Master of Landscape Architecture Thesis

A psychophysiological approach to evaluating participant experience in virtual environments

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Abstract

Conveying complex information using visualizations is becoming increasingly important for decision support as it allows stakeholders to critically evaluate and weigh different tradeoffs related to the sustainability of proposed designs (e.g ecological risks, aesthetic perceptions, habitat biodiversity). 3D and 4D visualizations are promising methods of visual communication in this context offering researchers and practitioners an expanded toolkit for engaging the public more broadly. The spatial and temporal accuracy of such visual representations increases a sense of presence allowing respondents to 'experience' different design scenarios more realistically. Despite a large body of research on the merits of including 3D and 4D visuals in decision support, there is limited empirical evidence of how a visual medium best creates presence and whether additional non-visual stimuli can contribute this realistic experience based on objective measure. Prior research has focused primarily on psychological responses to both multisensory simulations and the effect of different viewing hardware on experience. This study investigates physiological indicators (galvanic skin response) to assess participants responses to 4D visualizations. Participants (N = 39) were presented with digital animations via a conventional screen and virtual reality head mounted display, with two varied sound conditions (no sound and detailed sound) across three environments (community garden, playground, and woodlot). Perceived biodiversity, preference, realism, recreational value, arousal, and pleasure were assessed using a 1-5 Likert-type scale while simultaneously collecting GSR data. Results indicate biodiversity, preference, and pleasure were significantly impacted by sound and environment while Realism and arousal were only significantly impacted by environment. These findings

advance our understanding of how new technology and multisensory stimuli can influence stakeholders and impact environmental decision making.

Table 1: Significant effects and interactions: □: not significant; ○: significant ($p < 0.05$); ●: significant ($p < 0.001$)

Perceptual Measure	Display	Sound	Environment	Display X Sound	Display X Environment	Sound X Environment	Display X Environment X Sound
BEI	□	●	●	○	○	□	○
Preference	□	●	●	□	□	□	○
Realism	○	○	●	□	□	□	□
Recreational Value	□	●	□	○	○	□	□
Arousal	○	□	●	□	□	□	□
Pleasure	□	●	●	□	□	□	□
GSR	●	□	□	□	□	□	□

Introduction

To have long-term impact and sustainability, landscape designs require the buy-in of a variety of stakeholders and future users of those landscapes. Stakeholders are better able to express their views in the planning and design process when included from an early stage. (Carlsson-Kanyama, et al., 2008). Engaging stakeholders can be challenging because it is difficult for the broader public to visualize future scenarios. 3D and 4D visualizations are a powerful tool to help visualize the spatial and temporal implications of proposed designs to a diverse user group (Lange, 2001). Visualization effectiveness is highly related to presence—the sense of 'being' in a real or virtual environment— that includes all levels of the conscious and subconscious (Sanchez-Vives & Slater, 2005).

Research on multisensory perception for environmental decision-making, while still in its infancy, suggests that visualizations combined with additional sensory stimulation can result in a higher sense of presence in 3D visualizations (Lindquist, 2014; Lindquist, Maximb, Proctorc, & Dolinsd, 2020). This higher level of presence assists researchers and practitioners in communicating landscape designs to the general public (Orland, Budthimedhee, & Uusitalo, 2001). However, few studies have thoroughly evaluated additional sensory stimuli using an experimental design and objective physiological measures (e.g. heart rate, galvanic skin response (GSR)) that indicate presence.

In this study, we will use objective (GSR) and subjective (perceptual) measures to empirically evaluate the effect of auditory stimuli and viewing hardware on the evaluation of landscape presence in virtual landscapes. We hypothesized that there would be higher skin conductance levels, perceived biodiversity, preference, realism, recreational value, arousal, and pleasure of the virtual landscape increase with auditory stimuli and when experiencing via virtual reality (VR) using a a head mounted display (HMD). Previous research had found contradictions between objective and subjective measures (Higuera-Trujillo, Maldonado, & Millán, 2017), and further study is needed to assess whether this adversely impacts the results of landscape evaluation.

Literature Review

Background

The European Landscape Convention defines landscape as "part of the land, as perceived by local people or visitors, which evolves through time as a result of being acted upon by natural forces and human beings" (2000). This expansive definition of landscape provides a unique challenge to designers, as it requires accounting for environmental variation (e.g. ecozones, levels of intervention) and the perceptions and values of different groups and users (Lewis, 2010, Balling & Falk, 1982, Yu, 1995). Researchers and practitioners should consider these environmental variations and societal factors when proposing 4D visualizations and design interventions to stakeholders.

Landscape Assessment

Prior research has investigated how the public assesses landscapes through visual indicators. Kaplan (1985) acknowledges human vision and perception to define the landscape and a visual resource. Research supports the finding that natural features have a significant impact on perception and have identified four main influences on landscape preference: amount of natural features, topographic variation, presence of water, and amount of open space (Hagerhall, Purcell, & Taylor, 2004; Kaplan & Kaplan, 1982; Kaplan, Kaplan, & Wendt, 1972; & Lamb & Purce, 1984). Other research conducted by Cosgrove (1998), Nassauer (1988), and Thayer (1989) consider the personal experience and prior knowledge of an individual plays a more dominant role in the perception of a landscape. While landscape assessment in a 2-dimensional perspective has worked in the past, 3D and 4D visualizations offer possibilities to viewers and stakeholders to more realistically understand a landscape.

