1 (0.8%)	1 (0.01%)
Most days	0	1 (0.8%)	1 (0.01%)

* Not included in the mixed ANOVA due to the small group size

Gender

Participants were 57.3% female (114/199) and 42.7% (85/199) male. Lab based participants were 63.4% (45/71) female and 36.6% (26/71) male. Online participants were 53.9% (69/128) female and 46.1% (59/128) male.

Age

Participants supplied their age as an exact number. Participants average reported age was 31.31 years. Average age for lab participants was 29.2 years (SD=9.8, range 18-61); online participants averaged 32.48 years (SD=14.64, range 18-71).

First language

68.8% (137/199) of participants indicated that English was their first language, with 30.7% (61/199) reporting English as not their first language, and 0.5% (1/199) declining to answer. In the lab experiment 60.6% (43/71) of participants reported English as their first language and 39.4% (28/71) as not. Online 73.4% (94/128) of participants reported English as their first language, 25.8% (33/128) as not, with 0.8% (1/128) declining.

Country

47.7% (95/199) of participants indicated that they had lived the majority of their life in the United Kingdom, followed by Canada (10.1%, 20/199), the United States (6.5%, 13/199) and China (4.5%, 9/199). In the lab experiment the United Kingdom was the most indicated as the country participants spent the majority of their lives (45.1%, 32/71) followed by China (7.0%, 5/71), and Mexico (5.6%, 4/71). Most online participants reported they spent the majority of there life in the United Kingdom (49.2%, 63/128), Canada (14.8%, 19/128), the United States (8.6%, 11/128) and China (3.1%, 4/128). Total frequencies for participant countries are listed in Table 58, Appendix 13.7.

Professional background

Participants were asked to indicate their professional background as Architecture, Civil Engineering, Geography, Horticulture, Landscape Architecture, Planning, or ‘other’. Participants could select multiple options; therefore the total number of responses was higher than the number of participants (i.e. 211 responses vs 199 participants total). The majority of participants (50.3%, 100/211) indicated their professional background as ‘other’ (42.3%, in the lab; 54.7% online) followed by landscape architecture (24.1% overall; 45.1% lab; 12.5% online), and architecture (10.6% overall; 9.9% lab; 10.9% online). The verbal labels provided by participants when choosing ‘other’ are listed in Table 59, Appendix 13.7.

Familiarity with 3D computer graphics

The majority of participants indicated they had some degree of familiarity with 3D computer graphics (90.5%, 180/199) while 9.5% (19/199) indicated they had no familiarity. Lab based participants had a slightly higher familiarity 16.9% (12/71) compared to online participants 11.7% (15/126).

Experience of 3D computer graphics in design or planning context

The majority of participants (65.8%, 131/199) indicated they had no experience with 3D computer graphics in a design and planning context while 34.2 % (68/199) indicated they had some experience. In the lab experiment participants had more experience with computer graphics in a design or planning context, 46.5% (33/71) compared to the online experiment 35 (27.3%).

Noise sensitivity

Participant noise sensitivity was evaluated using a validated, self-reported 5-item noise sensitivity survey and averaging responses to the 5 questions (see section 6.3.1.4 for a discussion of the noise sensitivity survey). Mean responses to the five questions overall (M = 2.94, SD = 0.97) did not vary considerably between lab participants (M = 2.95, SD = 1.03) and online participants (M = 2.93, SD = 0.95).

Site familiarity and site visits

Site familiarity was conceptualized as an interaction between knowledge of the site and number of visits to the site (section 6.3.1.3). This was operationalized with two questions (familiarity with site and number of visits in past year). The majority of participants indicated they were not familiar with the site (107/199, 53.8%) and had not visited the site (123/199, 62.9%), while the remaining participants level of familiarity varied.

6.7 Measurement and analysis method: ANOVA and mixed ANOVA

The degree of realism and preference was calculated based on mean scores for each question and each image for all participants in the test. Analysis of variance (ANOVA) was used to determine the influence of the independent variables on perceived realism and preference as well as the interaction of audio and visual stimuli on perceived realism and preference. Sections 6.7.2 - 6.7.3.1 provide details of data processing, initial analysis for outliers and normality and other ANOVA assumptions, followed by general participant characteristics that are common across all three research questions in section 0. Details specific to each research question are provided in their respective sections.

6.7.1 Statistics reported

ANOVA produces an F-ratio, which is the variation due to the experimental effect divided by the experimental error, and a value above 1 indicates a good ratio (e.g. not too much error) (Field, 2009). Post-hoc tests were used to determine if any significant differences existed between groups in the mixed ANOVA. The chance of a Type I error (falsely rejecting the null hypothesis) increases with multiple comparisons[10], therefore, a Bonferroni correction was used to control the error rate. The Bonferroni correction was chosen over other popular tests (e.g. Tukey) as it guarantees control over Type I errors (Toothaker, 1993). In addition, effect size is reported in partial eta squared (η_p^2), which can be benchmarked against Cohen's (1969) criteria for small (.0099), medium (.0588) and large (.1379) effects (Richardson, 2011).

6.7.2 Data processing

As each participant completed the survey the results were stored online in the software. SurveyGizmo provided the robust functionality to export directly to SPSS, allowing for custom selection of questions and items to be saved. Identical but separate surveys were used to collect the data and each experiment condition (lab and online) was saved as a separate file for analysis. Analysis was conducted in SPSS 21 (version 21.0.0.2).

6.7.3 ANOVA and mixed ANOVA assumptions

The analysis employed a mixed repeated measures ANOVA to evaluate research questions two and three (in order to evaluate the effect of the between subject factors on realism and preference ratings) and a repeated measures ANOVA to evaluate research question one (to evaluate the effect of the within subject independent variables on realism and preference ratings). Both types of analysis rely on a number of assumptions of the underlying data: no significant outliers, normally distributed, sphericity, and, for mixed ANOVA, homogeneity of variance. ANOVA

6.7.3.1 Outliers

There were outliers in the dataset for the two dependent variables 'realism' and 'preference' (36 combinations of view, visual condition and sound each), as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the

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[10] When comparing differences across a group of tests there is an increased chance of a Type 1, or family-wise, error, owing to the cumulative nature of the errors. The increase can be calculated as follows: familywise error = $1 - (.95)^n$.(Field, 2009)

box (Figure 68 and Figure 69, Appendix 13.5). To determine any effect of the outliers on results an ANOVA was conducted comparing the original dataset to the same dataset with the outliers removed. There was no change to significance of F values for realism or preference, and a very small change to the actual F values (Table 54, Appendix 13.5). Based on these results, and because the outliers were deemed representative of the population being sampled, the outliers were kept in the subsequent analysis in order to maximize the data used.

6.7.3.2 Normality

The data was assessed for normality by inspection of absolute values for skew (< 2.0) and kurtosis (< 4.0) (West, Finch, & Curran, 1995)[11]. No substantial departure from normality was indicated for the data. Only 1 out of the 72 DV combinations exceeded the skew and kurtosis values: mean realism rating for view 3, visual condition 1, sound 2 (skew = 2.15, kurtosis = 4.30). As ANOVA has been shown to be robust to even large variations of the normality assumption (e.g. Schmider, Ziegler, Danay, Beyer, & Bühner, 2010) this minor variation was deemed acceptable.

6.7.3.3 Sphericity

ANOVA assumes sphericity, which is the assumption of the equal variances of the differences between levels of the dependent variable, which is tested with Mauchly's test (Field, 2009). A significant result indicates that the data is not spherical, though not meeting this assumption is not severe as corrections can be applied to produce a valid F-ratio, with the Greenhouse-Geisser correction recommended (Field, 2009). The Greenhouse-Geisser correction value is included in the table when the sphericity test is significant.

6.7.3.4 Homogeneity of variance

Research questions 2 and 3 used a mixed ANOVA that additionally requires homogeneity of variance, which is the assumption that the variance of the dependent variable(s) are the same in each group (Field, 2009). This is tested using Levene's test (Levene, 1960), where a significant result indicates that the data violates the assumption. Homogeniety of variance results are reported in Appendix 13.6. For research question 2 there was homogeneity of variance for the majority of responses (479/576, 83.2%) and (204/216, 94.4%) for research question 3. ANOVA is robust

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[11] West et. al suggest kurtosis of < 7.0, however, SPSS calculates 'excess' kurtosis by subtracting 3.0 from the absolute value, therefore, 4.0 is used in the assessment.

against reasonable violations of variance, especially when group sizes are relatively equal (Howell, 2012) therefore analysis continued.

6.7.4 Contrast tables and interaction graphs

ANOVA and mixed ANOVA provide what is known as an omnibus F test, which indicates that a significant difference between means exists; however, the procedure does not pinpoint the specific differences between means. In order to identify which means differ significantly from each other contrasts are performed, which narrow down the significant interaction(s) to specific independent variables. Following analysis of the contrasts an inspection of interaction graphs (e.g. Figure 48) is conducted to identify the specific significant interactions (Dunbar, 1998). Field (2009, p. 445) provides the following points on interpretation of interaction graphs:

- significant interactions are suggested by non-parallel lines
- crossing lines are very non-parallel, which should indicate a significant interaction

While the interaction graphs suggest significant interactions based on visual inspection they always need to be used in combination with ANOVA contrast tables to verify a significant interaction. One final note on interaction graphs: even though the means are not continuous, they are represented with connecting lines to enable easier interpretation (Field, 2009).

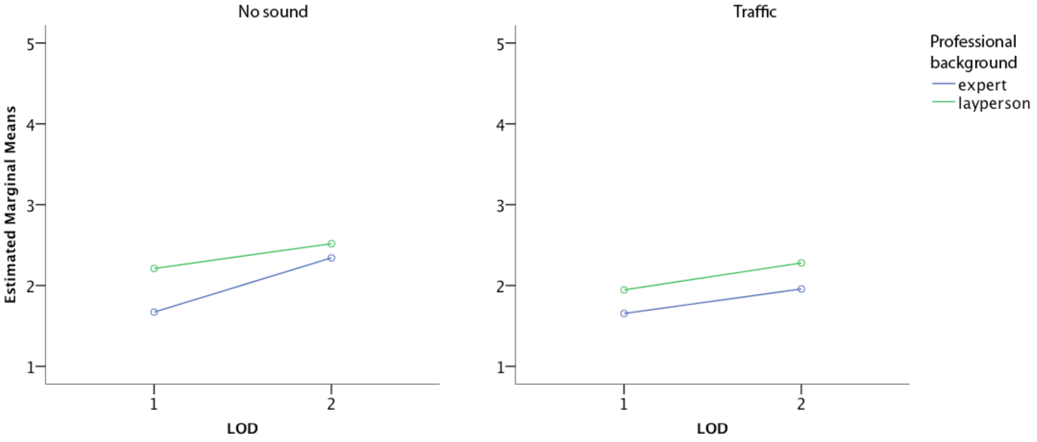

Figure 48: Example interaction graphs, non-parallel lines indicating significant interaction (left); parallel lines indicating no significant interaction (right)

6.8 Summary

The experiment was planned using a repeated measures design, exposing the same participant to 36 different combinations of aural and visual stimuli. In addition, the experiment had within-subject, and between-subject, independent variables. As a result of the presence of dependent groups (i.e. the same participant) combined with some independent groups (e.g. gender) ANOVA and mixed ANOVA were deemed the most suitable to analysing this type of experiment, provided the ANOVA and mixed ANOVA assumptions are met. The data met the majority of assumptions with only minor variations in normality and homogeneity of variance, therefore the ANOVA and mixed ANOVA were concluded to be suitable for analysis.

7 RESEARCH QUESTION 1 ANALYSIS AND RESULTS: REALISM AND PREFERENCE RATINGS BY ALL

Research question 1

How do different landscape elements in visualizations (i.e. terrain, vegetation and built form) interact with different sounds to alter perceived realism of, and preference for, 3D landscape visualizations?

This chapter aims to explore the effects of the interaction of aural and visual stimuli on the perception of realism and preference for all participants. The statistical analysis assumptions, methodology and reported statistics are described in section 6.7. Section 7.1.1 provides results of participant evaluation of loudness and preference for the three sounds used in order to contextualize the main results. Section 7.1.2 presents the results of the realism ratings, with results for preference presented in section 7.1.3. Section 7.2 provides a discussion of the results, while the final section concludes the chapter.

7.1 ANOVA results

7.1.1 Sound characteristics: loudness and preference

To contextualize the sounds used in the experiment participants rated each of the three sounds for loudness and preference to determine if the sounds were perceived differently from each other. Loudness and preference were both assessed by a 1 – 5 point likert-type scale. For loudness the question was posed ‘How loud is this sound?’ Responses ranged from 1 ‘Not loud’ to 5 ‘Very loud’. For preference the question was posed ‘How much do you like this sound?’ Responses ranged from 1 ‘Not at all’ to 5 ‘Very much’. As indicated in Table 21 participants rated the three sounds significantly different for loudness and preference, and for all contrasts.

Table 21: ANOVA and contrasts of loudness and preference for sounds used in the experiment

Source	Contrast	Type III Sum of Squares	df	Mean Square	F	Sig.	η_p^2
Loudness		34.58	2, 396	17.29	36.15	**< .001**	**0.154**
	traffic vs speech	13.07	1, 198	13.07	13.92	**< .001**	0.066
	traffic vs nature	68.79	1, 198	68.79	72.37	**< .001**	**0.268**
	speech vs nature	21.89	1, 198	21.89	22.33	**< .001**	0.101
Preference		99.76	2, 396	49.88	62.20	**< .001**	**0.239**
	traffic vs speech	9.29	1, 198	9.29	5.75	**0.017**	0.028
	traffic vs nature	181.41	1, 198	181.41	104.84	**< .001**	**0.346**
	speech vs nature	108.59	1, 198	108.59	74.03	**< .001**	**0.272**

df = degrees of freedom; F = F ratio; Sig. = significance; η_p^2 = partial eta squared (effect size).
The assumption of sphericity was not violated for loudness: $\chi 2(2) = 0.13$, $p = .937$ or preference: $\chi 2(2) = 1.79$, $p = .409$. Significance (at .05) and Large Effects (> .1379) are in **bold**.

A priori tests were used to examine the two hypotheses that all three sounds would be rated significantly different for loudness from each other (traffic loudest, followed by speech then nature) and that preference would significantly differ between all three (nature most preferred, followed by speech, then traffic). Table 22 characterises the differences between ratings showing mean loudness and preference ratings for each variable.

Table 22: Mean loudness and preference ratings for sounds used in the experiment

	Loudness			Preference		
Source	Mean	SD	N	Mean	SD	N
Traffic	2.68	0.95	199	2.02	1.02	199
Speech	2.42	0.98	199	2.24	0.93	199
Nature	2.09	0.87	199	2.97	1.04	199

7.1.2 Realism

Realism was assessed by a 1 – 5 point likert-type scale (1 ‘Not real’ – 5 ‘Very real’; 0). The combined data (N=199) was analysed by repeated measures ANOVA to determine if there was a statistically significant difference in mean realism ratings at each level of the independent variables. The ANOVA employed three within subject factors with the following levels in each: view(3) x visual condition(3) x sound(4). The results of the ANOVA are shown in Table 23.

Table 23: ANOVA results for realism, all participants

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	η_p^2	**ε***
Realism							
Main effects							
view	17.45	2, 394	8.72	17.14	**< .001**	0.080	
visual condition	874.35	1.56, 307.72	559.75	126.93	**< .001**	**0.392**	0.781
sound	22.50	2.53, 498.43	8.89	6.35	**0.001**	0.031	0.843
Two-way interactions							
view*vis cond.	15.43	4, 788	3.86	7.49	**< .001**	0.037	
view*sound	14.33	6, 1182	2.39	6.79	**< .001**	0.033	
vis cond*sound	231.27	5.23, 1029.38	44.26	46.54	**< .001**	**0.191**	0.871
Three-way interaction							
view*vis cond*sound	19.03	10.31, 2030.98	1.85	4.56	**< .001**	0.023	0.859

df = degrees of freedom; F = F ratio; Sig. = significance; η_p^2 = partial eta squared (effect size).
*A value in this column indicates Mauchly's sphericity test was significant, and the indicated Greenhouse-Geisser correction applied to the results. Significance (at .05) and Large Effects (> .1379) are in **bold**.

As can be seen from the ANOVA table, all main effects and interactions were significant ($p < .05$ for all). The mean ratings are illustrated in Figure 49, grouped by the independent variable of visual condition for each view, and separated by sound type. The mean realism ratings for each combination of view, visual condition and sound type are presented in Table 24.

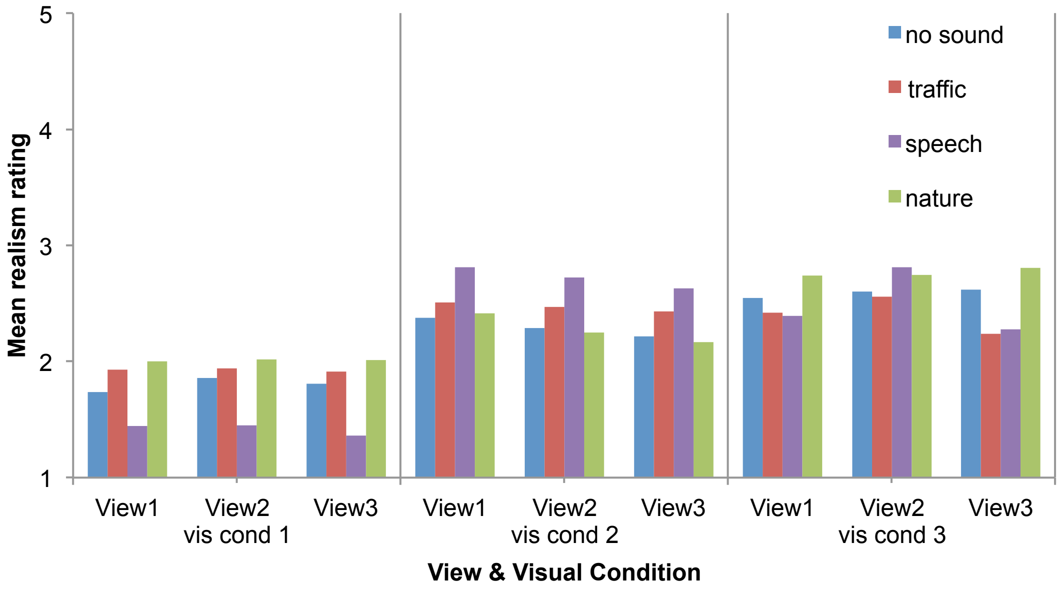

Figure 49: Mean realism rating by sound type for each view and visual condition

Table 24: Mean realism rating for each view, visual condition and sound, n = 198

View	Vis Cond	Sound	Mean	SD	Min	Max
1	1	No sound	1.73	0.99	1	5
		Traffic	1.94	1.05	1	5
		Speech	1.41	0.71	1	4
		Nature	1.98	0.97	1	5
	2	No sound	2.37	0.99	1	5
		Traffic	2.51	1.04	1	5
		Speech	2.82	1.11	1	5
		Nature	2.41	1.05	1	5
	3	No sound	2.57	1.11	1	5
		Traffic	2.43	1.06	1	5
		Speech	2.39	1.06	1	5
		Nature	2.76	1.15	1	5
2	1	No sound	1.84	1.03	1	5
		Traffic	1.94	1.02	1	5
		Speech	1.42	0.74	1	4
		Nature	2.02	1.03	1	5
	2	No sound	2.29	1.04	1	5
		Traffic	2.51	0.99	1	5
		Speech	2.76	1.17	1	5
		Nature	2.26	1.02	1	5
	3	No sound	2.63	1.03	1	5
		Traffic	2.59	1.09	1	5
		Speech	2.85	1.07	1	5
		Nature	2.75	1.07	1	5
3	1	No sound	1.8	1.03	1	5
		Traffic	1.89	1.08	1	5
		Speech	1.33	0.66	1	4
		Nature	2.02	1.02	1	5
	2	No sound	2.22	0.97	1	5
		Traffic	2.41	0.96	1	5
		Speech	2.62	1.08	1	5
		Nature	2.19	0.97	1	5
	3	No sound	2.63	1.12	1	5
		Traffic	2.24	1.10	1	5
		Speech	2.26	1.09	1	5
		Nature	2.81	1.10	1	5

As presented in Figure 49 a clear pattern of the impact of sound on mean realism is evident for visual condition 1 (terrain) and 2 (terrain with built form), while the interaction is more complex for the third visual condition (terrain, vegetation and some built form). The research question focused on the impact of sound on perception while varying landscape elements, therefore the data was analysed further by isolating each visual condition by the level of the variables: view and sound.

7.1.2.1 Realism visual condition 1 (terrain)

A repeated measures ANOVA was run to determine if there were statistically significant differences in realism ratings for visual condition 1 with different sounds. As indicated in Table 25, the ANOVA revealed that the main effect of view, and the interaction of view and sound, was not significant (p = .307 and .301, respectively), indicating that the responses did not differ significantly across the three views. The main effect of sound was significant (p < .0005), supporting the hypothesis that sounds would alter realism ratings. The data was collapsed across views with mean realism ratings computed for each level of the independent variable sound, and post hoc contrasts performed to test the hypothesis.

Table 25: ANOVA and contrasts for realism, visual condition 1

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**η_p^2**	**ε***
Main effects							
view	0.85	2, 396	0.42	1.19	.307	0.006	
sound	132.24	3, 594	44.08	45.50	**< .001**	**0.187**	
Interactions							
view*sound	1.93	5.58, 1104.85	0.35	1.21	.301	0.006	0.93
Contrasts**							
no sound vs traffic	3.49	1, 198	3.49	4.79	.179	0.024	
no sound vs speech	31.89	1, 198	31.89	43.59	**< .001**	**0.18**	
no sound vs nature	8.86	1, 198	8.86	15.58	**.001**	0.073	
traffic vs speech	56.46	1, 198	56.46	83.44	**< .001**	**0.296**	
traffic vs nature	1.23	1, 198	1.23	2.23	.820	0.011	
speech vs nature	74.39	1, 198	74.39	120.56	**< .001**	**0.378**	

df = degrees of freedom; F = F ratio; Sig. = significance; η_p^2 = partial eta squared (effect size).
*A value in this column indicates Mauchly's sphericity test was significant, and the indicated Greenhouse-Geisser correction applied to the results. Significance (at .05) and Large Effects (> .1379) are in **bold**.
. **Contrasts adjusted for multiple comparisons with Bonferroni adjustment

Contrasts are also shown in Table 25, which indicated significant differences between all sound conditions (p < .05 for all) except for the ‘no sound vs. traffic’ condition (p = .179) and the ‘traffic vs. nature’ condition (p = .820). Mean ratings collapsed across view are shown in Table 26.

Table 26: Mean realism ratings by sound for visual condition 1

Source	Mean	Std. Deviation	N
No sound	1.80	0.95	199
Traffic	1.93	0.91	199
Speech	1.40	0.62	199
Nature	2.01	0.90	199

When compared to no sound, traffic sound increased perceived realism of the visualization by 0.13, which was not statistically significant; speech reduced perceived realism by 0.40, which was statistically significant ($p < .001$), while natural sound increased perceived realism by 0.21, which was statistically significant ($p < .001$). Figure 50 illustrates these interactions.

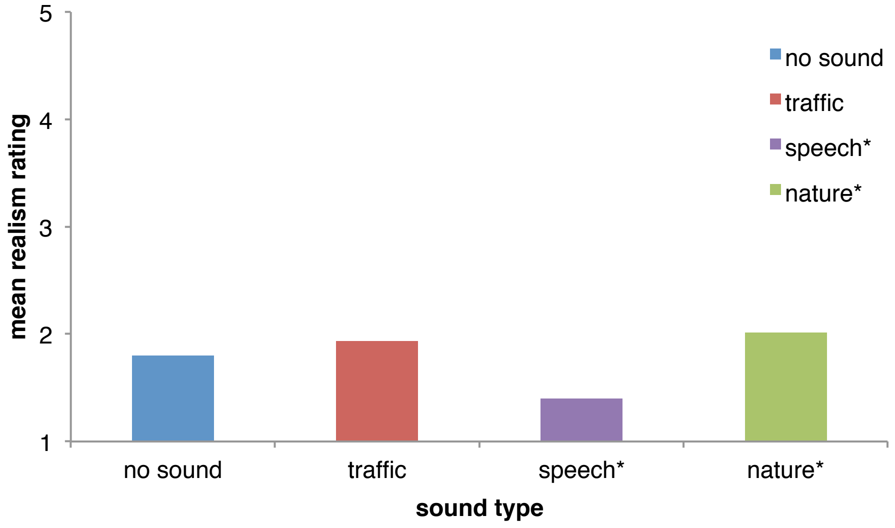

Figure 50: Mean realism ratings for visual condition 1 (*significant difference compared to 'no sound')

7.1.2.2 Realism visual condition 2 (terrain and built form)

A repeated measures ANOVA was run to determine if there were statistically significant differences in realism ratings for visual condition 2 with different sounds. As indicated in Table 27, the ANOVA revealed that the main effects of view and sound were significant ($p < .001$ for both), while the interaction of view and sound was not significant ($p = .684$). This supports the hypothesis that sounds would alter realism ratings, and also indicated there were differences between ratings by view. Contrasts revealed that realism ratings differed significantly between views one and three, and two and three, while view one and two did not differ significantly; therefore view three was considered in isolation while realism ratings for view one and view two were considered together. The contrasts for the three views, and the three views by sound, are shown in Table 27.

Table 27: ANOVA and contrasts for realism, visual condition 2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	η_p^2	ε*
Main effects							
view	11.54	2, 396	5.77	10.81	**< .001**	0.052	
sound	78.50	2.85, 563.29	27.59	30.33	**< .001**	0.133	0.948
Interactions							
view*sound	1.47	5.61, 1110.07	0.26	0.64	0.684	0.003	0.934
Contrasts**							
Views							
view 1 vs view 2	1.02	1, 198	1.02	4.11	0.132	0.02	
view 1 vs view 3	5.72	1, 198	5.72	20.67	**< .001**	0.095	
view 2 vs view 3	1.91	1, 198	1.91	6.95	**0.027**	0.034	
View 1&2 collapsed							
sound	27.67	3, 594	9.22	25.56	**< .001**	0.114	
no sound vs traffic	6.33	1.00	6.33	9.58	**0.014**	0.046	
no sound vs speech	42.07	1	42.07	59.01	**< .001**	**0.230**	
no sound vs nature	0.01	1, 198	0.01	0.02	1.000	0.000	
traffic vs speech	15.76	1.00	15.76	24.52	**< .001**	0.110	
traffic vs nature	5.81	1, 198	5.81	7.14	**0.049**	0.040	
speech vs nature	40.70	1, 198	40.70	47.61	**< .001**	**0.190**	
View 3							
sound	23.60	2.855	8.27	16.29	**< .001**	0.076	
no sound vs traffic	7.29	1, 197	7.29	7.46	**0.034**	0.036	
no sound vs speech	31.52	1, 197	31.52	30.82	**< .001**	0.135	
no sound vs nature	0.18	1, 197	0.18	0.22	1.000	0.001	
traffic vs speech	8.49	1, 197	8.49	9.58	**0.013**	0.046	
traffic vs nature	9.78	1, 197	9.78	10.81	**0.007**	0.052	
speech vs nature	36.49	1, 197	36.49	30.39	**< .001**	0.134	

df = degrees of freedom; F = F ratio; Sig. = significance; η_p^2 = partial eta squared (effect size).
*A value in this column indicates Mauchly's sphericity test was significant, and the indicated Greenhouse-Geisser correction applied to the results. Significance (at .05) and Large Effects (> .1379) are in **bold**.
. **Contrasts adjusted for multiple comparisons with Bonferroni adjustment

As shown in Table 27, contrasts revealed significant differences between realism ratings for all sound combinations ($p < .05$) except for the ‘no sound vs. nature’ condition, which was not significant for any view ($p = 1.000$).

Table 28: Mean realism ratings for visual condition 2 by sound, for each view

	View 1&2		View 3		
Source	**Mean**	**SD**	**Mean**	**SD**	**N**
No sound	2.34	0.91	2.22	0.97	199
Traffic	2.52	0.91	2.42	0.97	199
Speech	2.80	1.02	2.62	1.08	199
Nature	2.34	0.94	2.20	0.97	199

As shown in Table 28, traffic increased realism significantly compared to no sound (+ 0.18 views 1 and 2, + 0.20 view 3) and speech increased realism more so (+ 0.46 views 1 and 2, + 0.40 view 3). Mean realism values for each view are shown in the table with the relationship illustrated in Figure 51.

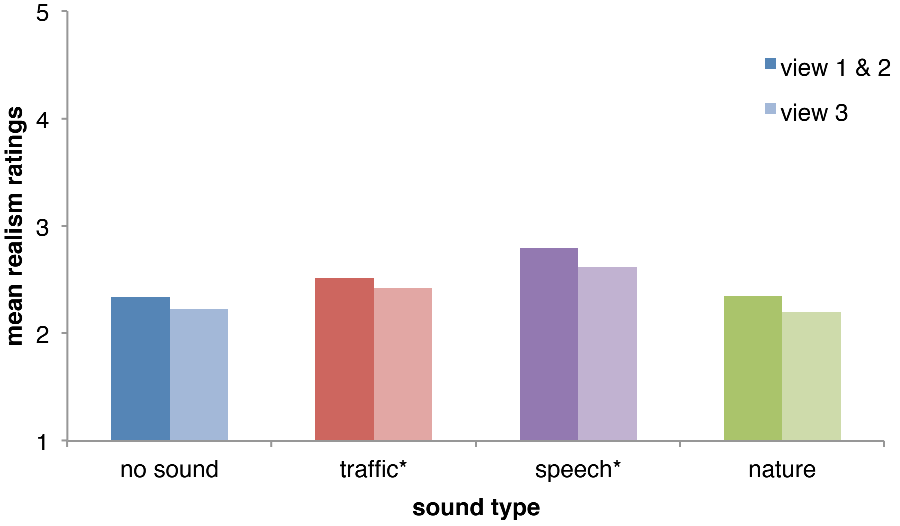

Figure 51: Mean realism ratings for visual condition 2 collapsed across view 1 and 2, compared to view 3 for all sound types.

7.1.2.3 Realism visual condition 3 (terrain, vegetation and some built form)

A repeated measures ANOVA was run to determine if there were statistically significant differences in realism ratings for visual condition 3 with different sounds. As indicated in Table 29, the ANOVA revealed that the main effects and interactions were all significant (p < .0005 for all). This supports the hypothesis that sounds would alter realism ratings, and the interaction indicated that different sounds affected realism ratings differently based on the view. Contrasts revealed that realism ratings differed significantly between view 1 and view 2 (p < .0005 for both) but not between view 1 and view 3 (p = .191). To isolate the interactions contrasts were run for each view at visual condition 3. The contrasts for the three views, and the three views by sound, are shown in Table 29.

Table 29: ANOVA and contrasts for realism, visual condition 3

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**η_p^2**	**ε***
Main effects							
view	20.54	1.93, 380.62	10.63	15.94	**< .001**	0.075	0.966
sound	41.77	2.76, 543.91	15.13	13.91	**< .001**	0.066	0.92
Interactions							
view*sound	30.05	5.58, 1098.34	5.39	12.55	**< .001**	0.06	0.959
Contrasts**							
Views							
view 1 vs view 2	5.58	1, 197	5.58	18.19	**< .001**	0.085	
view 1 vs view 3	0.48	1, 197	0.48	1.72	0.191	0.009	
view 2 vs view 3	9.33	1, 197	9.34	24.56	**< .001**	0.111	
View 1							
sound	16.50	2.88, 567.08	5.73	9.58	**< .001**	0.046	0.96
no sound vs traffic	3.96	1, 197	3.96	2.98	0.516	0.015	
no sound vs speech	6.55	1, 197	6.55	5.25	0.138	0.026	
no sound vs nature	6.91	1, 197	6.91	5.58	0.115	0.028	
traffic vs speech	0.32	1, 197	0.32	0.37	1.000	0.002	
traffic vs nature	21.34	1, 197	21.34	18.30	**< .001**	0.085	
speech vs nature	26.91	1, 197	26.91	25.98	**< .001**	0.117	
View 2							
sound	8.52	2.84, 562.08	3.00	5.13	**0.002**	0.025	0.946
no sound vs traffic	0.25	1, 197	0.25	0.19	1.000	0.001	
no sound vs speech	9.78	1, 197	9.78	8.15	**0.029**	0.04	
no sound vs nature	3.16	1, 197	3.16	3.38	0.404	0.017	
traffic vs speech	13.14	1, 197	13.14	14.08	**0.001**	0.067	
traffic vs nature	5.17	1, 197	5.17	4.34	0.199	0.022	
speech vs nature	1.82	1, 197	1.83	1.65	1.000	0.008	
View 3							
sound	46.76	2.85, 564.95	16.39	23.37	**< .001**	0.106	0.951
no sound vs traffic	29.94	1, 197	29.94	21.29	**< .001**	0.098	
no sound vs speech	26.91	1, 197	26.91	15.87	**0.001**	0.075	
no sound vs nature	6.55	1, 197	6.55	5.09	0.151	0.025	
traffic vs speech	0.08	1, 197	0.08	0.07	1.000	0.000	
traffic vs nature	64.49	1, 197	64.49	55.60	**< .001**	**0.22**	
speech vs nature	60.01	1, 197	60.01	43.62	**< .001**	**0.181**	

df = degrees of freedom; F = F ratio; Sig. = significance; η_p^2 = partial eta squared (effect size).
*A value in this column indicates Mauchly's sphericity test was significant, and the indicated Greenhouse-Geisser correction applied to the results. Significance (at .05) and Large Effects (> .1379) are in **bold**.
. **Contrasts adjusted for multiple comparisons with Bonferroni adjustment

Contrasts revealed varied significant differences between realism ratings depending on the view. Table 30 provides specifics of the mean realism ratings for each view and sound condition; Figure 52 illustrates the relationship. As shown, all views were rated similarly with no sound, and had similar increases in realism when accompanied by the natural sound (+ 0.19, 0.12, 0.18, respectively), which were not significant (p > .05 for all). Traffic sound lowered realism for all compared to no sound, but by varying degrees: 0.14 for view one; 0.04 for view 2; and 0.39 for view three, which was only significant for view three (p < .0005). Interestingly, speech lowered mean realism ratings for view one and three (significant for view three, p = .001) but raised realism significantly for view two (+ 0.22, p = .029).

Table 30: Mean realism ratings for visual condition 3 by sound, for each view

	View 1		**View 2**		**View 3**		
Source	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**N**
No sound	2.57	1.11	2.63	1.03	2.63	1.12	198
Traffic	2.43	1.06	2.59	1.09	2.24	1.10	199
Speech	2.39	1.06	2.85	1.07	2.26	1.09	199
Nature	2.76	1.15	2.75	1.07	2.81	1.10	199

When comparing the effects of sounds to each other, traffic sound compared to speech resulted in very little change to mean ratings for views one and three (+ 0.04, - 0.02, respectively, not significant), but resulted in a significant positive increase (+ 0.26, p = .001). Additionally traffic compared to speech and nature was significantly different for views one and three, but not for view two.

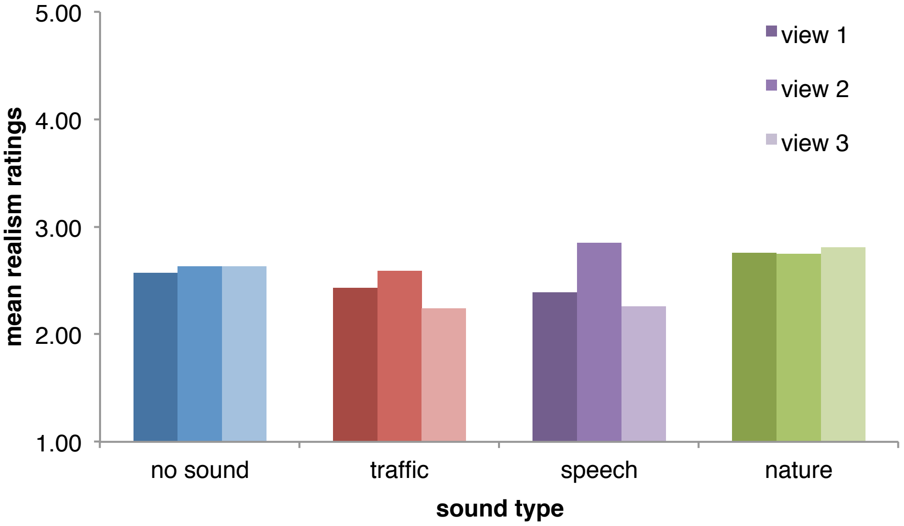

Figure 52: Mean realism ratings for visual condition 3 at each view, for all sound types

7.1.3 Preference

Preference was assessed by a 1 – 5 point likert-type scale (1 ‘Not at all’ – 5 ‘Very much’;). The combined data (N=199) was analysed by repeated measures ANOVA to determine if there was a statistically significant difference in mean preference ratings at each level of the independent variables. The ANOVA employed three within subject factors with the following levels in each: view(3) x visual condition(3) x sound(4). The results of the ANOVA are shown in Table 31.

Table 31: ANOVA results for preference, all participants

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**η_p^2**	**ε***
Preference							
Main effects							
view	15.29	2, 392	7.65	13.57	**< .001**	0.065	
visual condition	840.16	1.53, 299.81	549.26	145.71	**< .001**	**0.426**	0.765
sound	291.36	2.74, 536.23	106.50	55.84	**< .001**	**0.222**	0.912
Two-way interactions							
view*vis cond	33.84	3.74, 732.01	9.06	16.32	**< .001**	0.077	0.934
view*sound	5.75	5.63, 1103.20	1.02	2.87	**0.011**	0.014	0.938
vis cond*sound	131.18	5.57, 1091.61	23.55	37.14	**< .001**	**0.159**	0.928
Three-way interaction							
view*vis cond*sound	20.90	10.85, 2125.76	1.93	5.30	**< .001**	0.026	0.904

df = degrees of freedom; F = F ratio; Sig. = significance; η_p^2 = partial eta squared (effect size).
*A value in this column indicates Mauchly's sphericity test was significant, and the indicated Greenhouse-Geisser correction applied to the results. Significance (at .05) and Large Effects (> .1379) are in **bold**.
. **Contrasts adjusted for multiple comparisons with Bonferroni adjustment

As can be seen from the ANOVA table, all main effects and interactions were significant (p < .05 for all). The mean preference ratings for each combination of view, visual condition and sound type are given in Table 32, with the independent variable of visual condition grouped by view and separated by sound type illustrated in Figure 53.

Table 32: Mean preference rating for each view, visual condition and sound, n = 197

View	Vis cond	Sound	Mean	SD	Min	Max
1	1	No sound	1.87	1.08	1	5
		Traffic	1.72	0.91	1	5
		Speech	1.54	0.77	1	4
		Nature	2.15	1.05	1	5
	2	No sound	2.62	1.02	1	5
		Traffic	2.25	1.01	1	5
		Speech	2.56	1.00	1	5
		Nature	2.63	1.03	1	5
	3	No sound	3.01	1.10	1	5
		Traffic	2.39	0.97	1	5
		Speech	2.36	0.92	1	5
		Nature	3.07	1.07	1	5
2	1	No sound	2.06	1.11	1	5
		Traffic	1.89	0.99	1	5
		Speech	1.56	0.78	1	4
		Nature	2.29	1.12	1	5
	2	No sound	2.44	1.00	1	5
		Traffic	2.11	0.93	1	5
		Speech	2.49	0.95	1	5
		Nature	2.45	1.02	1	5
	3	No sound	2.95	1.03	1	5
		Traffic	2.44	0.97	1	5
		Speech	2.72	1.01	1	5
		Nature	3	1.04	1	5
3	1	No sound	1.97	1.08	1	5
		Traffic	1.83	1.03	1	5
		Speech	1.51	0.75	1	5
		Nature	2.23	1.14	1	5
	2	No sound	2.22	0.90	1	4
		Traffic	2.01	0.85	1	5
		Speech	2.29	0.84	1	5
		Nature	2.28	0.99	1	5
	3	No sound	3.13	1.07	1	5
		Traffic	2.24	1.01	1	5
		Speech	2.35	0.97	1	5
		Nature	3.06	1.06	1	5

As can be seen in Figure 53 a clear pattern of the impact of sound on mean preference ratings is evident for visual conditions 1 (terrain) and 2 (terrain and built form) across all views, with a slightly more complex interaction across views for visual condition 3 (terrain, vegetation and some built form). The research question focused on the impact of sound with varying landscape elements, therefore the data was analysed further by isolating each visual condition by the level of the variables: view and sound.

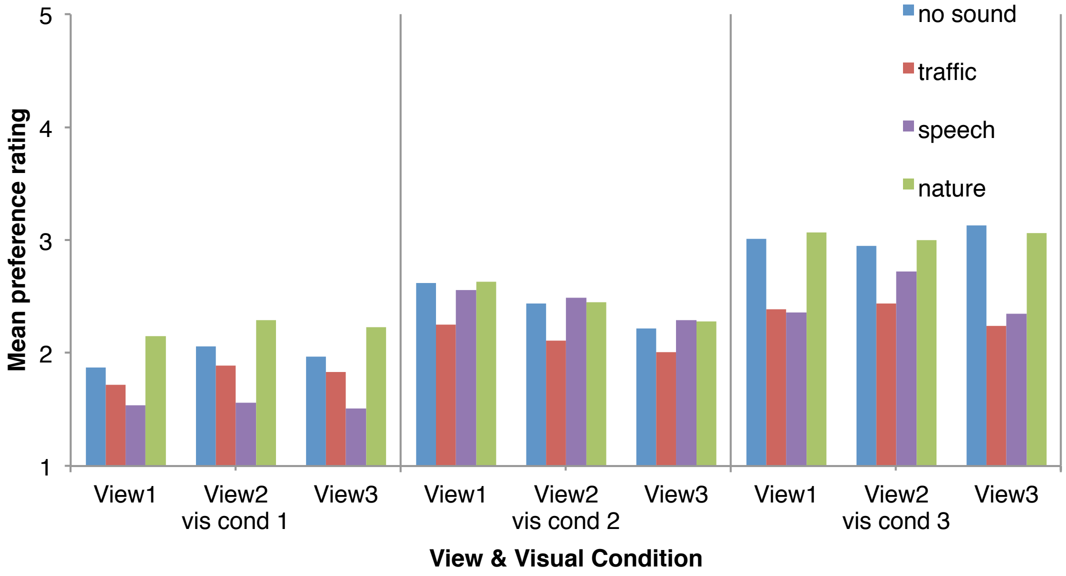

Figure 53: Mean preference rating by sound type for each view and visual condition

7.1.3.1 Preference visual condition 1 (terrain)

A repeated measures ANOVA was run to determine if there were statistically significant differences in preference ratings for visual condition 1 with different sounds. As indicated in Table 33, the ANOVA revealed that the main effect of view and sound were significant ($p < .0005$) though not the interaction. This supported the hypothesis that sounds would alter preference ratings, and also indicated there were differences between ratings by view. Contrasts revealed that preference ratings differed significantly between views one and two, and two and three, while view one and three did not differ significantly; therefore view two was considered in isolation while preference ratings for view one and view three were considered together. The contrasts for the three views, and the three views by sound, are shown in Table 33 with mean realism ratings shown in Table 34.

Table 33: ANOVA and contrasts for preference, visual condition 1

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**η_p^2**	**ε***
Main effects							
view	7.33	1.90, 375.21	3.87	10.77	**< .001**	0.052	0.948
sound	148.02	3, 594	49.34	50.85	**< .001**	**0.204**	
Interactions							
view*sound	2.12	5.60, 1108.15	0.38	1.26	0.275	0.006	0.933
Contrasts**							
Views							
view 1 vs view 2	3.66	1, 198	3.66	18.92	**< .001**	0.087	
view 1 vs view 3	0.95	1, 198	0.95	5.10	0.075	0.025	
view 2 vs view 3	0.88	1, 198	0.88	6.77	**0.030**	0.033	
View 1&3 collapsed							
sound	46.08	3, 594	15.36	43.90	**< .001**	**0.181**	
no sound vs traffic	3.94	1, 198	3.94	5.38	0.129	0.026	
no sound vs speech	32.16	1, 198	32.16	40.60	**< .001**	**0.17**	
no sound vs nature	13.85	1, 198	13.85	22.59	**< .001**	0.102	
traffic vs speech	13.59	1, 198	13.59	22.34	**< .001**	0.101	
traffic vs nature	32.56	1, 198	32.56	44.41	**< .001**	**0.183**	
speech vs nature	88.22	1, 198	88.22	122.56	**< .001**	**0.382**	
View 2							
sound	56.64	3, 594	18.88	34.23	**< .001**	**0.147**	
no sound vs traffic	4.83	1, 198	4.83	4.02	0.279	0.02	
no sound vs speech	50.25	1, 198	50.25	44.47	**< .001**	**0.183**	
no sound vs nature	10.63	1, 198	10.63	10.56	**0.008**	0.051	
traffic vs speech	23.93	1, 198	23.93	23.80	**< .001**	0.107	
traffic vs nature	29.79	1, 198	29.79	27.16	**< .001**	0.121	
speech vs nature	107.12	1, 198	107.12	91.07	**< .001**	**0.315**	

df = degrees of freedom; F = F ratio; Sig. = significance; η_p^2 = partial eta squared (effect size).
*A value in this column indicates Mauchly's sphericity test was significant, and the indicated Greenhouse-Geisser correction applied to the results. Significance (at .05) and Large Effects (> .1379) are in **bold**.
. **Contrasts adjusted for multiple comparisons with Bonferroni adjustment

Table 34: Mean preference ratings for visual condition 1 by sound, for each view

	View 1&3		**View 2**		
Source	**Mean**	**SD**	**Mean**	**SD**	**N**
No sound	1.93	1.02	2.07	1.12	199
Traffic	1.79	0.90	1.91	1.01	199
Speech	1.53	0.65	1.56	0.78	199
Nature	2.19	1.02	2.30	1.13	199

As shown in Table 33 contrasts revealed significant differences between realism ratings for all sound combinations ($p < .05$) except for the 'no sound vs. traffic' condition, which was not significant for any view. The relationship is illustrated in Figure 54.

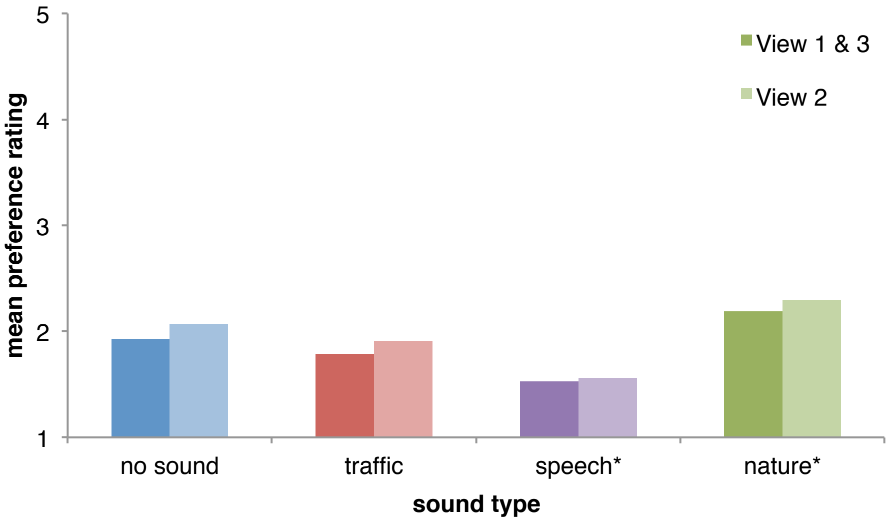

Figure 54: Mean preference ratings for visual condition 1 collapsed across view 1 and 3, compared to view 2 for all sound types.

7.1.3.2 Preference visual condition 2 (terrain and built form)

A repeated measures ANOVA was run to determine if there were statistically significant differences in preference ratings for visual condition 2 with different sounds. As indicated in Table 35, the ANOVA revealed that the main effect of view and sound were significant ($p < .0005$) though not the interaction. This supported the hypothesis that sounds would alter preference ratings, and also indicated there were differences between ratings by view. Contrasts revealed that preference ratings differed significantly between all views ($p < .005$ for all); therefore all views were considered independently. The contrasts for the three views, and the three views by sound, are shown in Table 35.

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Table 35: ANOVA and contrasts for preference, visual condition 2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	η_p^2	ε*
Main effects							
view	39.42	1.90, 371.65	20.79	31.67	**< .001**	**0.139**	0.948
sound	44.59	2.86, 561.38	15.57	18.90	**< .001**	0.088	0.955
Interactions							
view*sound	2.20	6, 1176	0.37	1.11	0.354	0.006	
Contrasts**							
Views							
view 1 vs view 2	4.20	1, 196	4.20	13.46	**< .001**	0.064	
view 1 vs view 3	19.67	1, 196	19.67	52.62	**< .001**	**0.212**	
view 2 vs view 3	5.70	1, 196	5.70	22.00	**< .001**	0.105	
View 1							
sound	18.63	3, 594	6.21	12.40	**< .001**	0.059	
no sound vs traffic	27.52	1, 198	27.52	25.90	**< .001**	0.116	
no sound vs speech	1.29	1, 198	1.29	1.35	1.000	0.007	
no sound vs nature	0.00	1, 198	0.00	0.00	1.000	0.000	
traffic vs speech	16.91	1, 198	16.91	17.89	**< .001**	0.083	
traffic vs nature	27.52	1, 198	27.52	25.89	**< .001**	0.116	
speech vs nature	1.29	1, 198	1.29	1.39	1.000	0.007	
View 2							
sound	17.87	3, 588	5.96	11.31	**< .001**	0.055	
no sound vs traffic	20.79	1, 196	20.79	18.94	**< .001**	0.088	
no sound vs speech	0.51	1, 196	0.51	0.44	1.000	0.002	
no sound vs nature	0.02	1, 196	0.02	0.02	1.000	0.000	
traffic vs speech	27.80	1, 196	27.80	30.57	**< .001**	0.135	
traffic vs nature	22.11	1, 196	22.11	19.71	**< .001**	0.091	
speech vs nature	0.33	1, 196	0.33	0.29	1.000	0.001	
View 3							
sound	10.82	2.88, 569.40	3.76	8.52	**< .001**	0.041	0.959
no sound vs traffic	9.29	1, 198	9.29	10.01	**0.011**	0.048	
no sound vs speech	1.13	1, 198	1.13	1.62	1.000	0.008	
no sound vs nature	0.72	1, 198	0.72	0.83	1.000	0.004	
traffic vs speech	16.91	1, 198	16.91	24.06	**< .001**	0.108	
traffic vs nature	15.20	1, 198	15.20	16.20	**< .001**	0.076	
speech vs nature	0.05	1, 198	0.05	0.05	1.000	0.000	

df = degrees of freedom; F = F ratio; Sig. = significance; η_p^2 = partial eta squared (effect size).
*A value in this column indicates Mauchly's sphericity test was significant, and the indicated Greenhouse-Geisser correction applied to the results. Significance (at .05) and Large Effects (> .1379) are in **bold**.
. **Contrasts adjusted for multiple comparisons with Bonferroni adjustment

Contrasts revealed varied significant differences between realism ratings depending on the view. Table 36 provides specifics of the mean realism ratings for each view and sound condition; Figure 55 illustrates the relationship. As shown, there was a clear downward trend in preference ratings between views; view one was most preferred, followed by view two, with view three least preferred, which all differed significantly ($p < .0005$ for all). In addition, traffic sound significantly reduced preference for all views ($p < .05$ for all), while speech and natural sound did not have a significant impact ($p > .05$).

Table 36: Mean preference ratings for visual condition 2 by sound, for each view

	View 1		View 2		View 3		
Source	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**N**
No sound	2.62	1.02	2.44	1.00	2.22	0.91	199
Traffic	2.25	1.01	2.11	0.93	2.01	0.84	199
Speech	2.54	1.01	2.49	0.95	2.30	0.85	199
Nature	2.62	1.03	2.45	1.02	2.28	1.00	199

When comparing the effects of sounds to each other, there were significant differences for traffic sound compared to speech, and traffic sound compared to nature, for all views ($p < .0005$ for all). There was no significant difference for speech compared to nature for all views ($p = 1.000$).

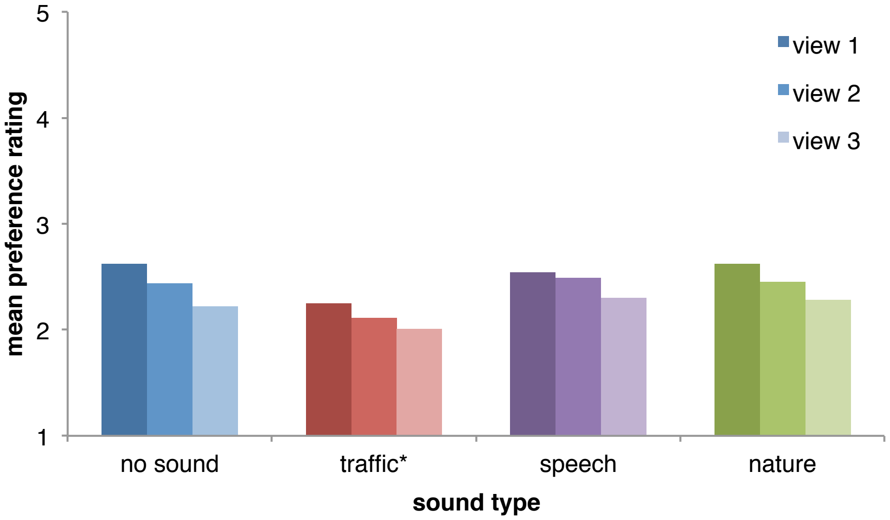

Figure 55: Mean preference ratings for visual condition 2 at each view, for all sound types

7.1.3.3 Preference visual condition 3 (terrain, vegetation and some built form)

A repeated measures ANOVA was run to determine if there were statistically significant differences in preference ratings for visual condition 3 with different sounds. As indicated in Table 37, the ANOVA revealed that the main effect of view was not significant (p = .085), while the main effect of sound and the interaction of view and sound was significant (p < .0005 for both). To isolate the interactions contrasts were run for each view at visual condition 3. The contrasts for the three views, and the three views by sound, are shown in Table 37.

Table 37: ANOVA and contrasts for preference, visual condition 3

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**η_p^2**	**ε***
Main effects							
view	3.22	1.90, 376.88	1.69	2.51	0.085	0.013	0.952
sound	231.01	2.80, 553.97	82.57	65.51	**< .001**	**0.249**	0.933
Interactions							
view*sound	23.14	5.6, 1108.84	4.13	9.99	**< .001**	0.048	0.933
View 1							
sound	91.46	2.88, 569.16	31.82	44.68	**< .001**	**0.184**	0.958
no sound vs traffic	77.27	1, 198	77.27	52.26	**< .001**	**0.209**	
no sound vs speech	90.23	1, 198	90.23	56.22	**< .001**	**0.221**	
no sound vs nature	0.61	1, 198	0.61	0.54	1.000	0.003	
traffic vs speech	0.50	1, 198	0.50	0.40	1.000	0.002	
traffic vs nature	91.58	1, 198	91.58	66.32	**< .001**	**0.251**	
speech vs nature	105.65	1, 198	105.65	78.25	**< .001**	**0.283**	
View 2							
sound	38.94	3, 594	12.98	22.41	**< .001**	0.102	
no sound vs traffic	52.28	1, 198	52.28	47.99	**< .001**	**0.195**	
no sound vs speech	10.18	1, 198	10.18	8.30	**0.026**	0.04	
no sound vs nature	0.41	1, 198	0.41	0.43	1.000	0.002	
traffic vs speech	16.33	1, 198	16.33	12.90	**0.002**	0.061	
traffic vs nature	61.92	1, 198	61.92	52.15	**< .001**	**0.208**	
speech vs nature	14.65	1, 198	14.65	11.92	**0.004**	0.057	
View 3							
sound	123.75	2.85, 564.07	43.44	60.09	**< .001**	**0.233**	0.950
no sound vs traffic	150.40	1, 198	150.40	88.47	**< .001**	**0.309**	
no sound vs speech	120.73	1, 198	120.73	77.04	**< .001**	**0.280**	
no sound vs nature	1.29	1, 198	1.29	1.11	1.000	0.006	
traffic vs speech	1.63	1, 198	1.63	1.25	1.000	0.006	
traffic vs nature	123.86	1, 198	123.86	92.50	**< .001**	**0.318**	
speech vs nature	97.09	1, 198	97.09	82.89	**< .001**	**0.295**	

df = degrees of freedom; F = F ratio; Sig. = significance; η_p^2 = partial eta squared (effect size).
*A value in this column indicates Mauchly's sphericity test was significant, and the indicated Greenhouse-Geisser correction applied to the results. Significance (at .05) and Large Effects (> .1379) are in **bold**.
. **Contrasts adjusted for multiple comparisons with Bonferroni adjustment

Contrasts revealed similar effects of sound across views one – three. Table 38 provides mean preference ratings for each view and sound; Figure 56 illustrates the relationship. As shown, traffic and speech both lowered preference ratings significantly compared to no sound (traffic: - 0.63, - 0.51, - 0.87; speech: - 0.68, - 0.23, - 0.78; $p < .05$ for all) while natural sound did not significantly alter preference ($p = 1.000$).

Table 38: Mean preference ratings for visual condition 3 by sound, for each view

	View 1		**View 2**		**View 3**		
Source	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**N**
No sound	3.02	1.10	2.95	1.04	3.13	1.08	199
Traffic	2.39	0.97	2.44	0.98	2.26	1.03	199
Speech	2.34	0.93	2.72	1.02	2.35	0.96	199
Nature	3.07	1.07	2.99	1.05	3.05	1.06	199

When comparing the effects of sounds to each other the interaction can be identified. There is no significant difference between traffic and speech for views one and three ($p = 1.000$). For view two speech resulted in far less of a difference from the 'no sound' condition, which was significantly different from traffic ($p = .002$). Natural sound was significantly higher than traffic and speech ($p < .05$ for all).

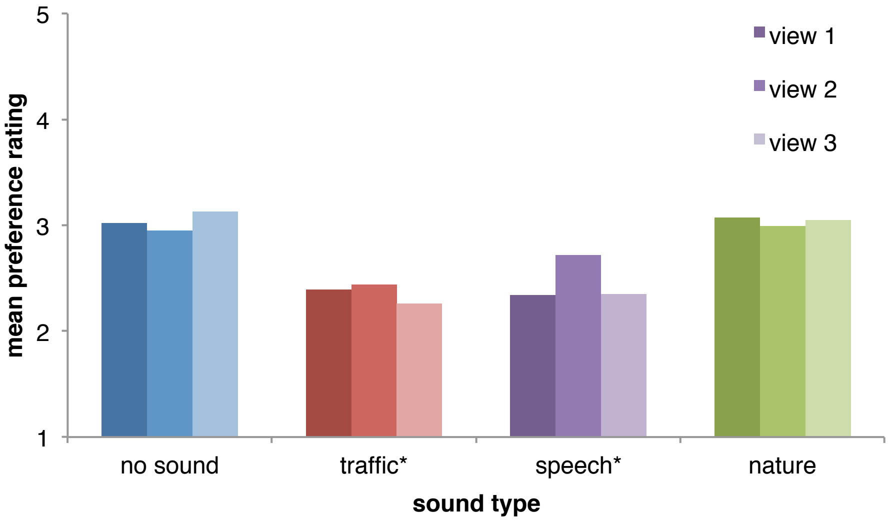

Figure 56: Mean preference ratings for visual condition 3 at each view, for all sound types

7.1.4 Realism and preference: mean differences

In order to compare the impact of sound on realism and preference across all three visual conditions the mean rating difference for all sounds compared to the 'no sound' condition for each visual condition and view are shown in Figure 57 and Figure 58 which are discussed further the following section.

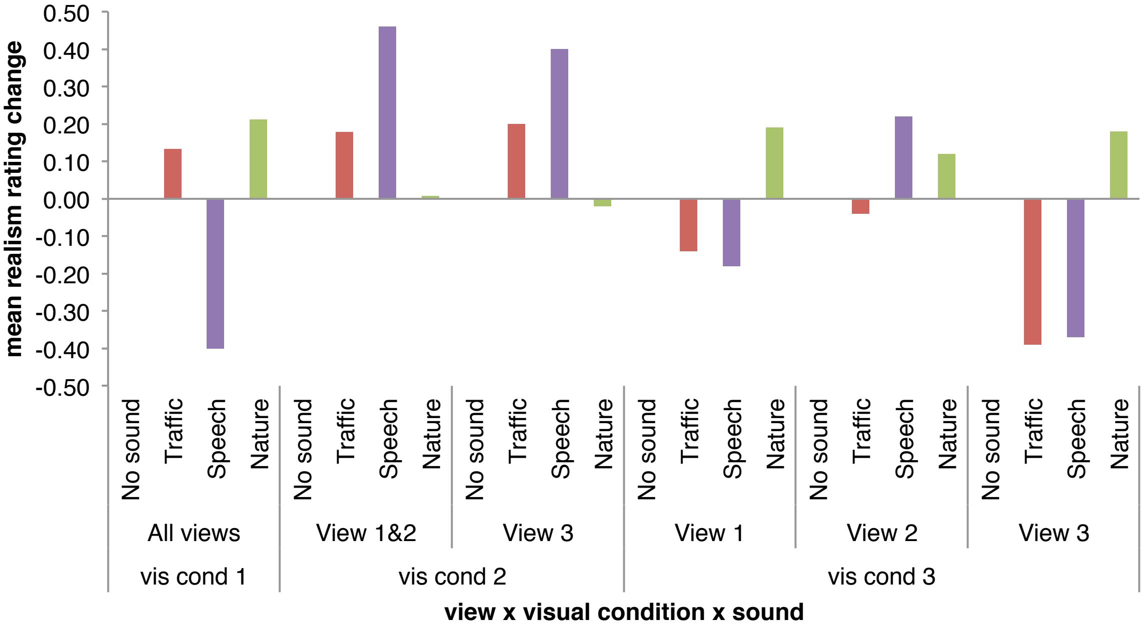

Figure 57: Mean realism rating change relative to 'no sound' condition

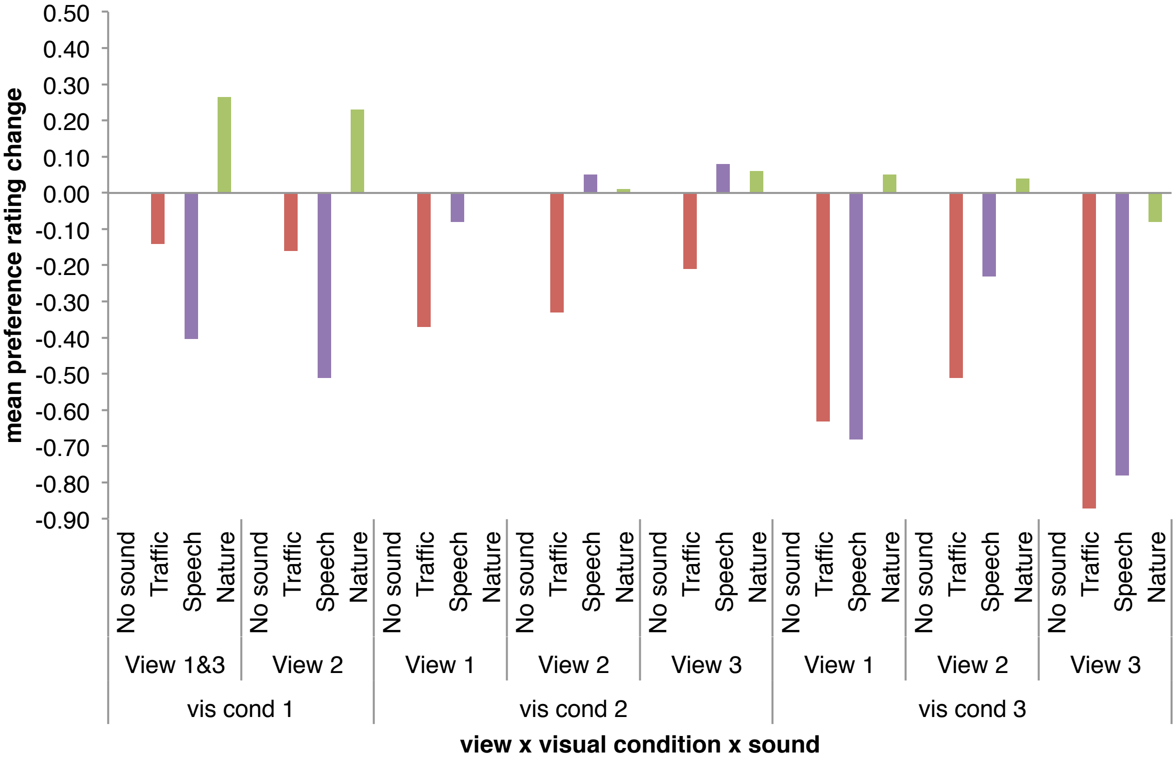

Figure 58: Mean preference rating change relative to the 'no sound' condition

7.2 Discussion

7.2.1 Limitations of the results

While online participant data was attempted to be collected to control for certain variables (e.g. audio device, monitor size) there are variables that were controlled in the lab that could not be accounted for in a participant's setting (e.g. ambient noise, level of focus to the task). In addition, the task that participants completed, either in the lab or via the Internet was artificial e.g. they were not evaluating the combinations of stimuli in the context of a real design or planning proposal. As such, the participant level of connection to the task may not reflect exactly that of a real-life situation.

7.2.2 Discussion of sound ratings and aural-visual interaction

7.2.2.1 Sound loudness and preference

Sound ratings were in line with the hypotheses: traffic sound was rated highest for loudness and lowest for preference, natural sound rated lowest for loudness and highest for preference, and speech in the middle for both. For loudness the small spread in ratings was not surprising, as the three sounds had been matched for their SPL. This suggests the sound content had an impact beyond the measured SPL, as there were still significant differences between the ratings of the sounds. The rating spread for preference was lower than expected, as it was anticipated that the traffic sound would be less preferred than it was, and the natural sound higher than it was. This can be partially explained by the abstract quality of the traffic (i.e. it is ambient noise) whereas the natural sound is the opposite (i.e. a direct bird call from a Coot [*Fulica atra]*). The differences were enough to contextualize the sounds and differentiate them for both acoustic parameters and content type.

7.2.2.2 Aural-visual interaction affect on realism and preference

Overall results

The results are consistent with the hypotheses that the interaction of aural and visual stimuli has a significant effect on realism and preference ratings for 3D visualizations, both negatively and positively affecting ratings, which varies by the landscape elements visualized and sound type. As was expected, for realism the main effect of visual condition was very large ($\eta_p^2 = 0.392$), and the interaction of visual condition with sound was large ($\eta_p^2 = 0.191$), $p < .001$ for both. When broken down by visual condition sound had a very large effect for visual condition 1 [terrain] ($\eta_p^2 = 0.191$), slightly less but still large for visual condition 2 [terrain and built form] ($\eta_p^2 = 0.133$) and a medium effect for visual condition 3 [terrain, vegetation and some built form] ($\eta_p^2 = 0.66$). This was in line with the hypothesis that the less visual information depicted in a visualization, the more impact a sound would have. For preference the results are also consistent with overall hypotheses, differing somewhat from realism ratings. When broken down by visual condition sound had very large effect for visual condition 1 (η_p^2 = 0.204), a medium effect at visual condition 2 (η_p^2 = 0.088), and the largest effect at visual condition 3 (η_p^2 = 0.249). This effect is clearly shown in Figure 58, with the largest effect on preference being negative for visualizations showing vegetation combined with traffic and human sounds.

Congruency of aural and visual stimuli

The result that speech had the largest impact on realism ratings, either positively or negatively, depending on the visual condition is very interesting. In addition, traffic and speech both had the most negative affect on preference ratings. This is consistent with previous research indicating the importance of the congruence of aural and visual stimuli on multimodal perception (e.g. Carles et al., 1999; Zhang & Kang, 2007). This is even more interesting when considering that all three sounds were recorded within St. James's Park, which offers some level of sensory congruence with the sounds (at least for visual condition 3). This suggests that not only are visually congruent stimuli important, but also temporal congruency of the time of day and, by extension season, if using real recordings.

What is most surprising is the moderating effect of any visual anthropogenic indicators (e.g. buildings) on both realism and preference ratings. This is evident for visual condition 3: traffic and speech both reduce realism the most for view 3 (predominantly vegetation); less for view 1 (mostly vegetation with a building just visible in the distance); and traffic leading to a slight reduction in realism for view 2, with speech actually increasing realism (showing mostly vegetation with a building clearly visible behind the trees). For preference traffic and speech again are moderated by the imagery containing built form, in a similar pattern to that for realism. This indicates that viewpoint selection is of critical importance when using aural stimuli in combination with visual for preference evaluation so as not to influence outcomes by too narrow a field of view. This also suggests that the spatiotemporal freedom provided by real-time 3D models may be of particular importance in multisensory environmental simulation (provided there is congruency of stimuli).

Effect of visual stimuli on aural perception

That traffic raised realism for visual condition 1, while lowering preference, is also surprising, as it was expected that the traffic sound would not be perceived as congruent with a visualization showing terrain only. Qualitative feedback from participants provided in the open-ended survey question offer some insight into this result (see Appendix 13.9 for all comments provided by participants). A number of participants indicated that the combination of the traffic sound with the terrain made them think they were looking at a beach, and/or the traffic sound was interpreted as wind or waves. This not only shows the impact of the sound on visual perception, but an interesting aspect of the interaction of aural and visual stimuli to alter the perception of both. This indicates that if visualizations without built form or vegetation are used in combination with aural stimuli it is very important that the visual and aural stimuli are specific to ensure responses collected are responding to the desired sensory interaction.

Difference between views

While some variation in ratings between views was expected, it was not expected that as many different views would be rated significantly different for the same visual condition for realism or preference. While significant, the actual effect was relatively small between some views, (e.g. 0.04 – 0.18 for realism and preference at visual condition 1) but quite large for others (e.g. realism for visual condition 3 and the speech sound resulting in up to 0.59 difference between view 2 and 3; or preference for visual condition 2 differing on average by 0.30 between views 1 and 3). Again this can be explained, e.g. it is hypothesized to be a result of the Ferris wheel (London Eye) visible in view 1 (most preferred), with more, and greener, terrain in view 2 compared to view 3 (least preferred). Regardless of these differences between views, for the current investigation the impact of the three sounds is relatively consistent, and the variation can be explained. The difference in ratings is hypothesized to be a result of the larger amount of low quality green terrain, and it’s variation, covering the image in view 2 compared to views 1 and 3, which is consistent with previous research (e.g. Hagerhall, et al., 2004).

Traffic and speech lower preference for visualizations showing vegetation

That traffic and speech both had the largest impact on lowering preference ratings when combined with visual condition 3 was expected, and this is in line with previous research suggesting lower preference for mechanical and anthropogenic sound than natural sounds (Carles, et al., 1999). However, what was not expected was the minimal effect on preference of natural sound for visual condition 3 (showing vegetation), though this can be explained by the relatively direct and sharp bird call (a Coot) used in the experiment. Participants indicated it sounded like a seagull, offering congruence with the perceived beach-like quality of visual condition 1 and incongruence with the vegetation in visual condition 3. This also relates to previous results that indicated the presence of any anthropogenic sound in a natural environment negatively impacted participants ratings, and that the inclusion of natural sounds had no impact on ratings (Benfield, et al., 2010).

Speech raises realism the most overall when paired with built form

The combination of visual condition 2 (terrain and built form) with the speech sound resulted in the highest increase in realism ratings (+ 0.50 compared to no sound). This again supports the importance of congruency of aural and visual stimuli, showing that even when no people are present in the visualization the presence of anthropogenic visual elements (i.e. buildings) provides the context for realism. In this instance natural sound did not significantly alter perceived realism, which suggests a stronger influence of anthropogenic sound on natural visualizations than natural sound on anthropogenic visualizations.

Accuracy of experience

The most critical take away based on the empirical evidence is that of accuracy of experience. It has been demonstrated that different sound types alter perceived realism and preference based on the landscape elements in a visualization. However it must be emphasized that all of the sounds used in the experiment were sourced from the same site that the visualizations are from. As a result of this any of the sounds could be argued to be valid for using in the evaluation of the landscape of St. James's Park depending on time of day or physical location. Of particular importance is the very large negative effect of speech and traffic on preference for visual condition 3. The speech sound was sourced from a location enclosed by vegetation that looked very similar to view 3, and the traffic recording was primarily ambient sound from within the park, which arguably are valid acoustically for the visual condition. That speech and traffic lowered preference the most for this scene (almost a full 1 point on a 5-point scale) raises important issues regarding the accuracy of experience of any visualization without sound, because the inclusion of traffic or speech sounds offer a more accurate experience of the site than with no sound at all.

7.3 Conclusions

The main conclusions are that sounds interact differently with visualizations depending on what landscape elements are present, and realism and preference ratings are moderated by even a small inclusion of congruent aural-visual stimuli (e.g. built form signalling a city context with traffic sounds or speech). Further, anthropogenic and mechanical sounds lower preference more for visualizations containing primarily natural features than natural sounds do for visualizations containing built form. Finally, the only significant increase in preference ratings was for visualizations showing terrain combined with natural sound, which also increased realism, demonstrating an overall preference for natural sound with low detail visualizations.

8 RESEARCH QUESTION 2 ANALYSIS AND RESULTS: REALISM AND PREFERENCE RATINGS BY USER CHARACTERISTICS

Research question 2

Do different user characteristics interact with aural-visual stimuli to alter perception of realism and preference for 3D visualizations?

This chapter expands on the results and discussion presented in Chapter 7 to investigate the impact of different user characteristics (e.g. gender, age) on realism and preference ratings for aural-visual sensory combinations. Section 6.6.2 provided details on the different user characteristics of the participants. The statistical analysis assumptions, methodology and reported statistics are described in section 6.7. Section 8.1 provides realism and preference results by user characteristics, with section 8.2 discussing the implications of the results. The final section concludes the chapter.

8.1 Mixed ANOVA results

The user characteristics were analysed in relation to mean realism and preference ratings in a mixed ANOVA, with the respective user characteristic as the between-subjects variable and the main effects of view, visual condition and sound as the within subject factors. As the research question focused on aural-visual interaction the analysis was limited to only significant interactions incorporating the sound variable, and main effects that were not explained by a visual variable. Table 39 shows the significant main effects, and any significant interactions, for aural-visual combinations by user characteristic.

Table 39: Mixed ANOVA results for research question 2 (significant aural-visual interactions)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	η_p^2	ε*
Realism							
gender * vis cond * sound	16.28	5.28, 1035.74	3.08	3.31	**0.005**	0.017	0.881
language	8.42	1, 195	8.42	7.97	**0.005**	0.039	
Preference							
age * view * sound	9.21	11.24, 1056.37	0.82	2.35	**0.007**	0.024	0.936
language * view * sound	4.97	5.61, 1088.34	0.89	2.50	**0.024**	0.013	0.935
language * vis cond * sound	8.58	5.57, 1079.93	1.54	2.44	**0.027**	0.012	0.928
lang*view*viscond*sound	8.13	10.80, 2095.95	0.75	2.07	**0.020**	0.011	0.900
country * view * sound	4.43	5.63, 1097.06	0.79	2.22	**0.043**	0.011	0.938
country * sound * vis cond	8.21	5.58, 1088.2	1.47	2.34	**0.034**	0.012	0.930
prof backgrnd * vis cond*sound	7.27	5.567	1.31	2.16	**0.049**	0.013	0.928
3D familiarity *vis cond* sound	32.10	22.30, 1070.30	1.44	2.33	**< .001**	0.046	0.929

df = degrees of freedom; F = F ratio; Sig. = significance; η_p^2 = partial eta squared (effect size).
*A value in this column indicates Mauchly's sphericity test was significant, and the indicated Greenhouse-Geisser correction applied to the results. Significance (at .05) and Large Effects (> .1379) are in **bold**.
. **Contrasts adjusted for multiple comparisons with Bonferroni adjustment

To break down the interactions contrasts were performed, comparing each level of mean realism and preference rating for the interaction variables; significant contrasts are presented in Table 40 (full contrast tables for each user characteristic are provided in Appendix H). The analysis of significant contrasts by user characteristic is presented in the following sections.

8.1.1 Gender

The interaction of gender, visual condition and sound was the only significant aural-visual interaction for realism (*p* = .005). This indicated that ratings differed between males and females depending on the landscape elements visualized and sound combination. Contrasts revealed significant interactions when comparing different realism ratings by gender between visual condition 1 and 2, and the ‘traffic vs. speech’ and ‘speech vs. nature’ categories: p = .036 and .018. Further analysis of the interaction graph (Figure 59) indicated that females perceived visual condition 1 (terrain) as more realistic than males with traffic or nature sounds, however, speech reduced perceived realism in females significantly.

Table 40: Significant contrasts by user characteristics for realism and preference[12]

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.***	**η_p^2**
Realism						
gender * vis cond * sound						
vc 1 vs vc 2; traffic vs speech	13.36	1, 196	13.36	9.43	**0.036**	0.046
vc 1 vs vc 2; speech vs nature	18.07	1, 196	18.07	11.48	**0.018**	0.055
Preference						
age * view * sound						
view 2 vs view 3; speech vs nature	7.50	2, 198	3.75	7.24	**0.018**	0.072
language * view * sound						
view 1 vs view 3; no sound vs speech	3.80	1.194	3.80	9.77	**0.036**	0.048
country * view * sound						
view 1 vs view 3; no sound vs speech	4.57	1. 195	4.57	11.92	**0.018**	0.058
country * sound * vis cond						
vc 1 vs vc 2; traffic vs speech	71.12	1. 195	71.12	82.01	**< .001**	**0.296**
vc 1 vs vc 2; speech vs nature	92.88	1. 195	92.88	114.82	**< .001**	**0.371**
vc 1 vs vc 3; traffic vs speech	32.12	1. 195	32.12	37.50	**< .001**	**0.161**
prof backgrnd * vis cond * sound						
vc 1 vs vc 2; no sound vs traffic	6.52	1, 168	6.52	11.54	**0.018**	0.064
3D familiarity * vis cond * sound						
vc 1 vs vc 3; no sound vs traffic	18.26	4, 192	4.56	4.70	**0.018**	0.089

df = degrees of freedom; F = F ratio; Sig. = significance; η_p^2 = partial eta squared (effect size).
*A value in this column indicates Mauchly's sphericity test was significant, and the indicated Greenhouse-Geisser correction applied to the results. Significance (at .05) and Large Effects (> .1379) are in **bold**.
. **Contrasts adjusted for multiple comparisons with Bonferroni adjustment

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[12] Note: for language * vis cond * sound the contrasts were not significant once corrected for multiple comparison with the Bonferroni correction, which also indicated the language * view * vis cond * sound interaction would not be significant

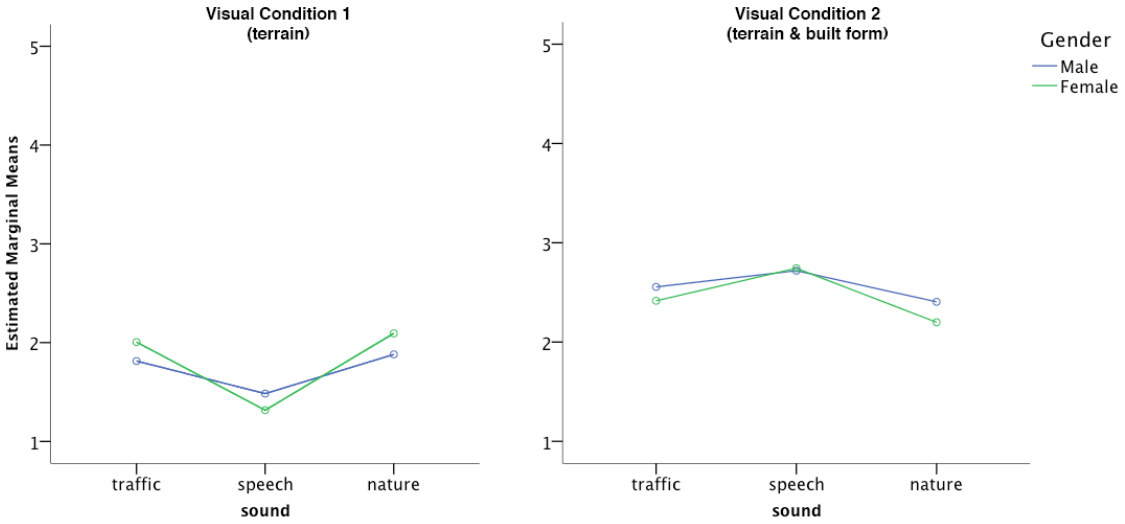

Figure 59: Interaction graph of mean realism ratings as a function of Gender (male vs. female); Visual Condition (1 vs. 2); and Sound Type (traffic vs. speech vs. nature)

For visual condition 2 males and females perceived visualizations with the speech sound similarly, however, traffic and nature reduced realism perception more for females than for males; this is shown in Table 41.

Table 41: Mean realism ratings by Gender (male vs. female); Visual Condition (1 vs. 2); and Sound Type (traffic vs. speech vs. nature)

					95% Confidence Interval	
Gender	**Visual condition**	**Sound**	**Mean**	**Std. Error**	Lower Bound	Upper Bound
Male	1	traffic	1.81	0.10	1.62	2.01
		speech	1.48	0.06	1.36	1.61
		nature	1.88	0.10	1.69	2.07
	2	traffic	2.56	0.09	2.37	2.74
		speech	2.72	0.11	2.51	2.93
		nature	2.41	0.09	2.22	2.59
Female	1	traffic	2.01	0.08	1.84	2.17
		speech	1.32	0.06	1.21	1.43
		nature	2.09	0.08	1.93	2.26
	2	traffic	2.42	0.08	2.26	2.57
		speech	2.74	0.09	2.56	2.92
		nature	2.20	0.08	2.04	2.36

8.1.1.1 Age

For analysis participants were grouped into four age categories: 15-24, 25-44, 45-64 and 65+. However, there were only six people aged 65 or over that participated. As a result, age was analysed as a between subjects variable for the first three groups only to satisfy the assumptions of the mixed ANOVA.

For preference the interaction of age, view and sound was significant (p = .007), indicating that ratings differed between age groups depending on the view and sound combination. Contrasts revealed significant interactions when comparing different preference ratings of age group between views 2 and 3, for speech vs. natural sound (p = .018). Further analysis of the interaction graph (Figure 60) indicated that natural sound had a similar effect on preference ratings for both views for 15-24 and 25-44 year olds, while it had less of an effect for view 3 on 45-64 year olds.

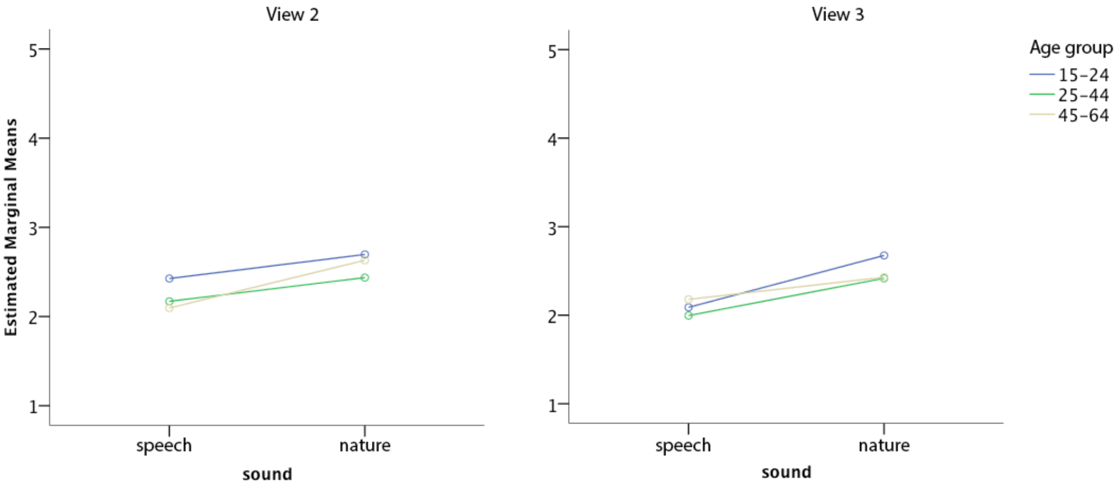

Figure 60: Interaction graph of mean preference ratings as a function of Age Group (15-24 vs. 25-44 vs. 45-64); View (2 vs. 3); and Sound Type (speech vs. nature)

The mean preference ratings by age are shown in Table 42, indicating the differences that were identified in the interaction graph above.

Table 42: Mean preference ratings by Age Group (15-24 vs. 25-44 vs. 45-64); View (2 vs. 3); and Sound Type (speech vs. nature)

					95% Confidence Interval	
Age group	**View**	**Sound**	**Mean**	**Std. Error**	Lower Bound	Upper Bound
15-24	2	speech	2.43	0.08	2.28	2.58
		nature	2.70	0.09	2.52	2.87
	3	speech	2.09	0.07	1.96	2.22
		nature	2.68	0.09	2.50	2.85
25-44	2	speech	2.17	0.07	2.03	2.32
		nature	2.44	0.09	2.27	2.61
	3	speech	2.00	0.07	1.87	2.13
		nature	2.42	0.09	2.25	2.59
45-64	2	speech	2.10	0.13	1.85	2.35
		nature	2.63	0.15	2.34	2.93
	3	speech	2.18	0.11	1.96	2.40
		nature	2.43	0.15	2.14	2.72

8.1.2 First language

For realism the main effect of the between subject factor ‘language’ was significant (p = .005). This indicated that if we ignore all other factors participants whose first language was English rated realism ratings lower than average, and those whose first language was not English rated preference higher than average (Table 43).

Table 43: Mean preference ratings by First Language (overall vs. English vs. other)

			95% Confidence Interval	
Group	**Mean**	**Std. Error**	Lower Bound	Upper Bound
Overall	2.32	0.05	2.23	2.41
English first language	2.19	0.05	2.09	2.29
English not first language	2.45	0.08	2.30	2.60

For preference the interaction of language with view and sound, and with visual condition and sound was significant (p < .05 for both). Contrasts revealed significant interactions when comparing different preference ratings of first language between views 1 and 3 for the ‘no sound’ vs. ‘speech’ condition (p = .036). Further analysis of the interaction graph (Figure 61) indicated that speech had a similar effect on preference ratings for both views for each group, while participants whose first language was not English ‘no sound’ condition resulted in preference ratings for view 1 that were significantly higher than view 3 (Table 44).

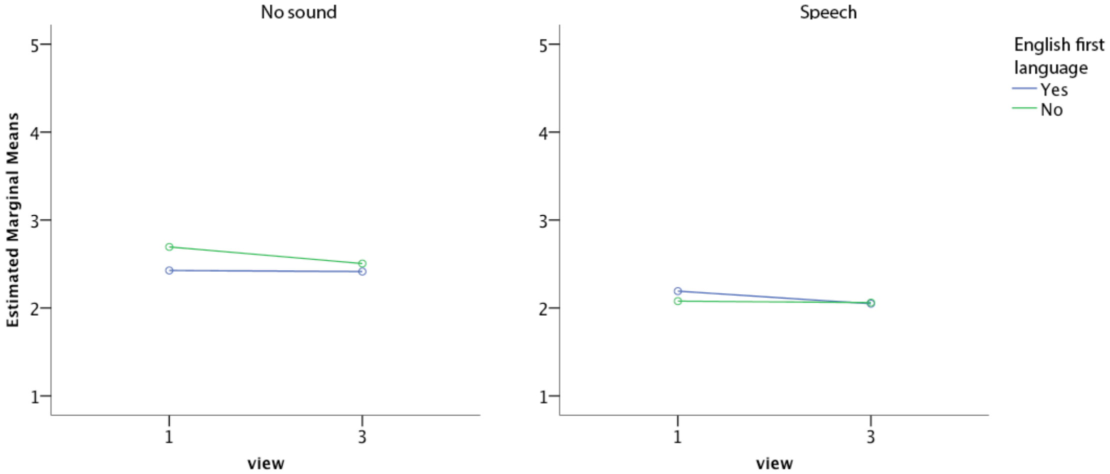

Figure 61: Interaction graph of mean preference ratings as a function of First Language (English vs. other); Sound Type (no sound vs. speech) and View (1 vs. 3)

Table 44: Mean preference ratings by First Language (English vs. other); Sound Type (no sound vs. speech) and View (1 vs. 3)

					95% Confidence Interval	
English first language	**view**	**sound**	**Mean**	**Std. Error**	Lower Bound	Upper Bound
Yes	1	no sound	2.43	0.07	2.29	2.57
		speech	2.19	0.06	2.08	2.30
	3	no sound	2.41	0.07	2.28	2.54
		speech	2.05	0.05	1.95	2.15
No	1	no sound	2.69	0.11	2.49	2.90
		speech	2.08	0.09	1.91	2.25
	3	no sound	2.51	0.10	2.31	2.70
		speech	2.06	0.08	1.91	2.22

8.1.3 Cultural background

To satisfy the assumptions of the mixed ANOVA participants were grouped by UK vs. non-UK cultural background, resulting in 95 UK and 103 non-UK (with one participant not indicating). It is acknowledged that this resulted in a comparison of one group with homogeneous characteristics (i.e. experience in the UK) with another group with heterogeneous characteristics (i.e. experience outside of the UK); this would allow conclusions to be drawn regarding the homogeneous group responses.

For preference the interactions were significant for view by sound by country, and visual condition by sound by country (p < .05 for both). This indicated that ratings differed between participants who lived the majority of their lives in the UK (UK participants), and those who did not (non-UK participants), depending on the view and sound combination, and also the visual condition and sound combination.

For the interaction of view, sound and country contrasts revealed significant interactions when comparing different preference ratings of cultural background between view 1 and view 3, for 'no sound' vs 'speech' (p = .018). Further analysis of the interaction graph (Figure 62) indicated that with 'no sound' participants rated view 1 and 3 similarly, while the addition of speech resulted in view 1 being rated lower for non-UK participants (Table 45).

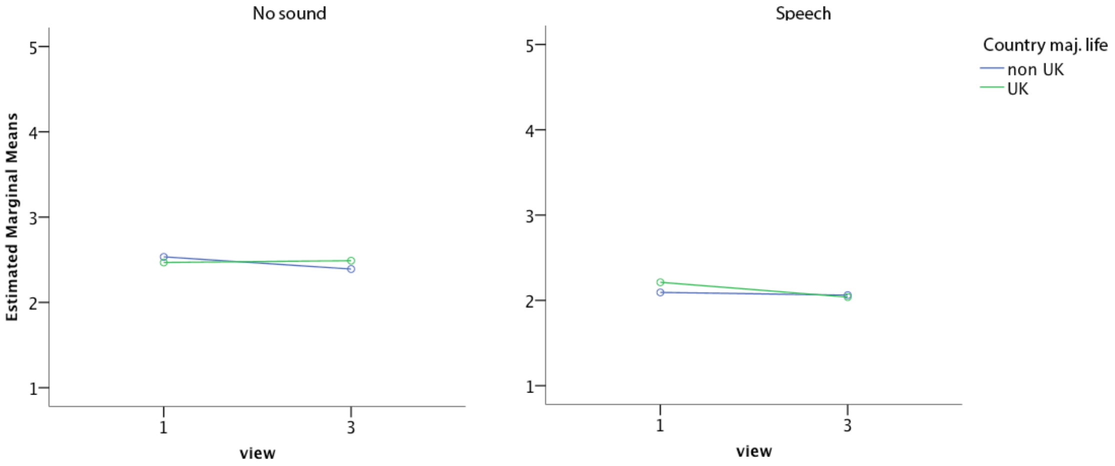

Figure 62: Interaction graph of mean preference ratings as a function of Participant's Country (UK vs. non-UK); Sound Type (no sound vs. speech); and View (1 vs. 3)

Table 45: Mean preference rating by Participant's Country (UK vs. non-UK); Sound Type (no sound vs. speech); and View (1 vs. 3)

Participant's Country	**View**	**Sound**	**Mean**	**Std. Error**	**95% Confidence Interval** Lower Bound	Upper Bound
Non UK	1	no sound	2.53	0.08	2.37	2.70
		speech	2.09	0.07	1.96	2.22
	3	no sound	2.39	0.08	2.24	2.54
		speech	2.06	0.06	1.94	2.18
UK	1	no sound	2.47	0.09	2.30	2.64
		speech	2.21	0.07	2.08	2.35
	3	no sound	2.49	0.08	2.33	2.65
		speech	2.04	0.06	1.92	2.16

For the interaction of visual condition, sound and country, contrasts revealed significant interactions when comparing different preference ratings of cultural background between visual conditions 1 and 2 for traffic vs. speech, and speech vs. nature; and visual conditions 1 and 3 for traffic vs. speech ($p < .001$ for all). Further analysis of the interaction graphs (Figure 63, a-c, following page) indicated that preference increased for visual condition 2 with both traffic and speech sounds, but increased less if a participant had not spent the majority of their life in the UK (Figure 63a). Further, participant cultural background did not significantly affect preference for visual condition 1 compared to visual condition 3 with the traffic sound, or for visual condition 1 with speech, but increased preference more for those who had spent the majority of their life in the UK for visual condition 3 (Figure 63b). Finally, the inclusion of the natural sound raised preference for visual condition 1 more for participants from the UK (Figure 63c).

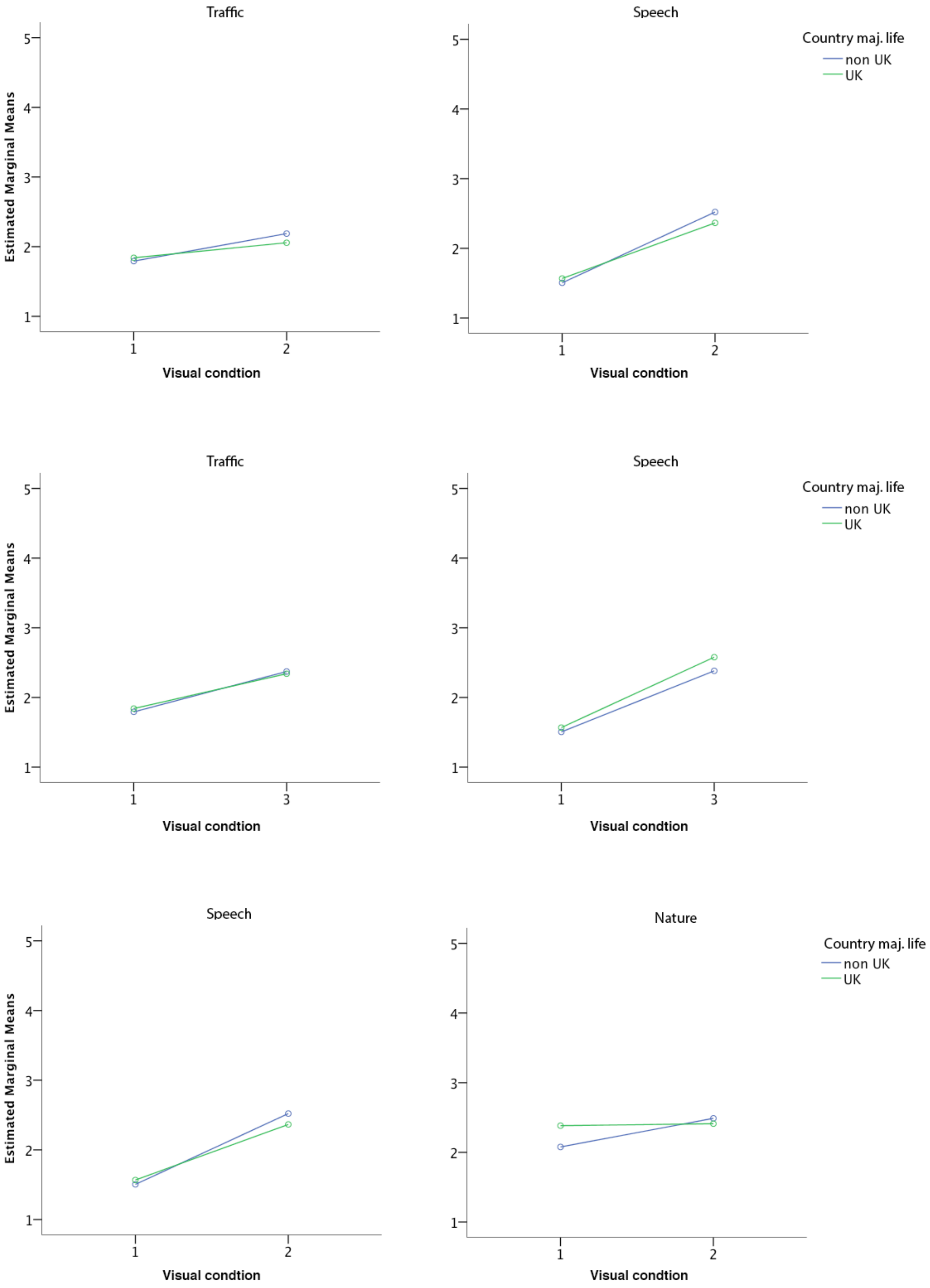

Figure 63: Interaction graphs of mean preference ratings as a function of Participant's Country (UK vs. non-UK) by a) Sound Type (traffic vs. speech; and Visual Condition (1 vs. 2) (top); b) Sound Type (traffic vs. speech; and Visual Condition (1 vs. 3) (middle); and c) Sound Type (speech vs. nature; and Visual Condition (1 vs. 2) (bottom)

Mean preference ratings for the significant interactions of a participants' country are shown in Table 46.

Table 46: Mean preference rating by Participant's Country (UK vs. non-UK); Visual Condition (1 vs. 2 vs. 3); and Sound Type (traffic vs. speech vs. nature)

Participant's Country	Visual Condition	Sound	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
non UK	1	traffic	1.79	0.08	1.63	1.96
		speech	1.51	0.06	1.38	1.63
		nature	2.08	0.10	1.89	2.27
	2	traffic	2.19	0.08	2.04	2.34
		speech	2.52	0.08	2.37	2.67
		nature	2.49	0.08	2.32	2.66
	3	traffic	2.37	0.08	2.21	2.53
		speech	2.38	0.08	2.23	2.54
		nature	3.03	0.09	2.86	3.21
UK	1	traffic	1.84	0.09	1.67	2.01
		speech	1.57	0.07	1.44	1.70
		nature	2.38	0.10	2.18	2.58
	2	traffic	2.06	0.08	1.90	2.22
		speech	2.37	0.08	2.21	2.52
		nature	2.41	0.09	2.24	2.59
	3	traffic	2.34	0.09	2.17	2.51
		speech	2.58	0.08	2.42	2.74
		nature	3.05	0.09	2.87	3.24

8.1.4 Professional background

Based on previous research (e.g. Lange, et al., 2008) analysis was going to be conducted across three groups (Landscape, Built Environment, and 'Other'). However, this resulted in very unbalanced groups (Landscape = 62, Built Environment = 16, Other = 94), which would not satisfy the mixed ANOVA assumptions of relatively equal cell sizes. As a compromise responses were combined into two categories: Landscape and Built Environment (Architecture, Civil Engineering, Geography, Horticulture, Landscape Architecture and Planning backgrounds) and 'Other', (i.e. expert and layperson), resulting in 78 *expert* and 92 *laypeople* (if participant left the option blank they were not included in the analysis).

For preference the three-way interaction of professional background, visual condition and sound was significant (*p* = .049), indicating that ratings differed between experts and laypeople depending on the combination of landscape elements and sound.

Contrasts revealed significant interactions when comparing different preference ratings of professional background between visual conditions 1 and 2, for the ‘no sound’ vs. ‘traffic’ condition (p = .018). Further analysis of the interaction graph (Figure 64) indicated that experts rated both visual conditions 1 and 2 lower than laypeople, however, traffic sound lowered preference more for experts for visual condition 2. Mean preference ratings for the significant interactions separated by a participant’s professional background are shown in Table 47.

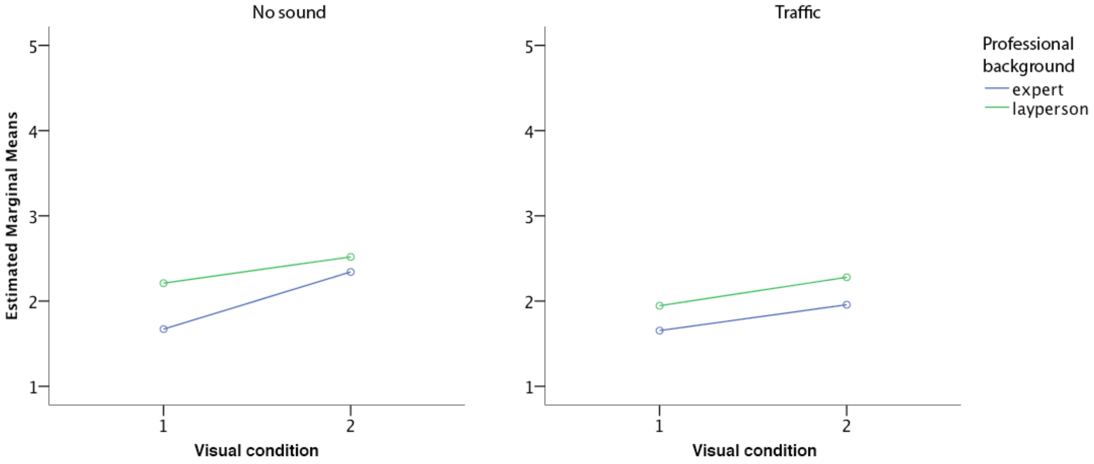

Figure 64: Interaction graph of mean preference ratings as a function of Professional Background (expert vs. layperson); Sound Type (no sound vs. traffic); and Visual Condition (1 vs. 2)

Table 47: Mean preference ratings by Professional Background (expert vs. layperson); Sound Type (no sound vs. traffic); and Visual Condition (1 vs. 2)

Professional Background	**Visual Condition**	**Sound**	**Mean**	**Std. Error**	**95% Confidence Interval** Lower Bound	Upper Bound
expert	1	no sound	1.67	0.11	1.45	1.89
		traffic	1.65	0.09	1.47	1.83
	2	no sound	2.34	0.09	2.16	2.53
		traffic	1.96	0.09	1.79	2.13
layperson	1	no sound	2.21	0.10	2.01	2.41
		traffic	1.95	0.08	1.78	2.11
	2	no sound	2.52	0.09	2.35	2.69
		traffic	2.28	0.08	2.12	2.44

8.1.5 Familiarity with computer graphics

For preference the interaction of 3D graphics familiarity, visual condition and sound was significant (*p* < .001), indicating that preference varied based on a participant's 3D graphics familiarity, and depended on the combination of landscape elements visualized and sound. Contrasts revealed significant interactions when comparing different preference ratings of 3D familiarity between visual conditions 1 and 3, for the 'no sound' and 'traffic' condition (p = .018), Further analysis of the interaction graph (Figure 65) indicated that all participants' preference ratings increased between visual condition 1 and visual condition 3 with 'no sound', but with the 'traffic' sound those with no 3D graphics familiarity preference was unchanged.

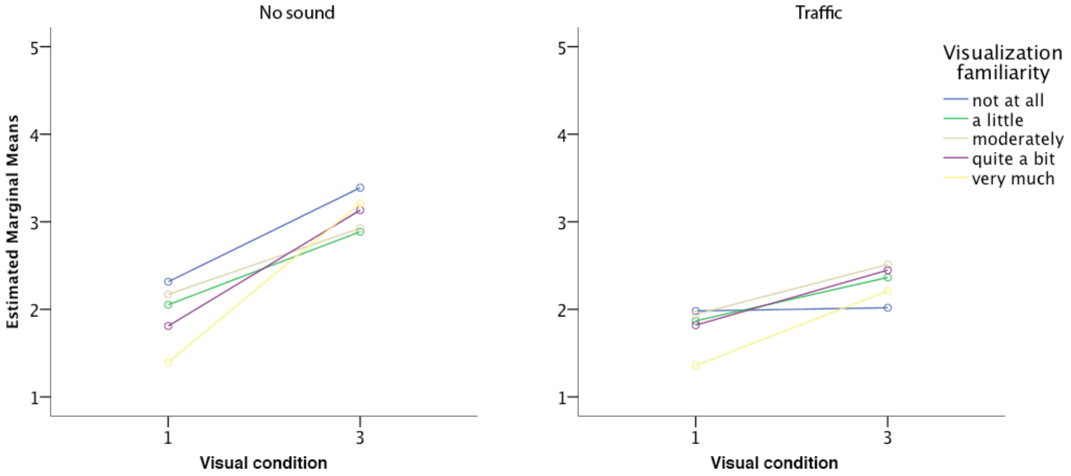

Figure 65: Interaction graph of mean preference ratings as a function of 3D Visualization Familiarity (not at all vs. a little vs. moderate vs. quite a bit vs. very much); and Sound Type (no sound vs. traffic); and Visual Condition (1 vs. 3)

Mean preference ratings separated by a participant's familiarity with 3D computer graphics for the significant interactions are shown in Table 48.

Table 48: Mean preference ratings by 3D Visualization Familiarity (not at all vs. a little vs. moderate vs. quite a bit vs. very much); and Sound Type (no sound vs. traffic); and Visual Condition (1 vs. 3)

3D Familiarity	Visual Condition	Sound	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
not at all	1	no sound	2.32	0.23	1.86	2.77
		traffic	1.98	0.20	1.59	2.37
	3	no sound	3.39	0.22	2.96	3.82
		traffic	2.02	0.19	1.64	2.40
a little	1	no sound	2.05	0.11	1.83	2.28
		traffic	1.87	0.10	1.68	2.06
	3	no sound	2.89	0.11	2.68	3.09
		traffic	2.36	0.09	2.18	2.55
moderately	1	no sound	2.17	0.15	1.87	2.47
		traffic	1.94	0.13	1.68	2.20
	3	no sound	2.93	0.14	2.64	3.21
		traffic	2.51	0.13	2.26	2.76
quite a bit	1	no sound	1.81	0.17	1.48	2.14
		traffic	1.82	0.14	1.54	2.10
	3	no sound	3.13	0.16	2.83	3.44
		traffic	2.45	0.14	2.18	2.72
very much	1	no sound	1.40	0.19	1.02	1.77
		traffic	1.36	0.16	1.04	1.68
	3	no sound	3.21	0.18	2.86	3.56
		traffic	2.21	0.16	1.90	2.52

8.1.6 Experience with 3D computer graphics in design and planning

There was no significant interaction of experience with 3D graphics in a design or planning context with realism or preference ratings.

8.1.7 Noise sensitivity

Participants were grouped into those reporting low, medium and high noise sensitivity based on their mean responses to the 5-item noise sensitivity survey (low 1.0-2.5, med 2.6-4.0, high 4.1-6.0). The mixed ANOVA indicated no significant main effects, or interactions, for realism or preference based on noise sensitivity.

8.1.8 Site familiarity

The responses to the two questions on site familiarity were averaged to provide an aggregate site familiarity score (Table 49). However, owing to the large number of participants that were not familiar with, nor had visited the park, aggregate scores were grouped in the middle, with the majority of scores resulting in a 4.0 or 4.5 (90.9% of participants). As a result of this central grouping this variable was not analysed.

Table 49: Aggregate site familiarity scores for participants

Score	Frequency	Percent
1.00	1	.5
3.00	1	.5
3.50	7	3.5
4.00	135	67.8
4.50	46	23.1
5.00	7	3.5
5.50	2	1.0
Total	199	100.0

8.2 Discussion

8.2.1 Limitations of the results

As presented above, some of the user characteristics could not be analysed due to low participant numbers in a given category (e.g. excluding participants aged 65+). Also, for analysis purposes there were groups that needed to be combined to meet statistical assumptions, though there could be differences within the grouping (e.g. grouping ‘built environment’ professionals with ‘environmental’ professionals because of too few participants in a category). In addition, while the statistical analysis was used to rule out chance results there could still be factors that influenced responses outside of the control of the researcher (e.g. environmental influences and/or distractions while survey was conducted).

8.2.2 Discussion of user characteristics

8.2.2.1 Gender

The hypothesis for the effect of gender based on the literature review was that there would be no significant main effect or interaction of gender on realism or preference ratings. The results are consistent with the hypothesis for preference, though proved significant for realism: females and males rated visualizations showing terrain only and terrain with vegetation differently with different sounds. This indicates that speech influences preference more for females for visual condition 1, but similarly for males and females for visual condition 2. Further, traffic and natural sounds result in lower preference for males than females for visual condition 1, but higher for visual condition 2 (i.e. with vegetation present). This could indicate that in some situations aural-visual congruency is more important, depending on gender. The effect size is medium, which results in mean realism-rating differences of 0.21 maximum, so the variation while significant is small.

8.2.2.2 Age

For preference there was a significant difference between older and younger participants, with speech raising preference more for younger participants for view 2 than for older participants, and natural sound lowering preference more for older participants than younger participants for view 3. This indicates a different response to both the inclusion of built form with vegetation in visualizations, and the interaction of this with natural vs. speech sounds. The implications are that if relatively close age groups are not used for multisensory preference evaluations then the interaction of aural and visual stimuli can alter preference ratings in an unpredicted way. Again it is emphasized that the effect is small, and results in mean ratings differences of 0.26 maximum.

8.2.2.3 First language

Participants in the experiment whose first language is not English rated realism higher than average, while those whose first language is English rated realism lower than average. This differed from the hypothesis, which was formulated based on the literature review and is surprising, as it did not indicate any significant affect of first language on perceptual realism ratings. The difference from average for each group is not large, (+/- 0.13), although this is 0.26 between the two groups. This should be kept in mind if multisensory environmental evaluation is conducted with a phonetically diverse group.

Preference ratings differed from the hypothesis (that there would be no effect of a participants first language on preference ratings) for the interaction of view, sound and language. The result of view 1 ratings with no sound being rated significantly higher for participants whose first language was not English is interesting, and requires further research to isolate. As expressed previously, using aural and visual stimuli together with people from diverse language backgrounds may alter results in unexpected ways.

8.2.2.4 Cultural background

Cultural background results were consistent with the hypothesis for preference ratings: participants differed in ratings depending on the combination of view and sound, and visual condition and sound, depending on whether they had spent the majority of their lives in the UK or not. These results, in combination with the results based on first language, strongly indicate that cultural background can influence multisensory environmental simulation in unexpected ways.

8.2.2.5 Professional background

There was no significant difference between experts and laypeople for realism, which is in line with previous research that indicated small differences based on professional background (Lange, 2001). For preference there were significant differences, indicating that if evaluations by parties that vary in professional background are to be engaged in decision making using multisensory stimuli then differences can be expected between groups. Worth noting again it that there were not enough participants to compare the three groups originally intended (layperson, built environment, and environmental expert), which have been shown to have significant differences for preference (Lange, et al., 2008)), therefore more research is required to determine any differences between the three groups.

8.2.2.6 3D graphics familiarity

Surprisingly realism ratings for the interaction of sound and vision were not influenced by a participants familiarity with 3D computer graphics, though preference ratings showed significant differences. Participants that were not at all familiar with computer graphics showed no difference in preference ratings between ‘no sound’ and ‘traffic’ sound for visual conditions 1 and 3, indicating there could be large discrepancies between ratings based on 3D computer graphic familiarity. Interestingly with ‘no sound’ the increase in preference between visual conditions 1 and 3 increases more when 3D graphics familiarity increases.

8.2.2.7 Experience with 3D computer graphics in design and planning

One of the larger surprises of the research was that realism and preference ratings were not shown to be significantly affected by participants’ experience with computer graphics in a design and planning process. This is interesting, and could indicate that the relative scarcity of multisensory environmental simulation processes, or the lack of focus on soundscape concepts in design and planning, mean that responses are not moderated by an increase in purely visual-based expertise and are perceived similarly regardless of ones visualization background.

8.2.2.8 Site familiarity

As the experiment did not attract a larger variety of participants with varying degrees of site familiarity, this was not investigated as a variable. There is much research indicating this to be an influence on both realism and preference ratings (e.g. Appleton & Lovett, 2005; Karjalainen & Tyrvainen, 2002; Lange, 2001; Messager Belveze & Miller, 2005 for realism; Kaplan & Kaplan, 1989 for preference), therefore, this is a topic that will benefit from further research for multisensory environmental simulation.

8.2.2.9 Noise sensitivity

That noise sensitivity did not significantly alter realism or preference ratings is encouraging, though not surprising. The sounds had been equalized for loudness to remove this as a variable in the experiment, and as a result, this would moderate noise sensitivity because the sounds used would normally not be experienced at the same decibel level. This is yet another area of research that needs further investigation for multisensory environmental simulation.

8.3 Conclusions

The main findings from this chapter show that with the exception of gender, there were very few user characteristics interacting with aural-visual stimuli that had a significant effect on realism ratings. In addition, preference was considerably more influenced by aural-visual interactions.

There was a small but significant interaction effect of gender on realism ratings for visual condition 1 and 2 between speech, traffic and nature sounds (females perceived the terrain with orthophoto more realistically than males with traffic and nature sounds, with this effect reversing at with the inclusion of built form, resulting in a 0.21 difference). In addition, there was a main effect of a participant's first language on realism ratings, with participants whose first language is not English rating realism 0.26 higher on average than participants whose first language is English.

Preference ratings varied by age, resulting in a 0.26 rating differences between younger and older participants, with natural sound having less of an effect for view 3 on 45-64 year olds. A participant's cultural background was shown to affect preference, interacting primarily with the speech sound, resulting in variance by view and visual condition of up to 0.20 depending on the interaction. Traffic sound lowered preference more for visual condition 2 for experts than laypeople (0.22 difference), and lowered ratings for participants with no 3D graphics familiarity for visual condition 3 much more than those with even a little familiarity.

The results indicate that if heterogeneous stakeholder groups are to be engaged in multisensory-based environmental decision making then the use of particular sounds, views and landscape elements need to be carefully considered.

9 RESEARCH QUESTION 3 ANALYSIS AND RESULTS: EFFECTIVENESS OF THE INTERNET FOR AURAL-VISUAL DATA COLLECTION

Research question 3

How effective is the Internet for aural-visual data collection compared to a laboratory setting?

The third research question arose out of the experiment design and the use of the Internet for survey data collection. The aim of this chapter is to explore the suitability of Internet delivered stimuli for multisensory experiments. The main objective of this chapter is to determine if there are any effects of participant audio and video hardware on realism and preference ratings. Hypotheses regarding effects of hardware were developed based on previous research that was detailed in section 6.3.6. The statistical analysis assumptions, methodology and reported statistics are described in section 6.7. Section 9.1 presents the results for research question three. Section 9.2 discusses the results and their implications, while the final section concludes the chapter.

9.1 Mixed ANOVA results

Data was analysed using a mixed ANOVA to determine any effect of audio hardware on ratings, followed by experimental condition and monitor size. Each DV of realism and preference was analysed separately using three mixed ANOVAs with the main effects of view, visual condition and sound as the within subject factors in each, and audio device, experiment condition and display size as the between-subject factor, respectively. The analysis focused on the main effect of each between-subjects factor, and the interaction of the between-subjects factor with each independent variable of view, visual condition and sound. The results are illustrated in Table 50.

Table 50: Mixed ANOVA results for realism and preference, research question 3

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	η_p^2	ε*
Realism							
Main effects							
audio device	1.06	1, 69	1.06	0.31	.579	0.004	
exp cond.	9.79	1, 196	9.79	0.74	.391	0.004	
display size	0.09	1, 182	0.09	0.03	.869	0.000	
Interactions							
audio dev*view	0.35	2, 138	0.17	0.30	.740	0.004	
audio dev*vis-cond	0.07	1.53, 105.40	0.04	0.01	.975	0.000	0.764
audio dev*sound	4.27	2.36, 163.03	1.81	1.11	.339	0.016	0.788
exp cond*view	0.72	2, 392	0.36	0.70	.495	0.004	
exp cond*vis-cond	4.45	1.56, 305.42	2.85	0.65	.488	0.003	0.779
exp cond*sound	2.28	2.52, 494.50	0.91	0.64	.561	0.003	0.841
disp size*view	0.33	2, 364	0.17	0.32	.727	0.002	
disp size*vis-cond	17.02	1.58, 364	10.76	2.51	.096	0.014	0.791
disp size*sound	2.82	2.49, 452.45	1.14	0.78	.484	0.004	0.829
Preference							
Main effects							
audio device	0.07	1, 68	0.07	0.02	.882	0.000	
exp cond.	6.04	1, 195	6.04	0.51	.475	0.003	
display size	0.78	1, 181	0.78	0.27	.607	0.001	
Interactions							
audio dev*view	1.42	2, 136	0.70	1.41	.248	0.020	
audio dev*vis-cond	2.35	1.45, 98.36	1.63	0.41	.600	0.006	0.723
audio dev*sound	5.32	3, 204	1.77	1.02	.384	0.015	
exp cond*view	2.14	2, 390	1.07	1.91	.150	0.01	
exp cond*vis-cond	7.33	1.52, 296.35	4.82	1.27	.276	0.006	0.760
exp cond*sound	10.28	2.72, 529.62	3.79	1.98	.122	0.01	0.905
disp size*view	5.09	2, 362	2.54	4.71	**.010**	0.025	
disp size*vis-cond	12.42	1.53, 276.63	8.13	2.16	.130	0.012	0.764
disp size*sound	6.30	2.69, 487.03	2.34	1.27	.285	0.007	0.897

df = degrees of freedom; F = F ratio; Sig. = significance; η_p^2 = partial eta squared (effect size).
*A value in this column indicates Mauchly's sphericity test was significant, and the indicated Greenhouse-Geisser correction applied to the results. Significance (at .05) and Large Effects (> .1379) are in **bold**.

9.1.1 Audio hardware effect

Lab data (N=71) was analysed to determine any effect of differing audio hardware on results. 34 participants were randomly assigned to the low quality condition and 37 to the high quality condition. As can be seen in Table 50 the main effect of audio device on realism and preference ratings was not significant (p > .05 for both). The interaction of audio device by view was not significant, nor were the other two-way interactions: audio device by visual condition and audio device by sound (*p* > .05 for all).

As there was no significant difference of the main effect of the between-subject factor audio device on the dependent variables realism and preference, or any significant interaction with the independent variables (view, visual condition, sound) it is concluded that audio hardware type does not significantly alter realism or preference ratings. Therefore, the lab and online results were combined for further analysis.

9.1.2 Experiment condition effect

To determine if the experiment condition had an effect on realism and preference ratings the combined data were analysed for differences occurring by experimental condition (lab vs online). Online participants (n = 128) were compared to lab-based participants (n = 71). As can be seen in Table 50 the main effect of experiment condition on realism and preference ratings was not significant (p > .05 for both). The interaction of experimental condition by view was not significant, nor was the other two-way interactions: by visual condition and audio device by sound (*p* > .05 for all).

As there was no significant difference of the main effect of the between-subject factor experiment condition on the dependent variables realism and preference, nor any significant interaction with the independent variables (view, visual condition, sound) it was concluded that the experiment condition did not alter realism or preference ratings. Participants in the lab and online results remained combined for further analysis.

9.1.3 Display size effect

The combined data (N=199) was analysed to determine any effect of differing video display hardware size on results using participant's self-reported responses of their monitor size. All laboratory-based participants used a 22" monitor (see section 6.4.1 for details), while online participants indicated the display size as part o the survey, the totals of which are shown in Figure 66.

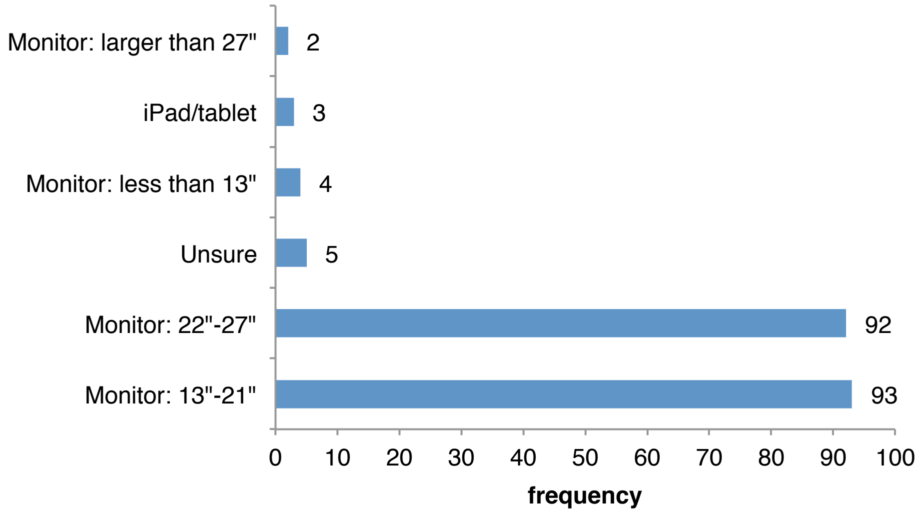

Figure 66: Combined online and laboratory-based display size frequency

The majority of participants used a monitor between 13” and 21” (93/199 or 46.7%) followed closely by a monitor between 22” and 27” (92/199 or 46.2%). As a result of the majority of participants using only two display sizes the analysis was limited to those two variables as there were not enough responses in the other categories to meet the assumption of the mixed ANOVA.

As can be seen in Table 50 the main effect of display size on realism and preference ratings was not significant (p > .05 for both). The interaction of display size by visual condition and sound was not significant (p > .05 for both). However, the interaction of display size by view was significant (*p* = .010) with an effect size of 0.025, which indicates a smaller effect.

The significant display size by view interaction indicates that the mean preference ratings for different views differed between participants depending on the display size used. To break down the interaction contrasts were performed comparing each level of mean preference rating of view across display types. This revealed significant interactions when comparing different display type preference ratings between view 1 and view 3: F(1,181) = 7.94, p = .005, partial η2 = .04; and view 2 and view 3: F(1,181) = 5.68, p = .018, partial η2 = .03, indicating a small to medium effect for both. View 1 and view 2 did not differ significantly. Further analysis of the interaction graph (Figure 67) indicated that participants with displays between 13”- 21” rated all views similarly, while those with displays between 22” and 27” rated preference significantly higher for views 1 and 2 than those with monitors between 13”- 21” (Table 51).

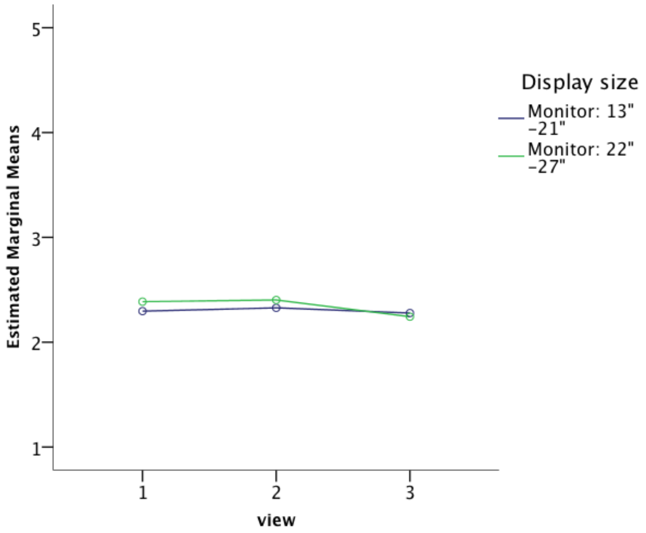

Figure 67: Interaction graph of mean preference ratings as a function of Display Size (13”-21” vs. 22”-27”); and View (1 vs. 2 vs. 3)

Table 51: Mean preference ratings by Display Size (13”-21” vs. 22”-27”); and View (1 vs. 2 vs. 3)

Display size	view	Mean	Std. Error
Monitor: 13"-21"	1	2.30	.06
	2	2.33	.06
	3	2.28	.06
Monitor: 22"-27"	1	2.39	.06
	2	2.40	.06
	3	2.24	.06

9.2 Discussion

9.2.1 Limitations of the results

The results are subject to some limitations. Not all variables were analysed because there were not enough people using smaller displays (< 13”) or very large displays (> 27”) to fulfil statistical requirements for the mixed ANOVA. In addition, while online participant data was attempted to be collected (e.g. audio device, monitor size) there are variables that were controlled in the lab that could not be accounted for in a participants setting (e.g. ambient noise, level of focus on the task).

9.2.2 Discussion of Internet vs. laboratory multisensory experiments

The results are mostly consistent with hypotheses for research question 3: audio hardware and experiment condition did not significantly alter realism and preference ratings. However, there was a signification effect of display size on preference ratings. It has been shown that larger monitors (22”-27”) can significantly raise preference ratings for one scene compared to others, depending on the elements within the scene and distance from viewer. It is emphasized that this effect was not large ($\eta_p^2 = .025$), which manifested in mean preference rating differences based on display size of 0.09 for view one and 0.07 for view two. This is only slightly higher than the non-significant difference between display sizes for view three (0.04). Preparers and presenters of visualizations will need to evaluate tolerances for each project to assess if these quite small effects are acceptable.

Previous landscape perception research indicated that monitor size did not influence preference scores (Wherrett, 2000), however, that research was conducted over a decade ago and only analysed 14” – 17” monitors. As monitor size and resolution increase, those wishing to employ Internet based survey techniques for landscape perception studies will need to be cautious of the potential disparity between preference ratings by display size. For the current research a very small minority of online participants indicated they were using displays less than 13” (2.3% iPad/tablet; 3.1% monitor less than 13”). However, display sizes, and potential display size disparity, will likely continue to grow, as more people shift to tablet and smartphone use for daily tasks (Fox & Duggan, 2013).

The result that low quality vs. high quality audio devices used for the experiment did not significantly alter realism or preference ratings is encouraging. While not all possible types of audio devices were tested (e.g. speakers vs. headphones) the use of very low quality earbuds compared to very high quality, over-ear headphones covers a large spectrum of potential audio listening devices and qualities, which satisfied that part of the research question. This means that preference ratings for combined aural-visual stimuli may not be affected by audio device quality, implying that researchers and practitioners may not have to control this as a variable for online research studies.

Analysing the combined online and laboratory data for significant differences in realism and preference ratings between the experimental conditions would not have highlighted any precise cause of discrepancies, but could alert the researcher to any significant differences. As the results showed no significant difference on realism or preference ratings between the two groups, it was concluded that any group differences did not have a significant impact on ratings.

9.3 Conclusions

It is concluded through the controlled laboratory-based study that listening to sounds through low quality earbuds did not significantly alter realism and preference ratings when compared with high quality headphones ($p > .05$). As a result of these findings it was concluded that online and laboratory based participants did not differ in their responses. The analysis of experiment condition, comparing online and laboratory-based responses, did not indicate any significant difference in ratings ($p > .05$). However, display size did significantly alter preference ratings ($p = .010$), which was dependent on the view. Further analysis indicated that view three in the study was rated not significantly different by participants with different display sizes (0.04 difference for mean preference) while views one and two differed significantly (0.07 and 0.09 respectively). This difference in mean values was small, and likewise a small effect size was reported ($\eta_p^2 = .025$) and as a result, it is concluded that the independent variables in this instance did not dramatically affect results.

10 CONCLUSIONS AND FUTURE RESEARCH

The final chapter of this thesis summarizes the results of the research, discusses the implications of the findings for researchers and practitioners and outlines future research areas.

10.1 Introduction

This study set out to explore the **impact of sound on virtual landscape perception** and identified the effects of three different sounds (anthropogenic, mechanical and natural) on the perception of realism and preference for 3D landscape visualizations showing different combinations of fundamental landscape elements (terrain, built form, and and vegetation). The study also identified differences in aural-visual perception based on different user characteristics, and validated the Internet as a means of aural-visual data collection.

The research presented here is **novel** in that for the first time **empirical evidence** has been presented confirming three key points that inform future research: 1. The effect of sounds on the perception of 3D landscape visualization both generally and by user characteristic; 2. Realism and preference ratings for Google Earth sourced visualizations; and 3. The utility of the Internet for aural-visual data collection for visualization research. Empirical evidence in general on perceptual aural-visual interaction was lacking, and specifically in the context of environmental simulation was non-existent, though researchers have repeatedly identified the importance of the research area. The study was conceptualized via the hypothesis that sound would alter perception of visualizations both negatively and positively depending on specific combinations of landscape elements and sound types, offering new techniques emphasizing experience in the design and planning process. The research sought to answer three specific questions:

1. How do different landscape elements in visualizations (i.e. terrain, vegetation and built form) interact with different sounds to alter perceived realism of, and preference for, 3D landscape visualizations?
2. Do different user characteristics interact with combined aural-visual stimuli to alter perception of realism and preference for 3D landscape visualizations?
3. How effective is the Internet for aural-visual data collection compared to a laboratory setting?

10.2 Main empirical findings

The main findings of this research are related to each of the three research questions and are summarized in their respective chapters: Chapter 7 Realism and preference ratings by all; Chapter 8 Realism and preference ratings by user characteristics; and Chapter 9 Effectiveness of the internet for aural-visual data collection. This section synthesizes the results to answer the study's three research questions:

1. How do different landscape elements in visualizations (i.e. terrain, vegetation and built form) interact with different sounds to alter perceived realism of, and preference for, 3D landscape visualizations?

Realism and preference ratings are significantly affected by sounds, the effects of which change based on the combination of visual elements and sound type, with more complex effects observed with combinations of vegetation and built form:

- For a **all visual conditions**
  - traffic sound significantly reduced **preference** (much more so when primarily vegetation was visible and less if built form was visible)
- For **visual condition 1** (i.e. terrain with orthophoto)
  - when compared to the 'no sound' condition human speech significantly lowers perceived **realism** while natural and traffic sound raised perceived realism
  - natural sound significantly increased **preference** ratings while speech significantly lowered preference
- For **visual condition 2** (i.e. terrain with built form)
  - speech and traffic sounds significantly raised **realism** ratings while natural sound had little effect
  - speech and natural sounds had little effect on **preference**
- For **visual condition 3** (i.e. terrain and vegetation with some built form visible)
  - Natural sound had the only consistent significant effect for **realism** ratings raising perceived realism across all views (though less for views containing built form); speech significantly reduced **preference** across all views
  - For view 1 (terrain, vegetation, small amount of built form visible) traffic and speech reduced **realism** slightly

- For view 2 (terrain, vegetation, some built form visible) speech significantly raised **realism** ratings while traffic slightly lowered ratings
- For view 3 (terrain and vegetation only) traffic and speech significantly lowered **realism** ratings

2. Do different user characteristics interact with combined aural-visual stimuli to alter perception of realism and preference for 3D landscape visualizations?

Different **user characteristics** interact with combined aural-visual stimuli to alter realism and preference for 3D visualizations with sound. **Realism** was altered significantly by the interaction of gender with visual condition and sound as well as first language; for **preference** there were significant aural-visual interactions for age, first language, cultural background, professional background and familiarity with 3D graphics, indicating small to medium effects for all.

3. How effective is the Internet for aural-visual data collection compared to a laboratory setting?

The quality of a participants' **sound apparatus** (i.e. high quality vs. low quality headphones) did not significantly effect **realism** or **preference** ratings, nor did the **experiment condition** (laboratory-based participants vs. online participants). However, **larger display sizes** (22”-27”) were shown to **increase preference** ratings for some views when compared to smaller displays (13”-21”), though the effect was small which manifested in mean preference rating differences based on display size of only 0.08 on a 5-point scale.

10.3 Implications of the research

The research presented here emphasizes the **essential contribution of using sound with 3D visualizations** to inform a multisensory environmental simulation process. There are broad implications for researchers and practitioners in field's including landscape aesthetics, presence research as well as for landscape architects and environmental designers.

10.3.1 Landscape research and aesthetics

The implications of this research are **profound** in relation to **accuracy or authenticity of landscape experience** as the results can potentially challenge previous preference-based landscape research that relies solely on visual stimuli. Because **all sounds** used in the experiment were **sourced from the site** it can be reasonably argued that each sound offers some level of **authenticity of experience** when compared to no sound. The most true to life representation of the landscape of St. James's Park was visual condition 3, depicting terrain, built form and vegetation. Traffic and speech lowered preference for this visual condition the most, which when compared to no sound resulted in an almost **1-point reduction in preference** on the 5-point scale used. As either sound condition can be considered a more authentic sensory experience than relying on the visuals alone, this indicates that preference research that does not engage with the aural sense could be inaccurate in terms of validity and accuracy of results. As such researchers and practitioners are encouraged to engage more fully with the human experiential condition.

There are important implications for landscape researchers, particularly in relation to **landscape aesthetic experience**. There is currently much discussion in relation to landscape aesthetics and experience of sustainable designs in regard to the **apprehension of beauty** (e.g. Meyer, 2008). The research presented here supports the importance of a combined **aural-visual aesthetic experience** and offers an enhanced method to strengthen the apprehension of **ecological landscapes**. For example, ecologically restored landscapes would invariably result in an altered soundscape from an increased capacity for wildlife, which when compared to an existing condition with less wildlife could increase the positive experience (e.g. preference) for that landscape. This is a particular area that would benefit from further research.

10.3.2 Presence research

Previous research has shown that **sound can increase perceived realism** in virtual indoor environments (e.g. Davis et al. 1999), and this study confirms the benefits for virtual **landscapes** while expanding on previous research to highlight the importance of **aural-visual congruence** for this benefit. It has been demonstrated that perceived realism increases consistently with natural sound, though can **increase the most when combining built form with human speech**. This confirms aural-visual congruency, as well indicating a relative preference for and positive effect of natural sound on landscape visualizations. Provided a natural sound is authentic to the experience of a landscape it would appear to be a good way to increase perceived realism of most visualizations whether depicting built form or a more natural environment.

Again, some key components to setting up aural-visual congruence include recognizing that for visualizations showing terrain only the traffic sound raised realism slightly (+ 0.13), which was surprising given the incongruence of aural and visual stimuli. Qualitative feedback indicated that the rather **abstract terrain with orthophoto** in combination with the ambient traffic sound resulted in some participants perceiving the grass covered terrain as a beach, and in turn h**earing the traffic sound as wind or waves**. This confirms previous research indicating the **'cross-sensory'** nature of perception in a virtual environment (e.g. Bormann, 2008) and warrants further research into the extent and effects of cross-sensory perception.

10.4 Recommendations

10.4.1 Landscape practitioners

This research has highlighted the important impact of multisensory landscape experience on landscape perception and by extension a potential impact on design evaluation and experience. For landscape architects and planners this signals the importance of considering the **total environmental experience** beyond how something looks. For example, natural sound increased preference for most of the visual conditions and views - if the primary aim of a design is to provide a **positive aesthetic experience** then the research presented here supports a design that incorporates wildlife attracting vegetation to maximize a users preference for a particular landscape. In addition, some focus on **enhanced soundscape design** can contribute positively to an overall experience of the environment and have positive knock-on effects such as aiding **spatial navigation for the visibly impaired** by enhancing sound based spatial cues (e.g. Parking & Smithies, 2012).

This research has also identified a very important aspect for landscape architects: the relative **perceptual ineffectiveness of Google Earth** for eye-level landscape evaluation. The move from a more paper-based landscape architecture workflow to one that is more digitally oriented has resulted in many practitioners using digital tools such as Sketchup. As a result it is relatively easy to export a 3D model completed in Sketchup into Google Earth (e.g. to benefit from existing context model data of terrain, built form and vegetation). Practitioners are cautioned that based on the visualizations used in this research the **highest level of realism** attributed to a Google Earth visualization is 2.81 (on a scale of 5), which is **very low** relative to other modelling techniques and environments (e.g. Lange, 2001). It is suggested that if the model to be exported from Sketchup is relatively high quality and is the primary focus of evaluation then the context in Google Earth may provide an appropriate level of contextual visual fidelity for evaluation. Relying solely on Google Earth would in most instances **lack the visual fidelity necessary** for the majority of design and planning processes.

10.4.2 Visualization researchers and preparers

The research here supports previous results indicating that **natural sounds** have either a positive effect or little effect on preference for photographs (e.g. Benfield, Bell, Troup, & Soderstrom, 2010). When coupled with the results of the current study that confirm a similar pattern for realism this indicates that **natural sounds are the most appropriate to use in conjunction with 3D visualizations** containing any landscape elements as they will not significantly lower perceived realism or preference, regardless of the elements in a scene. This is not the case for anthropogenic and mechanical sounds, which can have a very large negative effect on realism and preference particularly if a visualization contains vegetation. In addition, visualization preparers need to be conscious of the **cross-sensory** effect of aural-visual interaction, as a sound that may be obviously one thing to a researcher **can be altered by a visualization** to be heard as something different by a participant with potentially unwanted results.

The relative **perceptual ineffectiveness of Google Earth** for eye-level landscape evaluation is also an issue for visualization preparers, particularly those engaged with research questions of their own using Google Earth for base imagery. Previous research has suggested visualization realism is correlated to perceptual effectiveness and those using Google Earth will need to be aware of the limitations of the perception of realism and by extension the effectiveness of this tool if using existing imagery. As stated previously the lower visual fidelity of Google Earth could be offset by using models imported that are higher fidelity – preparers and presenters of visualizations need to be aware of these limitations and respond based on their project needs.

Consistency of use of sounds throughout a design or planning evaluation is critical as the effect of sound on realism and preference perception can vary based on the landscape elements visualized. While the impact of **sounds are relatively consistent**

for visualizations showing only terrain or terrain with built form, there are **more complicated perceptual responses** to visualizations depicting terrain, built form and vegetation, which depends on the relative amount of each landscape element in the scene and the corresponding sound(s) used. Preparers of visualizations need to be very conscious that the combination of landscape elements in the same 3D visualization but viewed from a different point can have very different perceptual responses depending on the sound. In particular, built form moderates the impact of both speech and traffic sounds on preference ratings, with preference increasing with an increase of built form in a visualization. This underscores the importance of **multiple viewpoints** for evaluation, as well as the potential contribution to multisensory environmental simulation of **real-time visualization** with accurately modelled spatialized sound.

Finally, the results of the research question on user characteristics indicate that if **heterogeneous stakeholder groups** are to be engaged in multisensory-based environmental decision making then the use of particular sounds, views and landscape elements need to be carefully considered, as realism can vary by gender and first language and preference by age, first language, cultural and professional background.

10.5 Limitations of the study and future research

Specific limitations for each research question are included in their respective chapters. This section discusses limitations of the research as they relate specifically to future research requirements and how future research can build on the research presented here by recognizing and responding to the limitations.

10.5.1 Audio and video hardware

Although the experiment variables were controlled, further work is still needed under controlled conditions to determine the impact of audio and video hardware on multisensory environmental perception ratings. Owing to the low number of participants using monitors below 13” or above 27” this could not be investigated, and the rise in the use of tablets and smart phones will no doubt be a significant factor in future studies of this type. It does confirm that t**he majority of participants in this case used a monitor between 13” and 27”**, which researchers can take into consideration regarding future data collection. In addition, while the difference between speakers and headphones on sound quality evaluation has been shown to vary (e.g. Fischetti, Jouhaneau, & Hemim, 1993; Kallinen & Ravaja, 2007) this research has provided evidence that for combined **aural-visual evaluation** there was not a significant difference based on **audio hardware**. Further research of the impact on realism and preference ratings of differing audio hardware could support the results presented here.

10.5.2 User characteristics

The research project provided an exploratory analysis of the effect and interaction of different user characteristics on multisensory environmental perception. The findings identify clear impacts on visualization perception of different user characteristics, particularly for landscape preference (i.e. significant differences for **realism** by the interaction of gender and first language; for **preference** by age, first language, cultural background, professional background and familiarity with 3D graphics). Further research is needed to verify these findings and to identify any influence of important user characteristic that the study did not examine. Specifically **site familiarity** could not be analysed due to the lack of participants who were familiar with the site. In addition, the experiment could not evaluate the difference in perceived realism and preference ratings between **laypeople, built environment experts and environmental experts** due to a lack of built environment experts in the participant sample. An understanding of the effect of these distinctions is recommended.

10.5.3 Visualization and sound quality

Responses to 3D landscapes visualized via Google Earth were used in the research, and as a result, the **imagery was only in the mid-range** for realism and preference ratings. Further research is needed on the perceptual response interactions of visualizations with **more realistic visualizations with different sound types**. In addition, **sound types that also vary** in level of perceived preference, loudness, and realism need to be investigated for their contribution to perception at all levels of detail, as well as different sound types at the **same level of audio fidelity** (e.g. ambient nature vs. ambient traffic). Finally, the research clearly indicated that visualizations accompanied by speech resulted in the most extreme negative changes for preference – it is critical to know if the **inclusion of people in visualizations** moderates this effect.

10.5.4 Realism as a variable

Perceived realism was evaluated in the experiment so results could be comparable to other landscape visualization studies (e.g. Lange, 2001). While this provided a good starting point for a landscape visualization based aural-visual interaction study the concept of **presence** as a conceptual construct may be a more potent measure of landscape experience. Further research is needed on the use of presence as a measure of landscape experience in general and specifically for multisensory interaction studies.

10.6 Outlook and conclusion

Evaluating landscape change with 3D landscape visualizations augmented with sound has the potential to include a wider variety of people (designers, users, participants) and considers a wider degree of inputs (e.g. multimodal) in the design and planning of landscape. The benefits have the potential to clarify meaning and foster understanding between different groups involved in decision-making in planning and design. The study presented here has raised important questions for visualization researchers particularly concerning the validity of mono-sensory landscape experience. While further research is needed in this area this exploratory investigation has provided a preliminary framework and empirical evidence as a point of departure for further study on important topics relating to landscape experience.

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12 PUBLICATIONS

This thesis is based on work that has been published in the following papers:

Lindquist, M., & Lange, E. (2014). Sensory Aspects of Simulation and Representation In Landscape And Environmental Planning: A Soundscape Perspective. In A. Contin, R. Salerno, P. Paolini & N. Diblas (Eds.), *Innovative Technologies in Urban Mapping*: Springer-Verlag Italia.

Lindquist, M., Lange, E., Kang, J. (2013). *Conducting Multisensory Perception Experiments Online: An Assessment of Web-based Tools for Multimodal Environment-Behaviour Research*. Proceedings of 10th Biennial Conference on Environmental Psychology, Magdeburg.

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13 APPENDIX

13.1 **Appendix A:** SPL and psychoacoustic characteristics of St. James's Park

Table 52: SPL and psychoacoustic characteristics of St. James's Park

Loc	Time	Leq	Lmin	Lmax	StdDev	Sharpness (acum)	Fluctuation (vacil)	Loudness (sone)	Roughness (asper)
1	700	56.9	51.8	66.7	2.6	2.01	0.020	29.7	3.02
2	700	56.3	52.5	63	2.1	2.11	0.009	32.7	2.95
3	700	56	50.5	60.9	2.4	2.03	0.009	33.3	3.1
4	700	60.8	55.3	64.6	2	2.39	0.009	37.1	3.32
5	700	55.3	51.3	59.7	1.8	2.05	0.011	29.7	2.84
6	700	54.8	52.7	59.5	1.3	2.13	0.011	26.4	2.62
1	1200	59	55.5	64.3	1.7	2.03	0.018	31.1	2.84
2	1200	56.1	54.3	58.7	0.9	1.99	0.013	30.5	2.86
3	1200	56.3	53.3	59.8	1.4	1.91	0.010	29.6	2.8
4	1200	61.4	56.6	67.5	2.1	2.33	0.014	38.9	3.27
5	1200	56.8	54.6	61.6	1.1	1.92	0.011	27.6	2.67
6	1200	55.3	52.4	59.5	1	2	0.010	26.6	2.56
1	1700	56.5	54.1	60.9	1	2.12	0.013	31.5	2.93
2	1700	55.2	53.7	57.7	0.9	1.84	0.010	27.1	2.59
3	1700	57.3	53.4	61.9	1.6	1.97	0.009	29.6	2.77
4	1700	60.6	55.4	66.6	2.6	2.23	0.010	35.4	3.13
5	1700	56.1	54.4	58.8	1	1.99	0.015	27.5	2.68
6	1700	57.2	54	70	1.9	2.07	0.016	27.4	2.68
1	2200	53.7	49.9	58.9	1.9	2.07	0.009	29.4	2.86
2	2200	56.1	54.4	58.8	1	1.71	0.009	27	2.76
3	2200	54	48	56.9	2.1	1.86	0.007	28.6	2.84
4	2200	57	49.2	62.5	3.8	2.01	0.009	30.7	2.92
5	2200	52.6	48.3	60.1	2.1	1.63	0.009	24.7	2.57
6	2200	50.9	49.7	52.2	0.4	1.62	0.007	23.2	2.43

Green shading: low values; Red shading: high values; Intensity level: extreme indication
Box outline indicates sounds used in the experiment

13.2 **Appendix B:** Pilot study comments

Table 53: Pilot study comments

Interesting. I think images that are a little more photo realistic would have had a greater impact on if I thought the environments seemed real, but it was obvious that the appropriate sound can greatly influence how I experienced the environment, even as an image.

I found with hearing people talking without seeing any kind of people or vehicles or movement in the scene hard to see the picture as real.

The landscapes were not realistic, in my view--if this is what advanced 3D software produces, I'd stick to drawing.

Thanks for the invite to the survey. Not sure if this is what the comment box are for, but two quick reflections! 1. Trees / vegetation in combination with topography make a much more realistic environment than just topography and the mapped google earth aerial photo. The topography alone makes it hard to gage depth. 2. Sound seems to be both able to add or detract from the realism of the image. For me, I felt it made it more real if the sound matched the image and less real if it felt foreign to the image. Best of luck and curious about the results.

I may have answered differently if I could see or knew the source of the noise.North Dakota prairie with a howling blizzard is unpleasant ,but when it is totally silent it can cause uneasiness as well.My expensive hearing aids are programmed to diminish loud background noise but that function is not consistent and can make ordinary sounds feel muffled The sound of a chainsaw can be quite soothing,while wailing children can be nerve -wracking.Very subjective situations. Best of luck.

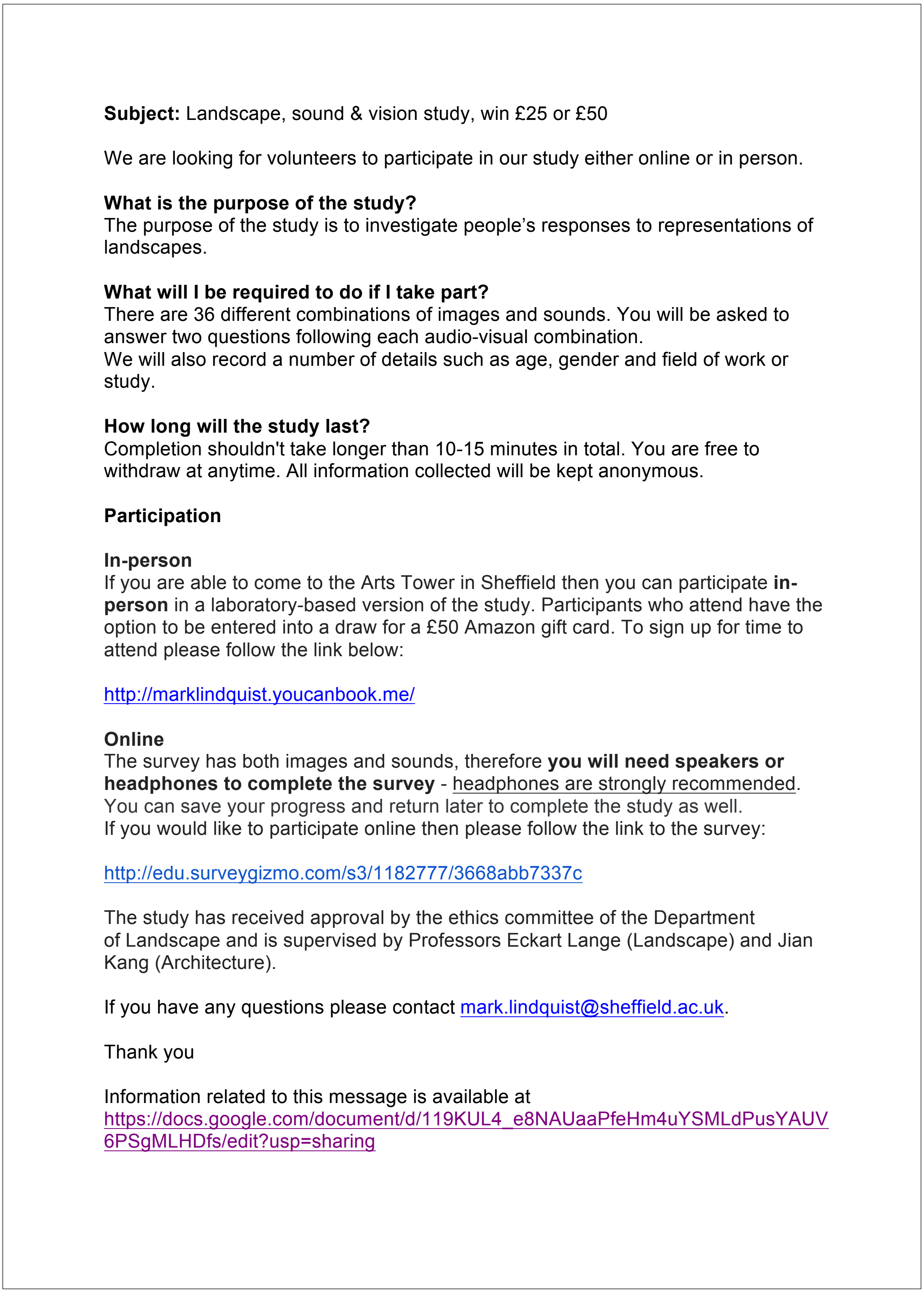
It grew tiresome - 50 questions using the same handful of images and sounds, just shuffled. I think my responses were biased as I grew bored and let a matrix of decision-making rules determine my responses, as opposed to the sensory impressions I had of each scene. I would say that there needs to be far more images and sounds - repition ruined it for me. Fewer questions would also be benefitial in my opinion.

too much noise, i feel headache, but it is good to know how much the noise affect my mood. i feel i really hate noise

Since I'm so used to looking at really good images made from 3D models (teaching architecture and urban design) I really cannot experience the environments as real.

It is probably just me but I found the lower half of some of the pictures, which looks like grass, a little ambiguous because I did not know whether it was to be included as part of the environment or not. This was because it was not realistic lawn or park land.

13.3 **Appendix C:** Online experiment invitation and information



Subject: Landscape, sound & vision study, win £25 or £50

We are looking for volunteers to participate in our study either online or in person.

What is the purpose of the study?
The purpose of the study is to investigate people's responses to representations of landscapes.

What will I be required to do if I take part?
There are 36 different combinations of images and sounds. You will be asked to answer two questions following each audio-visual combination.
We will also record a number of details such as age, gender and field of work or study.

How long will the study last?
Completion shouldn't take longer than 10-15 minutes in total. You are free to withdraw at anytime. All information collected will be kept anonymous.

Participation

In-person
If you are able to come to the Arts Tower in Sheffield then you can participate **in-person** in a laboratory-based version of the study. Participants who attend have the option to be entered into a draw for a £50 Amazon gift card. To sign up for time to attend please follow the link below:

http://marklindquist.youcanbook.me/

Online
The survey has both images and sounds, therefore **you will need speakers or headphones to complete the survey** - headphones are strongly recommended.
You can save your progress and return later to complete the study as well.
If you would like to participate online then please follow the link to the survey:

http://edu.surveygizmo.com/s3/1182777/3668abb7337c

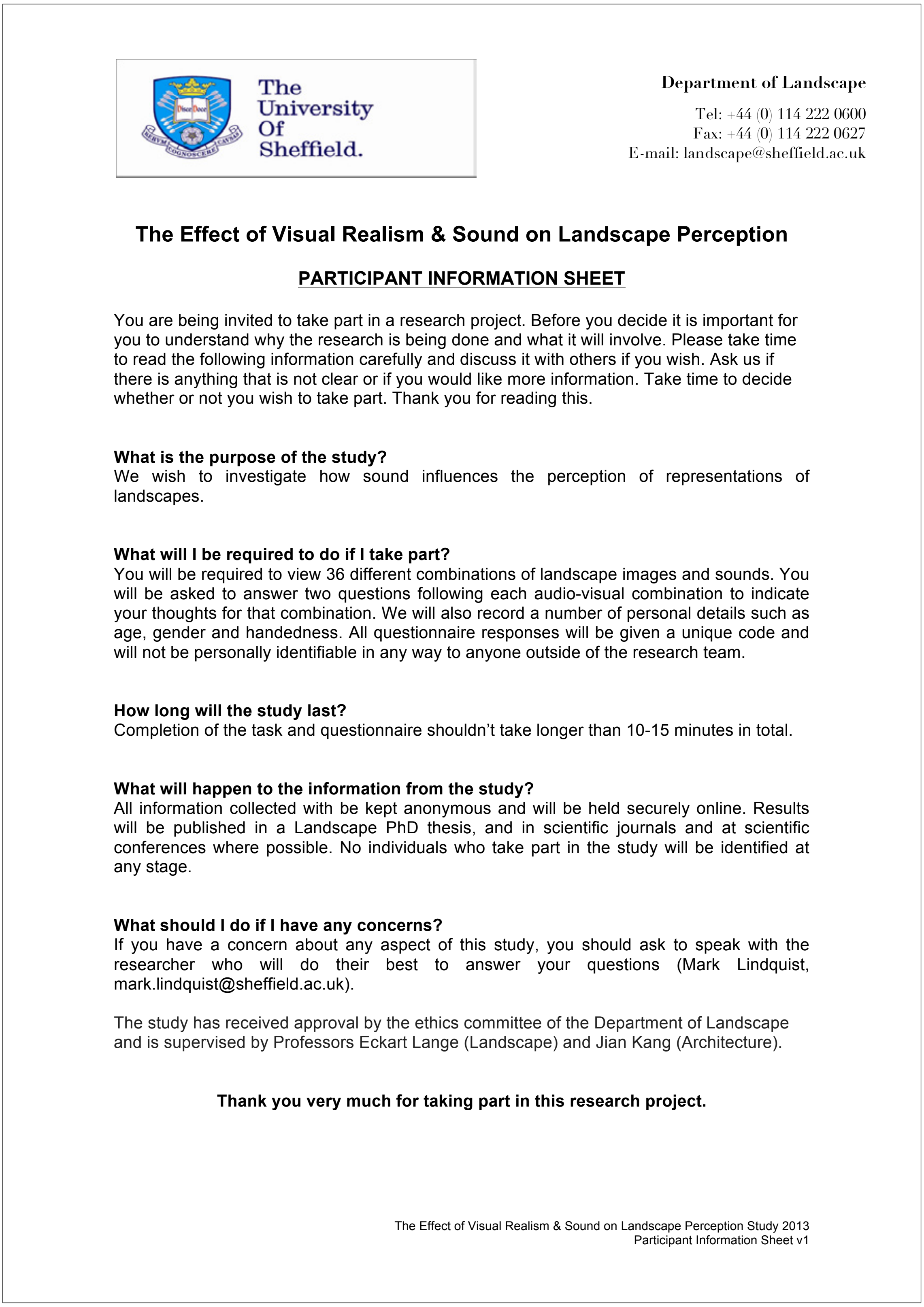
The study has received approval by the ethics committee of the Department of Landscape and is supervised by Professors Eckart Lange (Landscape) and Jian Kang (Architecture).

If you have any questions please contact mark.lindquist@sheffield.ac.uk.

Thank you

Information related to this message is available at
https://docs.google.com/document/d/119KUL4_e8NAUaaPfeHm4uYSMLdPusYAUV6PSgMLHDfs/edit?usp=sharing

13.4 **Appendix D:** Laboratory based experiment information sheet and consent form



The University Of Sheffield.

Department of Landscape
Tel: +44 (0) 114 222 0600
Fax: +44 (0) 114 222 0627
E-mail: landscape@sheffield.ac.uk

The Effect of Visual Realism & Sound on Landscape Perception

PARTICIPANT INFORMATION SHEET

You are being invited to take part in a research project. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

What is the purpose of the study?
We wish to investigate how sound influences the perception of representations of landscapes.

What will I be required to do if I take part?
You will be required to view 36 different combinations of landscape images and sounds. You will be asked to answer two questions following each audio-visual combination to indicate your thoughts for that combination. We will also record a number of personal details such as age, gender and handedness. All questionnaire responses will be given a unique code and will not be personally identifiable in any way to anyone outside of the research team.

How long will the study last?
Completion of the task and questionnaire shouldn't take longer than 10-15 minutes in total.

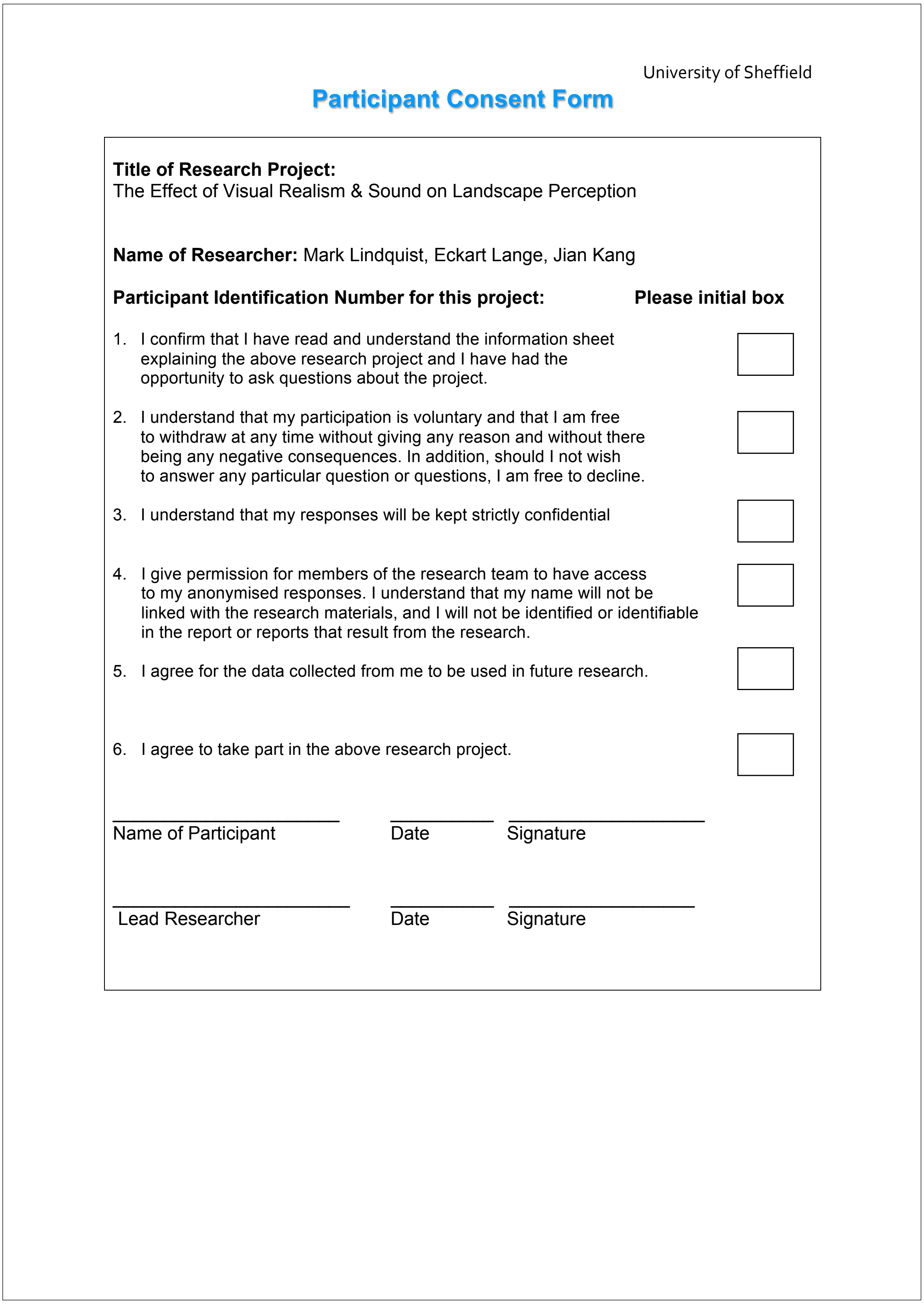
What will happen to the information from the study?
All information collected with be kept anonymous and will be held securely online. Results will be published in a Landscape PhD thesis, and in scientific journals and at scientific conferences where possible. No individuals who take part in the study will be identified at any stage.

What should I do if I have any concerns?
If you have a concern about any aspect of this study, you should ask to speak with the researcher who will do their best to answer your questions (Mark Lindquist, mark.lindquist@sheffield.ac.uk).

The study has received approval by the ethics committee of the Department of Landscape and is supervised by Professors Eckart Lange (Landscape) and Jian Kang (Architecture).

Thank you very much for taking part in this research project.

The Effect of Visual Realism & Sound on Landscape Perception Study 2013
Participant Information Sheet v1



University of Sheffield

Participant Consent Form

Title of Research Project:
The Effect of Visual Realism & Sound on Landscape Perception

Name of Researcher: Mark Lindquist, Eckart Lange, Jian Kang

Participant Identification Number for this project: **Please initial box**

1. I confirm that I have read and understand the information sheet explaining the above research project and I have had the opportunity to ask questions about the project. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline. ☐
3. I understand that my responses will be kept strictly confidential ☐
4. I give permission for members of the research team to have access to my anonymised responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. ☐
5. I agree for the data collected from me to be used in future research. ☐
6. I agree to take part in the above research project. ☐

________________________ ____________ ____________________
Name of Participant Date Signature

________________________ ____________ ____________________
Lead Researcher Date Signature

13.5 **Appendix E:** ANOVA assumption testing

Table 54: ANOVA results comparing original dataset vs. dataset with outliers removed

Source	Type III Sum of Squares	df	Mean Sq	F	Sig.	Part Eta Sq
Realism						
Original						
view	17.45	2, 394	8.72	17.14	p < .0005	0.08
vis cond	874.35	2, 394	437.17	126.93	p < .0005	0.39
sound	22.50	3, 591	7.50	6.35	p < .0005	0.03
view * vis cond	15.43	4, 788	3.86	7.49	p < .0005	0.04
view * sound	14.33	6, 1182	2.39	6.79	p < .0005	0.03
vis cond * sound	231.27	6, 1182	38.55	46.54	p < .0005	0.19
view * vis cond * sound	19.03	12, 2364	1.59	4.56	p < .0005	0.02
Outliers removed						
view	17.31	2, 366	8.65	17.34	p < .0005	0.09
vis cond	979.05	2, 366	489.52	150.67	p < .0005	0.45
sound	27.99	3, 549	9.33	8.18	p < .0005	0.04
view * vis cond	12.54	4, 732	3.14	6.59	p < .0005	0.04
view * sound	13.25	6, 1098	2.21	6.98	0.009	0.04
vis cond * sound	168.80	6, 1098	28.13	41.33	p < .0005	0.18
view * vis cond * sound	14.89	12, 2196	1.24	4.06	p < .0005	0.02
Preference						
Original						
view	15.29	2, 392	7.65	13.57	p < .0005	0.07
vis cond	840.16	2, 392	420.08	145.71	p < .0005	0.43
sound	291.36	3, 588	97.12	55.84	p < .0005	0.22
view * vis cond	33.84	4, 784	8.46	16.32	p < .0005	0.08
view * sound	5.75	6, 1176	0.96	2.87	p < .0005	0.01
vis cond * sound	131.18	6, 1176	21.86	37.14	p < .0005	0.16
view * vis cond * sound	20.90	12, 2352	1.74	5.30	p < .0005	0.03
Outliers removed						
view	17.07	2, 380	8.53	15.34	p < .0005	0.08
vis cond	892.89	2, 380	446.45	164.93	p < .0005	0.47
sound	257.00	3, 570	85.67	52.37	p < .0005	0.22
view * vis cond	34.76	4, 760	8.69	16.92	p < .0005	0.08
view * sound	5.71	6, 1140	0.95	2.87	0.009	0.02
vis cond * sound	118.52	6, 1140	19.75	33.56	p < .0005	0.15
view * vis cond * sound	19.38	12, 2280	1.62	5.06	p < .0005	0.03

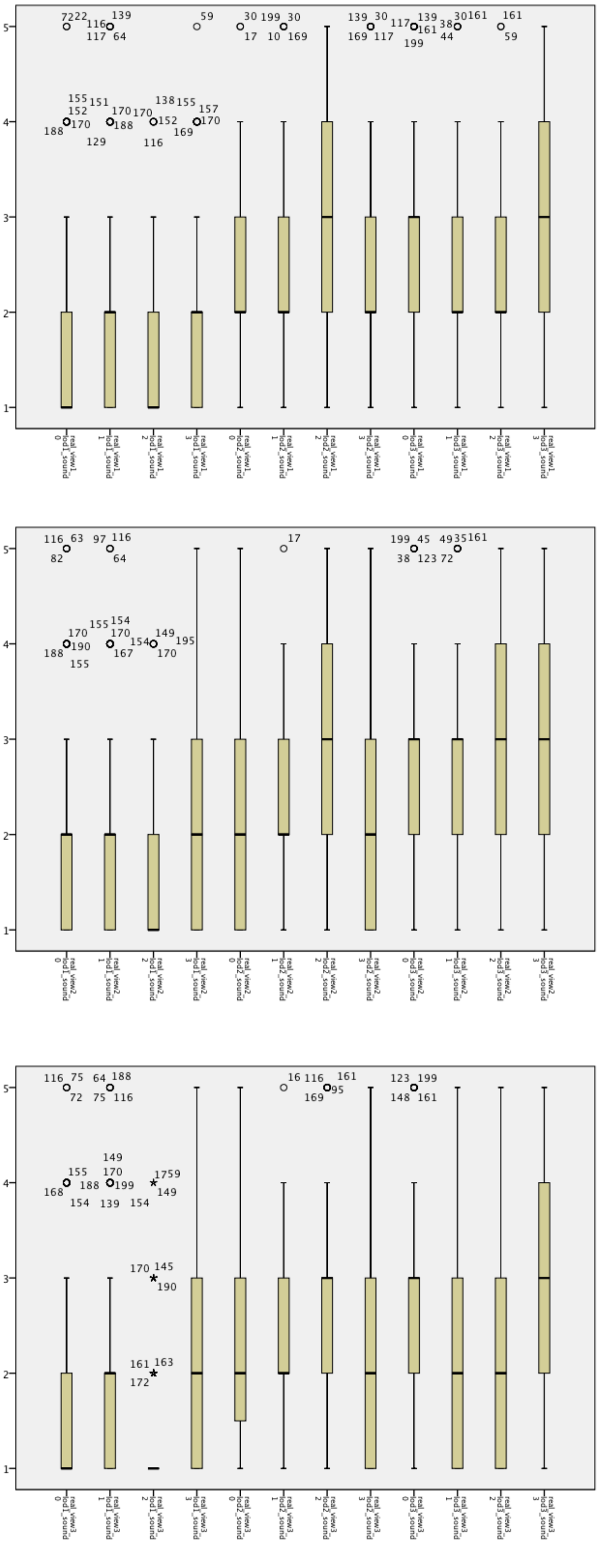


Figure 68: Box plots of mean realism ratings for view 1 (top); view 2 (middle); view 3 (bottom)

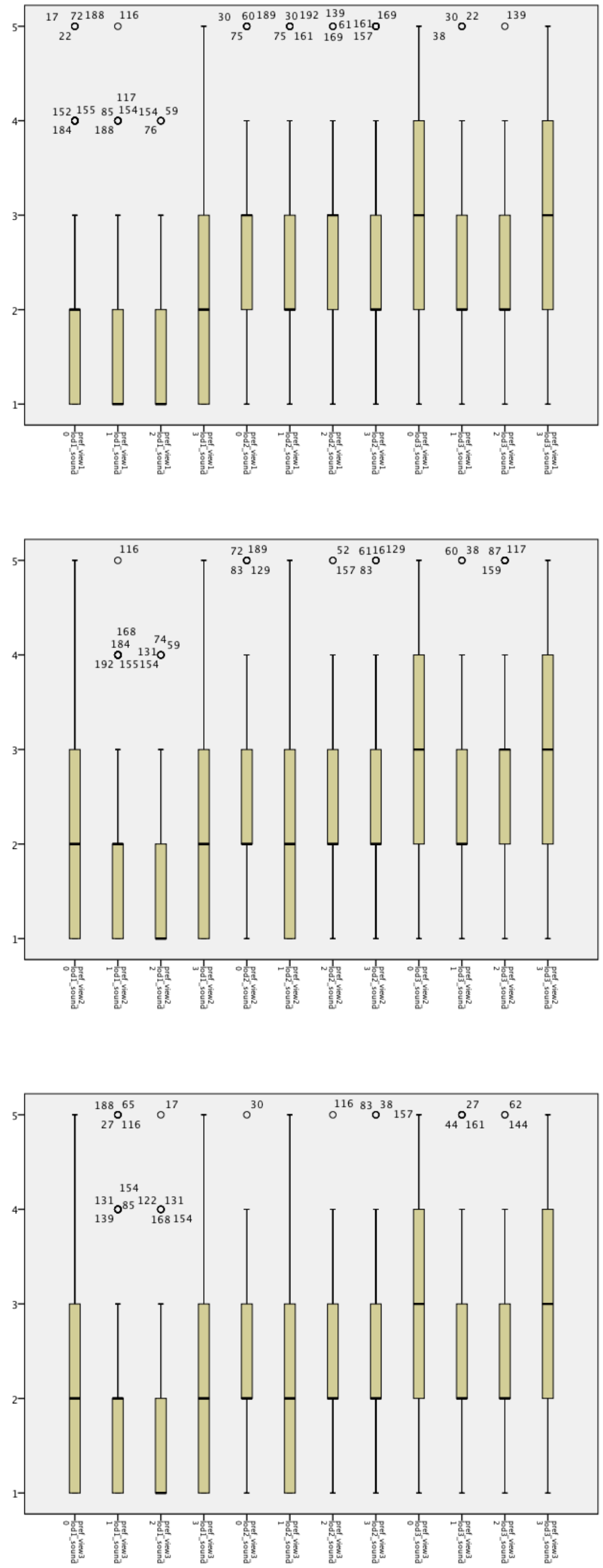


Figure 69: Box plots of mean preference ratings for view 1 (top); view 2 (middle); view 3 (bottom)

13.6 Appendix F: Homogeneity of variance results

Table 55: Homogeneity of variance results, Research Question 2 (1 of 2)

Source			Gender		Age		Language		Country	
View	Vis-Cond	Sound	Real$_p$	Pref$_p$	Real$_p$	Pref$_p$	Real$_p$	Pref$_p$	Real$_p$	Pref$_p$
1	1	No sound	0.328	0.568	0.523	0.858	0.012	0.462	0.912	0.912
		Traffic	0.596	0.052	0.272	0.958	0.001	0.078	0.135	0.135
		Speech	0.013	0.061	0.009	0.674	0.157	0.39	0.068	0.068
		Nature	0.698	0.716	0.297	0.891	0.018	0.143	0.882	0.882
	2	No sound	0.556	0.307	0.87	0.249	0.009	0.334	0.349	0.349
		Traffic	0.78	0.328	0.018	0.007	0.652	0.575	0.570	0.570
		Speech	0.053	0.407	0.589	0.673	0.319	0.042	0.023	0.023
		Nature	0.219	0.994	0.674	0.073	0.217	0.028	0.007	0.007
	3	No sound	0.295	0.461	0.273	0.887	0.332	0.012	0.086	0.086
		Traffic	0.728	0.379	0.419	0.289	0.226	0.027	0.348	0.348
		Speech	0.179	0.817	0.736	0.913	0.673	0.404	0.356	0.356
		Nature	0.741	0.864	0.949	0.963	0.863	0.42	0.180	0.180
2	1	No sound	0.287	0.432	0.182	0.906	0.462	0.181	0.605	0.605
		Traffic	0.94	0.359	0.19	0.285	0.125	0.126	0.279	0.279
		Speech	0	0.131	0.006	0.028	0.019	0.35	0.912	0.912
		Nature	0.919	0.588	0.117	0.275	0.545	0.366	0.275	0.275
	2	No sound	0.323	0.923	0.305	0.639	0.212	0.1	0.696	0.696
		Traffic	0.394	0.867	0.409	0.012	0.035	0.21	0.142	0.142
		Speech	0.414	0.191	0.848	0.257	0.023	0.836	0.173	0.173
		Nature	0.937	0.607	0.005	0.866	0.232	0.331	0.324	0.324
	3	No sound	0.646	0.489	0.787	0.631	0.579	0.724	0.784	0.784
		Traffic	0.128	0.829	0.063	0.093	0.777	0.127	0.095	0.095
		Speech	0.29	0.984	0.024	0.079	0.679	0.686	0.821	0.821
		Nature	0.054	0.24	0.637	0.769	0.795	0.755	0.157	0.157
3	1	No sound	0.912	0.711	0.344	0.263	0.058	0.285	0.772	0.772
		Traffic	0.689	0.307	0.909	0.943	0.021	0.075	0.208	0.208
		Speech	0.119	0.082	0.486	0.065	0.012	0.168	0.082	0.082
		Nature	0.27	0.143	0.057	0.047	0.45	0.712	0.352	0.352
	2	No sound	0.518	0.531	0.023	0.066	0.005	0.063	0.547	0.547
		Traffic	0.409	0.875	0.014	0.35	0.013	0.198	0.943	0.943
		Speech	0.437	0.47	0.668	0.29	0.001	0.006	0.001	0.001
		Nature	0.083	0.596	0.544	0.466	0.201	0.064	0.337	0.337
	3	No sound	0.048	0.001	0.355	0.322	0.182	0.114	0.998	0.998
		Traffic	0.709	0.479	0.058	0.178	0	0.001	0.006	0.006
		Speech	0.067	0.257	0.362	0.574	0.789	0.278	0.819	0.819
		Nature	0.448	0.958	0.417	0.089	0.155	0.114	0.038	0.038

Realism (Real$_p$) and Preference (Pref$_p$) values for Levene's test.
V = view

Table 56: Homogeneity of variance results, Research Question 2 (2 of 2)

Source			Prof. Backgrnd		3D Familiarity		3D Experience		Noise Sensitiv.	
V	Vis-Cond	Sound	Real_p	Pref_p	Real_p	Pref_p	Real_p	Pref_p	Real_p	Pref_p
1	1	No sound	0.046	0.046	0.182	0.02	0.015	0.076	0.337	0.721
		Traffic	0.051	0.811	0.443	0.732	0.422	0.535	0.534	0.27
		Speech	0.001	0	0.131	0.008	0.006	0	0.125	0.955
		Nature	0.103	0.095	0.67	0.358	0.557	0.07	0.272	0.78
	2	No sound	0.501	0.048	0.467	0.415	0.378	0.927	0.972	0.84
		Traffic	0.712	0.006	0.531	0.008	0.128	0.001	0.762	0.234
		Speech	0.773	0.262	0.552	0.919	0.448	0.26	0.495	0.034
		Nature	0.025	0.801	0.565	0.11	0.697	0.8	0.889	0.196
	3	No sound	0.011	0.043	0.464	0.582	0.95	0.587	0.097	0.042
		Traffic	0.867	0.149	0.614	0.126	0.329	0.048	0.154	0.902
		Speech	0.746	0.138	0.847	0.878	0.349	0.768	0.094	0.59
		Nature	0.854	0.724	0.959	0.631	0.967	0.709	0.797	0.53
2	1	No sound	0.018	0.06	0.328	0.07	0.531	0.188	0.828	0.655
		Traffic	0.372	0.871	0.254	0.198	0.844	0.492	0.98	0.499
		Speech	0	0.08	0.036	0.012	0.003	0.133	0.114	0.079
		Nature	0.004	0.007	0.116	0.043	0.049	0.002	0.729	0.771
	2	No sound	0.011	0.797	0.115	0.454	0.008	0.519	0.735	0.295
		Traffic	0.842	0.028	0.963	0.035	0.576	0.003	0.891	0.862
		Speech	0.757	0.391	0.723	0.736	0.901	0.507	0.474	0.554
		Nature	0.004	0.146	0.869	0.482	0.048	0.133	0.185	0.88
	3	No sound	0.567	0.491	0.502	0.301	0.239	0.664	0.453	0.32
		Traffic	0.97	0.757	0.472	0.013	0.468	0.486	0.487	0.949
		Speech	0.479	0.846	0.209	0.678	0.691	0.953	0.692	0.288
		Nature	0.915	0.444	0.858	0.342	0.599	0.349	0.18	0.914
3	1	No sound	0.025	0.006	0.028	0.001	0.076	0.002	0.663	0.215
		Traffic	0.343	0.263	0.823	0.003	0.309	0.087	0.618	0.93
		Speech	0.035	0.026	0.328	0.059	0.022	0.107	0.991	0.742
		Nature	0.036	0.004	0.213	0.187	0.111	0.037	0.647	0.053
	2	No sound	0.202	0.349	0.645	0.189	0.572	0.015	0.491	0.592
		Traffic	0.165	0.084	0.215	0.249	0.421	0.751	0.842	0.387
		Speech	0.306	0.778	0.839	0.012	0.751	0.763	0.656	0.88
		Nature	0.007	0.517	0.098	0.493	0.108	0.267	0.445	0.846
	3	No sound	0.124	0.354	0.062	0.404	0.61	0.713	0.487	0.449
		Traffic	0.38	0.385	0.989	0.095	0.783	0.273	0.01	0.582
		Speech	0.185	0.438	0.204	0.496	0.811	0.897	0.002	0.018
		Nature	0.448	0.958	0.417	0.089	0.155	0.114	0.046	0.034

Realism (Real_p) and Preference (Pref_p) values for Levene's test.
V = view

Table 57: Homogeneity of variance results, Research Question 3

Source			Audio hard.		Exp. Cond.		Display Size	
View	Vis - Cond	Sound	Real_p	Pref_p	Real_p	Pref_p	Real_p	Pref_p
1	1	No sound	0.932	0.281	0.24	0.624	0.369	0.712
		Traffic	0.694	0.169	0.061	0.253	0.359	0.698
		Speech	0.874	0.411	0.037	0.108	0	0.137
		Nature	0.531	0.9	0.699	0.855	0.99	0.639
	2	No sound	0.43	0.749	0.115	0.436	0.086	0.198
		Traffic	0.199	0.458	0.766	0.679	0.87	0.877
		Speech	0.284	0.743	0.709	0.833	0.653	0.087
		Nature	0.972	0.779	0.825	0.927	0.81	0.333
	3	No sound	0.151	0.68	0.369	0.084	0.936	0.314
		Traffic	0.421	0.637	0.816	0.223	0.204	0.34
		Speech	0.571	0.007	0.732	0.622	0.443	0.704
		Nature	0.195	0.12	0.87	0.159	0.578	0.023
2	1	No sound	0.256	0.102	0.135	0.387	0.414	0.403
		Traffic	0.219	0.491	0.805	0.801	0.599	0.602
		Speech	0.192	0.261	0	0.538	0	0.442
		Nature	0.229	0.042	0.423	0.988	0.143	0.798
	2	No sound	0.826	0.817	0.299	0.84	0.767	0.664
		Traffic	0.752	0.829	0.035	0.728	0.214	0.531
		Speech	0.657	0.434	0.361	0.572	0.977	0.258
		Nature	0.425	0.668	0.671	0.528	0.928	0.768
	3	No sound	0.48	0.408	0.134	0.895	0.332	0.429
		Traffic	0.557	0.156	0.092	0.361	0.19	0.266
		Speech	0.933	0.614	0.653	0.605	0.281	0.458
		Nature	0.214	0.962	0.907	0.574	0.493	0.521
3	1	No sound	0.712	0.678	0.268	0.073	0.642	0.058
		Traffic	0.819	0.285	0.035	0.066	0.015	0.081
		Speech	0.51	0.363	0.093	0.424	0.014	0.082
		Nature	0.232	0.865	0.258	0.545	0.239	0.458
	2	No sound	0.867	0.442	0.01	0.968	0.006	0.52
		Traffic	0.703	0.299	0.753	0.369	0.954	0.057
		Speech	0.503	0.912	0.681	0.52	0.438	0.16
		Nature	0.592	0.399	0.641	0.447	0.712	0.683
	3	No sound	0.871	0.122	0.949	0.314	0.264	0.216
		Traffic	0.489	0.133	0.226	0.102	0.244	0.614
		Speech	0.413	0.159	0.018	0.173	0.408	0.158
		Nature	0.881	0.965	0.247	0.818	0.112	0.314

Realism (Real_p) and Preference (Pref_p) values for Levene's test.

13.7 **Appendix G:** Participant background

Table 58: Participant country majority of life

Country	Frequency	Percent
United Kingdom	95	47.7
Canada	20	10.1
United States	13	6.5
China	9	4.5
Germany	5	2.5
Mexico	5	2.5
Australia	4	2.0
France	4	2.0
Hong Kong	4	2.0
Malaysia	4	2.0
Romania	4	2.0
Turkey	3	1.5
India	2	1.0
Iraq	2	1.0
New Zealand	2	1.0
Spain	2	1.0
Argentina	1	.5
Belgium	1	.5
Burma	1	.5
Chile	1	.5
Cyprus	1	.5
Czech Republic	1	.5
Egypt	1	.5
Iceland	1	.5
Iran	1	.5
Ireland	1	.5
Italy	1	.5
Japan	1	.5
Norway	1	.5
Pakistan	1	.5
Portugal	1	.5
Russia	1	.5
Singapore	1	.5
Slovenia	1	.5
Sweden	1	.5
United Arab Emirates	1	.5
Uzbekistan	1	.5
Total	**199**	**100.0**

Table 59: Participant professional background (self identified)

Background	**Frequency**	**Percent**
No comment	102	51.3
Law	4	2.0
Psychology	4	2.0
English Literature	3	1.5
Linguistics	3	1.5
urban design	3	1.5
archaeology	2	1.0
Biology	2	1.0
Computer Science	2	1.0
dentistry	2	1.0
Dentistry	2	1.0
education	2	1.0
English	2	1
English Lit	2	1.0
History	2	1.0
Management	2	1.0
Management School	2	1.0
Medicine	2	1.0
None	2	1.0
Admin Rep	1	.5
aerospace engineering	1	.5
Agriculture	1	.5
Also a first degree in the History of Art	1	.5
APS	1	.5
Archaeology	1	.5
Art, Social Sciences and Cultural Studies	1	.5
building physics, indoor environment	1	.5
Buisness	1	.5
Ecology	1	.5
English Literature and History	1	.5
Fine art	1	.5
Fine Art	1	.5
French	1	.5
Health Science	1	.5
heavy duty mechanic	1	.5
history	1	.5
History/Politics	1	.5
Humanities	1	.5
Illustration / Design	1	.5
Informatics	1	.5

Information Science	1	.5
Information Systems	1	.5
IT	1	.5
journalism	1	.5
Landscape archaeology	1	.5
Landscape Archaeology	1	.5
LANGUAGES	1	.5
Literature	1	.5
Mathematics	1	.5
mechanical engineering	1	.5
medical research	1	.5
medicine	1	.5
Music	1	.5
n/a	1	.5
Natural and Human Environments	1	.5
No I studied psychology	1	.5
none	1	.5
nursing	1	.5
personnel	1	.5
Photography	1	.5
Political Science/Photography	1	.5
psycholofy	1	.5
psychology	1	.5
Radiography	1	.5
Research Nurse	1	.5
Science	1	.5
Social Sciences	1	.5
Speech therapy	1	.5
surveying	1	.5
Sustainable Urban Design	1	.5
System Engineering (ACSE)	1	.5
teacher	1	.5
Zoology	1	.5
Total	**199**	**100.0**

13.8 **Appendix H:** Research question 2, full contrast tables

Table 60: Contrasts for realism by gender: visual condition x sound

Visual Condition	**Sound**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.***	**η_p^2**
1 vs 2	no sound vs traffic	1.04	1, 196	1.04	0.893	1.000	0.005
	no sound vs speech	6.942	1, 196	6.942	5.412	0.378	0.027
	no sound vs nature	2.613	1, 196	2.613	2.84	1.000	0.014
	traffic vs speech	13.355	1, 196	13.355	9.428	**0.036**	0.046
	traffic vs nature	0.356	1, 196	0.356	0.305	1.000	0.002
	speech vs nature	18.074	1, 196	18.074	11.479	**0.018**	0.055
1 vs 3	no sound vs traffic	0.634	1, 196	0.634	0.493	1.000	0.003
	no sound vs speech	2.604	1, 196	2.604	2.382	1.000	0.012
	no sound vs nature	0.961	1, 196	0.961	1.074	1.000	0.005
	traffic vs speech	5.806	1, 196	5.806	5.293	0.396	0.026
	traffic vs nature	0.034	1, 196	0.034	0.032	1.000	0
	speech vs nature	6.729	1, 196	6.729	6.436	0.216	0.032
2 vs 3	no sound vs traffic	0.05	1, 196	0.05	0.072	1.000	0
	no sound vs speech	1.043	1, 196	1.043	1.103	1.000	0.006
	no sound vs nature	0.405	1, 196	0.405	0.551	1.000	0.003
	traffic vs speech	1.549	1, 196	1.549	1.86	1.000	0.009
	traffic vs nature	0.17	1, 196	0.17	0.15	1.000	0.001
	speech vs nature	2.747	1, 196	2.747	2.106	1.000	0.011

df = degrees of freedom; F = F ratio; sig. = significance; η_p^2 = partial eta squared.
*Significance adjusted for multiple comparisons with Bonferroni adjustment
Bold indicates significant at .05.

Table 61: Contrasts for preference by age: view x sound

View	Sound	Type III Sum of Squares	df	Mean Square	F	Sig.*	η_p^2
view 1 vs view 2	no sound vs traffic	1.011	2, 188	0.506	1.17	1.000	0.012
	no sound vs speech	0.459	2, 188	0.23	0.638	1.000	0.007
	no sound vs nature	0.294	2, 188	0.147	0.369	1.000	0.004
	traffic vs speech	1.717	2, 188	0.859	2.273	1.000	0.024
	traffic vs nature	0.228	2, 188	0.114	0.237	1.000	0.003
	speech vs nature	0.994	2, 188	0.497	1.224	1.000	0.013
view 1 vs view 3	no sound vs traffic	2.392	2, 188	1.196	3.267	0.720	0.034
	no sound vs speech	2.982	2, 188	1.491	3.812	0.432	0.039
	no sound vs nature	0.574	2, 188	0.287	0.535	1.000	0.006
	traffic vs speech	0.883	2, 188	0.441	1.098	1.000	0.012
	traffic vs nature	2.012	2, 188	1.006	2.051	1.000	0.021
	speech vs nature	3.953	2, 188	1.977	4.721	0.180	0.048
view 2 vs view 3	no sound vs traffic	1.558	2, 188	0.779	1.831	1.000	0.019
	no sound vs speech	4.656	2, 188	2.328	6.045	0.054	0.06
	no sound vs nature	1.159	2, 188	0.58	1.154	1.000	0.012
	traffic vs speech	3.33	2, 188	1.665	4.298	0.270	0.044
	traffic vs nature	1.122	2, 188	0.561	0.996	1.000	0.01
	speech vs nature	7.497	2, 188	3.748	7.239	**0.018**	0.072

df = degrees of freedom; F = F ratio; sig. = significance; η_p^2 = partial eta squared.
*Significance adjusted for multiple comparisons with Bonferroni adjustment
Bold indicates significant at .05.

Table 62: Contrasts for preference by language: view x visual condition x sound

Source	View	Visual Condition	Sound	Type III Sum of Squares	df	Mean Square	F	Sig.*	η_p^2
Language * view * sound									
	view 1 vs 2		no sound vs traffic	0.02	1.194	0.02	0.05	1.000	0.00
			no sound vs speech	2.51	1.194	2.51	7.16	0.144	0.04
			no sound vs nature	0.58	1.194	0.58	1.45	1.000	0.01
			traffic vs speech	3.00	1.194	3.00	7.67	0.108	0.04
			traffic vs nature	0.82	1.194	0.82	1.76	1.000	0.01
			speech vs nature	0.68	1.194	0.68	1.64	1.000	0.01
	view 1 vs 3		no sound vs traffic	0.86	1.194	0.86	2.27	1.000	0.01
			no sound vs speech	3.80	1.194	3.80	9.77	**0.036**	0.05
			no sound vs nature	2.87	1.194	2.87	5.59	0.342	0.03
			traffic vs speech	1.04	1.194	1.04	2.49	1.000	0.01
			traffic vs nature	0.59	1.194	0.59	1.15	1.000	0.01
			speech vs nature	0.07	1.194	0.07	0.15	1.000	0.00
	view 2 vs 3		no sound vs traffic	1.16	1.194	1.16	2.72	1.000	0.01
			no sound vs speech	0.13	1.194	0.13	0.34	1.000	0.00
			no sound vs nature	0.88	1.194	0.88	1.74	1.000	0.01
			traffic vs speech	0.51	1.194	0.51	1.27	1.000	0.01
			traffic vs nature	0.02	1.194	0.02	0.04	1.000	0.00
			speech vs nature	0.33	1.194	0.33	0.59	1.000	0.00
Language * visual condition * sound									
		1 vs 2	no sound vs traffic	2.41	1.194	2.41	3.36	1.000	0.02
			no sound vs speech	0.55	1.194	0.55	0.66	1.000	0.00
			no sound vs nature	0.12	1.194	0.12	0.19	1.000	0.00
			traffic vs speech	0.66	1.194	0.66	0.76	1.000	0.00
			traffic vs nature	3.59	1.194	3.59	4.46	0.648	0.02
			speech vs nature	1.18	1.194	1.18	1.45	1.000	0.01
		1 vs 3	no sound vs traffic	0.22	1.194	0.22	0.21	1.000	0.00
			no sound vs speech	2.61	1.194	2.61	2.57	1.000	0.01
			no sound vs nature	1.43	1.194	1.43	1.94	1.000	0.01
			traffic vs speech	1.32	1.194	1.32	1.53	1.000	0.01
			traffic vs nature	2.76	1.194	2.76	3.56	1.000	0.02
			speech vs nature	7.91	1.194	7.91	8.71	0.072	0.04
		2 vs 3	no sound vs traffic	1.18	1.194	1.18	1.71	1.000	0.01
			no sound vs speech	0.76	1.194	0.76	1.21	1.000	0.01
			no sound vs nature	0.73	1.194	0.73	1.29	1.000	0.01
			traffic vs speech	3.85	1.194	3.85	5.31	0.396	0.03
			traffic vs nature	0.05	1.194	0.05	0.08	1.000	0.00
			speech vs nature	2.99	1.194	2.99	4.26	0.720	0.02

df = degrees of freedom; F = F ratio; sig. = significance; η_p^2 = partial eta squared.
*Significance adjusted for multiple comparisons with Bonferroni adjustment
Bold indicates significant at .05.

Table 63: Contrasts for preference by participant country: view x visual condition x sound

Source	View	Visual Condition	Sound	Type III Sum of Squares	df	Mean Square	F	Sig.	η_p^2
Country * view * sound									
	view 1 vs 2		no sound vs. traffic	0.00	1. 195	0.00	0.01	1.000	0.000
			no sound vs speech	1.34	1. 195	1.34	3.77	0.972	0.019
			no sound vs nature	0.37	1. 195	0.37	0.93	1.000	0.005
			traffic vs speech	1.46	1. 195	1.46	3.64	1.000	0.018
			traffic vs nature	0.44	1. 195	0.44	0.92	1.000	0.005
			speech vs nature	0.30	1. 195	0.30	0.73	1.000	0.004
	view 1 vs 3		no sound vs traffic	0.81	1. 195	0.81	2.08	1.000	0.011
			no sound vs speech	4.57	1. 195	4.57	11.92	**0.018**	0.058
			no sound vs nature	2.92	1. 195	2.92	5.71	0.324	0.028
			traffic vs speech	1.54	1. 195	1.54	3.60	1.000	0.018
			traffic vs nature	0.66	1. 195	0.66	1.27	1.000	0.006
			speech vs nature	0.19	1. 195	0.19	0.43	1.000	0.002
	view 2 vs 3		no sound vs traffic	0.91	1. 195	0.91	2.12	1.000	0.011
			no sound vs speech	0.97	1. 195	0.97	2.46	1.000	0.012
			no sound vs nature	1.22	1. 195	1.22	2.43	1.000	0.012
			traffic vs speech	0.00	1. 195	0.00	0.00	1.000	0.000
			traffic vs nature	0.02	1. 195	0.02	0.04	1.000	0.000
			speech vs nature	0.01	1. 195	0.01	0.03	1.000	0.000
Country * visual condition * sound									
		1 vs 2	no sound vs traffic	1.77	1. 195	1.77	2.47	1.000	0.013
			no sound vs speech	1.11	1. 195	1.11	1.34	1.000	0.007
			no sound vs nature	0.01	1. 195	0.01	0.02	1.000	0.000
			traffic vs speech	71.12	1. 195	71.12	82.01	**0.000**	0.296
			traffic vs nature	2.05	1. 195	2.05	2.53	1.000	0.013
			speech vs nature	92.88	1. 195	92.88	114.82	**0.000**	0.371
		1 vs 3	no sound vs traffic	0.20	1. 195	0.20	0.19	1.000	0.001
			no sound vs speech	3.78	1. 195	3.78	3.76	0.972	0.019
			no sound vs nature	0.98	1. 195	0.98	1.32	1.000	0.007
			traffic vs speech	32.12	1. 195	32.12	37.50	**0.000**	0.161
			traffic vs nature	2.07	1. 195	2.07	2.65	1.000	0.013
			speech vs nature	3.39	1. 195	3.39	3.76	0.972	0.019
		2 vs 3	no sound vs traffic	0.77	1. 195	0.77	1.12	1.000	0.006
			no sound vs speech	0.80	1. 195	0.80	1.26	1.000	0.006
			no sound vs nature	0.79	1. 195	0.79	1.40	1.000	0.007
			traffic vs speech	3.14	1. 195	3.14	4.33	0.702	0.022
			traffic vs nature	0.00	1. 195	0.00	0.00	1.000	0.000
			speech vs nature	3.17	1. 195	3.17	4.47	0.648	0.022

df = degrees of freedom; F = F ratio; sig. = significance; η_p^2 = partial eta squared.
*Significance adjusted for multiple comparisons with Bonferroni adjustment
Bold indicates significant at .05.

Table 64: Contrasts for preference by professional background: visual condition x sound

Visual Condition	Sound	Type III Sum of Squares	df	Mean Square	F	Sig.*	η_p^2
1 vs 2	no sound vs traffic	6.52	1, 168	6.52	11.54	**0.018**	0.064
	no sound vs speech	3.30	1, 168	3.30	4.32	0.702	0.025
	no sound vs nature	0.44	1, 168	0.44	0.69	7.344	0.004
	traffic vs speech	0.54	1, 168	0.54	0.73	7.074	0.004
	traffic vs nature	2.75	1, 168	2.75	3.42	1.188	0.020
	speech vs nature	1.34	1, 168	1.34	1.68	3.528	0.010
1 vs 3	no sound vs traffic	5.35	1, 168	5.35	5.38	0.396	0.031
	no sound vs speech	3.14	1, 168	3.14	3.25	1.314	0.019
	no sound vs nature	0.43	1, 168	0.43	0.57	8.154	0.003
	traffic vs speech	0.29	1, 168	0.29	0.35	10.026	0.002
	traffic vs nature	0.06	1, 168	0.06	0.08	14.04	0.000
	speech vs nature	1.25	1, 168	1.25	1.39	4.32	0.008
2 vs 3	no sound vs traffic	0.06	1, 168	0.06	0.08	14.022	0.000
	no sound vs speech	0.00	1, 168	0.00	0.00	17.19	0.000
	no sound vs nature	0.00	1, 168	0.00	0.00	17.928	0.000
	traffic vs speech	0.04	1, 168	0.04	0.06	14.616	0.000
	traffic vs nature	0.06	1, 168	0.06	0.08	14.04	0.000
	speech vs nature	0.00	1, 168	0.00	0.00	17.316	0.000

df = degrees of freedom; F = F ratio; sig. = significance; η_p^2 = partial eta squared; ε = epsilon.
*Significance adjusted for multiple comparisons with Bonferroni adjustment
Bold indicates significant at .05.

Table 65: Contrasts for preference by 3D graphics familiarity: visual condition x sound

Visual Condition	Sound	Type III Sum of Squares	df	Mean Square	F	Sig.*	η_p^2
1 vs 2	no sound vs traffic	10.00	4, 192	2.50	3.65	0.126	0.071
	no sound vs speech	10.80	4, 192	2.70	3.44	0.180	0.067
	no sound vs nature	5.39	4, 192	1.35	2.23	1.000	0.044
	traffic vs speech	3.25	4, 192	0.81	0.94	1.000	0.019
	traffic vs nature	6.18	4, 192	1.54	1.93	1.000	0.039
	speech vs nature	8.03	4, 192	2.01	2.55	0.720	0.051
1 vs 3	no sound vs traffic	18.26	4, 192	4.56	4.70	**0.018**	0.089
	no sound vs speech	5.73	4, 192	1.43	1.42	1.000	0.029
	no sound vs nature	3.13	4, 192	0.78	1.06	1.000	0.022
	traffic vs speech	7.00	4, 192	1.75	2.07	1.000	0.041
	traffic vs nature	8.60	4, 192	2.15	2.83	0.468	0.056
	speech vs nature	3.99	4, 192	1.00	1.06	1.000	0.022
2 vs 3	no sound vs traffic	10.90	4, 192	2.73	4.20	0.054	0.080
	no sound vs speech	2.72	4, 192	0.68	1.07	1.000	0.022
	no sound vs nature	2.78	4, 192	0.69	1.24	1.000	0.025
	traffic vs speech	9.49	4, 192	2.37	3.37	0.198	0.066
	traffic vs nature	7.59	4, 192	1.90	2.70	0.576	0.053
	speech vs nature	4.56	4, 192	1.14	1.60	1.000	0.032

df = degrees of freedom; F = F ratio; sig. = significance; η_p^2 = partial eta squared;.
*Significance adjusted for multiple comparisons with Bonferroni adjustment
Bold indicates significant at .05.

13.9 **Appendix I:** Responses to the open-ended survey question

It would be interesting to know what people's responses are to non-computer generated imagery too. I think the images reminded me of getting lost in my brother's Zelda game about 20 years ago...!

Not sure I understood why it is being done nor what it proves, but I may well be atypical due to age etc

I think one issue I have with deciding about to what degree I appreciate the environment is that I expect to see the source of the sounds or some cue as to the source - I like the sound of people interacting but can't marry this with the image as I can't see the people - I would expect to see them in the image. Likewise with the birdsong..... Really interesting

Sound of wind played with city image is confusing. When seeing buildings you expect noise of cars and people and it was quite the opposite. It was confusing when a bird song played next to a city. It got me thinking, how the soud of the bird could be so loud in a city and I know this bird, it's water-loving creature. Sometimes, nature sound (no humans) were shown with park or a valley and I could hear some metal scraching against something or could've been something else, high-pitched sound and it irritated me a little bit. The most favourite part was a sound of wind with a valley picture (only horizon could be seen). I could just picture myself there, being blown away by wind.

I found the images a bit overpowering probably because I find it difficult to relate to real places. I felt the sounds rather annoying. It was very repetitive but I guess that part of the game.

The repeated combinations are confusing! Also, the green parts of the images (not the trees--they're done well) are so unrealistic that it's hard to imagine that they're likeable in any context.

I find the 3D model with the right sound related to it really makes me feel realistic. I prefer the bird songs much more then the roadside one.

Just that I'm curious to know what it's about! It's intriguing.

Towards the end of the experiment I noticed that the foregrounds were repeated, with/without buidlings or trees. Some of the ambient sounds sounded like waves or helicopters, which did not sounds natural to me given the pictures they were paired with.

I understand that it is to test the variosu sounds at various environment. It would be wonderful if the uni campus has an area where it is away from the hustle and bustle of life, yet is still accessible to the city area. =) Thank you.

It was interesting though I couldn't figure out what you were actually trying to measure.

a bit confused, wasn't sure how to interpret 'realistic' in this context

The underlying thing for me is that I really didn't like those 3D graphics (just like I hate what I've seen of computer game graphics) and they mostly felt very unreal. The ones with trees I realised felt a little more real, relative to the other ones. Then the sound did add to the sense of reality on occasion. But I'm not sure my answers will be helpful: found it difficult to get beyond the fact that imagery I associate with virtual reality.

I enjoyed partaking in the study and it would ne interesting to know of the results and purpose.

The noise stops too early. This is a problem for the second question: the noise is already away and I am still thinking about my impression the noise could stay longer or a time limit pressure could have been implemented, taht people are forced to answer this quickly as long the sound is still there One page in the beginning with all images would have been a possibility to show the whole range also in the beginning of the survey it is not clear if there will be later on noices which are even worse/nicer (to click the answers not at all or very much)

I believe the landscape having trees surrounding buildings or open spaces creates community space and areas for people to meet and relax. This makes our experiences more realistics with the differents noise backgrounds that we heard throughout the experiment and it make some the noise or sounds more believeable... drawing from personal experiences.   I hope this helps.

When you ask if the setting is realistic, at first I answered purely on visual terms. Subsequently, I found the mismatch between sound and scene to be quite jarring and not realistic in terms of an aural landscape.

I think there are too many repetitions of same pictures and sounds while less options for pictures and sounds, which makes the testees feel boring. Besides, if the designer of the pictures and sounds made better samples of these materials, it would be better.

I have no knowledge about landscape studies but for me the same sounds made the images with sounds becoming more and more anoying.

\esd dlightly confused by what 'environment' i.e. imagining both sound and visual together, or just the visual with the sound in the background. At some points I was confused about how the sound would relate to the picture.

There were no people - making it hard for me to think any of the landscapes were real

General unreality of scenes left me unable to really 'get into' them but I understand the reasoning behind using the 3D models.

It is a shame the graphics for the ground layer are not more realistic because they dulled my 'experience'. Consequently the sound effects of the waves really made the images that were just grass/sand really come to life. Maybe that is a good thing though if those graphics cannot be improved further?

Interesting to note how the mind notes familiarity between images and sounds. The coherence of the two is what pleases the mind. Knowing which sounds are appropriate for which images is comforting almost.

Stimulating survey. Very striahgt forward to understand and answer

I think that nice historic architecture and also the sound of other people had a positive influence on me, as well as vegetation and bird sounds.

The sounds ended quite quickly. A slightly longer soundtrack would have been nice.

Town images with no sound looks scary. It looks like all people are killed by a psycho or the buildings are cursed by ghosts! I can't quite tell what the noises are... if the first sound is the sound of wind, it suits well to nature environment. I prefer the order of the combination of sound and pictures are in random. Later I found out I prefer the 1st sound (the sound of wind or vehicles?) to the 2nd one. I found I don't like the high-pitch sound in the 3rd sound (birds?) so I don't like most of the pictures with the sound. It looks a bit odd that buildings stand on soil (green and brown). It would look more realistic if they stand on grey ground.

its quite boring,could you make more picture?

In empty or forest areas I expect to be able to hear wind blowing on most days. Not sure if one of the sounds was wind or a car driving past. Also, the sound with the squeaky noise, I wasn't sure if that was to signify a creaking age or some sort of wildlife.

It was entertaining and nice to do! One of a kind!

Interesting - would like to know more....

The landscapes were not realistic, in my view--if this is what advanced 3D software produces, I'd stick to drawing.

The wording for each sound/picture was incredibly precise and very easy follow. I found myself leaning towards a more realistic end of the spectrum with additional layers of sound present, regardless of the landscape view. Also, off topic...I appreciate the very first question 'Do you consider yourself male or female'. Surveys rarely word gender and sex appropriately.

no comments apart from an interesting survey to question why I like certain sounds in certain enviornments. Is is my expectation and conditioning or is it simply a personality trait such as patience as loud unpleasant sounds annoy me quickly.

It was fun and interactive.

Very intriguing!

Very repetitive

different people might have different ideas of what 'quite real' etc mean

I think the images are not clear enough especially the ground covers in them. And during the experiment I was thinking that it might suggest that those with noise should receive a lower rating and that' s might be the result you expect to get. I don't want to be effected by this so I was trying to be objective which may have lead to another bias that I tended to assign the same score for the same image regardless of the sound.

Sound and photo don't always match.

Interesting to see connection between how real an environment seems and how much you like it.

perhaps a a bit too long, i lost interest towards the end

The sound clips were not clear - they sounded highly compressed. Perhaps this was intended, but I was unable to determine whether the 'wind' clip was meant to be wind or indiscernible chatter. Wind would have fitted better with the landscape scenery, chatter less so. I assumed the clip was of chatter.

I have a particular dislike of the noise of seagulls, so although I tried not to let this influence my responses it probably did!

I found the pictures very challenging and no very life-like which sort of put me off!

Drags on quite a lot, shorten it and vary the images more

It grew tiresome - 50 questions using the same handful of images and sounds, just shuffled. I think my responses were biased as I grew bored and let a matrix of decision-making rules determine my responses, as opposed to the sensory impressions I had of each scene. I would say that there needs to be far more images and sounds - repition ruined it for me. Fewer questions would also be benefitial in my opinion.

I found with hearing people talking without seeing any kind of people or vehicles or movement in the scene hard to see the picture as real.

The computerized images of grassland looked very blurred and unrealistic and thus quite unpleasant. The images of the buildings were rendered better, although the 'cut and paste' nature of most of the final images was clearly evident, making them look very unrealistic.

What is asked is a bit difficult to discern at the beginning.

for me it showed again how much the sounds influence us and our choices depend not only on image but on the noise and sounds we hear around.

It is too repetitive, the window for the environment is too small to be realistic.

I think because I'm currently fed up of windy weather the sound of what could have been blustering wind made me feel like I didn't much like that environment

I found the busy noises nice to listen to, the seagulls were very comforting and relaxing bringing fond memories back.The trees in front of the large buildings seemed to make the overall picture much nicer. Hope this helps you further and if i can be of further help i will.

Interesting. I think images that are a little more photo realistic would have had a greater impact on if I thought the environments seemed real, but it was obvious that the appropriate sound can greatly influence how I experienced the environment, even as an image.

Thanks for the invite to the survey. Not sure if this is what the comment box are for, but two quick reflections!   1. Trees / vegetation in combination with topography make a much more realistic environment than just topography and the mapped google earth aerial photo. The topography alone makes it hard to gage depth.   2. Sound seems to be both able to add or detract from the realism of the image. For me, I felt it made it more real if the sound matched the image and less real if it felt foreign to the image.   Best of luck and curious about the results.

Goes on a bit but straightforward to do and quite interesting

I may have answered differently if I could see or knew the source of the noise.North Dakota prairie with a howling blizzard is unpleasant ,but when it is totally silent it can cause uneasiness as well.My expensive hearing aids are programmed to diminish loud background noise but that function is not consistent and can make ordinary sounds feel muffled The sound of a chainsaw can be quite soothing,while wailing children can be nerve -wracking.Very subjective situations. Best of luck from quiet Mulmur.

There were only really the combinations of beach and seagulls that were compatibly descriptive -the rest of the sounds jarred with the images -sounds of people but no people, still trees but wind sounds

A bit too long and boring

That bird sound just irritated me by the end.

Where there was a sound I was unclear whether it was supposed to be traffic noise, the wind, or just white noise from the recording.   Having spent most of my life in London, I fully expect a continuous background noise.

Since I'm so used to looking at really good images made from 3D models (teaching architecture and urban design) I really cannot experience the environments as real.

This was an interesting survey, I felt 'experience' was a bit vague, maybe more explanations about that would be nice, but overall friendly, fun to do survey.

I found it a bit confusing as I only figured out about half way through that 1 sound may have been a motorway? and one just a normal road? and then were the birds seagulls? So I found it hard to distinguish between the differences in the pictures and sounds and I am assuming that when there was no sound that this was supposed to be peace a quiet?

too much noise, i feel headache, but it is good to know how much the noise affect my mood. i feel i really hate noise