3D and 4D Visualizations

3D (3-dimensional computer models) and 4D (animated 3D computer models) offer designers the opportunity to effectively communicate spatial ideas and constructs to a diverse audience (Bishop, 2005; Kwartler, 2005). Visualizations can range from being static with little to no immersive characteristics to highly dynamic and immersive (Danahy, 2001; Lange, 2001). Empirical studies by Lange (2001) suggest that very high levels of detail and texture would be necessary for viewers to experience a high degree of realism. Through 3D and 4D-visualizations, researchers and practitioners are better able to create more immersive landscape visualizations and presentations that enable a more stakeholder input during the design and development process (Kunze, Burkhard, Gebhardt, & Tuncer, 2012). Combining soundscapes with 3D and 4D visualizations, provides stakeholders the opportunity to experience a proposed landscape in a more realistic way (Lindquist, Maximb, Proctorc, & Dolinsd, 2020).

Soundscape in Landscape Visualization

The term soundscape was introduced in 1977 by Schafer as a way of describing the sonic environment (Schafer, 1977). Later, Porteous and Mastin (1985) defined soundscape as the "overall sonic environment of an area, ranging in size for a room to a region." The idea of a soundscape is traced as early as the 1950's when composer John Cage wrote a three-movement piece entitled 4:33. 4.33 was four minutes and thirty-three seconds of emptiness allowing the listeners the opportunity to experience the soundscape of Woodstock, New York, where this piece premiered (Gann, 2010). Current research on soundscape involves both objective measurements as well as perceptual studies (Genuit & Fiebig, 2006; Daniel & Meitner, 2001; Lindquist, et al., 2020).

Over the past ten years, there is a growing body of research to show how auditory stimuli may affect one's presence of a landscape. Combining soundscapes with visualizations are also valuable at reaching a broader audience, especially those across different socio-economic levels (Scott, Carter, Brown, & White, 2009). For the visualizations to be fully immersive, they must have the correct soundscape to match the scene (Truax & Schafer, 1978).

For landscape perception, this idea of a soundscape is a fundamental consideration as it has been shown to alter our experience of both real and virtual worlds (Lindquist, Lange, & Kang, 2016; Pijanowski, et al., 2011). The interaction of sound and visuals in urban environments has shown to have a direct impact on the perception of a landscape (Jeon & Jo, 2020). Sound has been used in immersive and non-immersive landscape simulations, e.g., to convey the impact of wind turbine sound on preference (Manyoky, et al., 2012; Manyoky, Wissen Hayek, Heutschi, Pieren, & Grêt-Regamey, 2014). There is physiological evidence in support of sound altering the visual perception of tranquil spaces (Hunter, et al., 2010). Through the combination of visualizations and soundscape, researchers hope to increase the perceived presence in a landscape visualization (Lindquist, 2014).

Virtual Environmental Presence

Presence is often used as a measure of effectiveness when evaluating a virtual landscape (Slater, 2018). Draper, Kaber, & Usher (1998) define presence as the sensation or experience of '*Being There';* While Sanchez-Vives & Slater (2005) expand this previous definition to include all levels of conscious and subconscious. Both the use of HMD's and sound positively affect the viewer's sense of presence in a virtual environment (Terkildsen & Makransky, 2019).

A 2020 study found that viewers of a virtual field trip showed consistently higher perceived virtual presence levels when viewing through an HMD when compared to a traditional TV setup (Han, 2020). Blauert (1997) and Hendrix & Barfield (1996) reported an increase in user presence when viewing visualizations by adding spatialized sound. Davis et al. (1999) and Lindquist, Lange, & Kang (2016) further elaborated these findings, highlighting sound increased perceived realism in virtual environments. Previous research into user's presence that utilized questionnaires is subject to user bias and interpretation. Objective measures of presence have been developed, including a change in heart rate, galvanic skin response, and skin temperature (IJsselsteijn, et al., 2000). Two perceptual indications of presence in a virtual environment that can correlate with physiological measures are arousal and pleasure (Terkildsen & Makransky, 2019).

Arousal and Pleasure

Arousal and pleasure are often used to indicate full emotional affective response (Bradley & Lang, 1994). Self-assessment methods are widely used in emotion research for the collection of subjective affective ratings (Betella & Verschure, 2016). Developed by Peter Lang in 1980, the Self-Assessment Manikin (SAM) model has been successfully used to determine the user's arousal and pleasure levels when viewing different media (Bradley & Lang, 1994). SAM is a non-verbal picture-based assessment that directly measures the pleasure, arousal, and dominance associated with an individual's reaction to a wide range of stimuli. In 2016, researchers developed and validated the Affective Slider (AS) as a digital alternative to the

SAM model as experiments were increasingly being conducted online and with digital surveys (Betella & Verschure, 2016).

Pleasure in an activity is an essential first step to eventual growth and learning (Han, 2020). As practitioners and researchers continue to use VR as a tool for increased understanding and learning, pleasure in the environment and activity must be considered. In 1975, Mihaly Csikszentmihalyi developed the flow theory that represents an individual's enjoyment and creative potential in a task. The theory states that individuals are happiest when their skills and a challenge are equal, and those who experience the flow state will continue their involvement, solely for the pleasure and enjoyment of the experience (Csikszentmihalyi, 1975). As such the aim was to determine if pleasure varied with sound and by display type.

Physiological Methods in Landscape Visualization

To accurately assess the immersion of participants, reliable and objective measures of arousal and pleasure should be used. Many options for measuring ones' physiological changes are available to researchers (Bagozzi, 1991; Karmanov, 2008). One physiological measure in landscape assessment are a change in heart rate (Insko, 2003). Change in heart rate measures the increase or decrease in the number of heart beats per minute and can be measured with an electrocardiogram (ECG) (Insko, 2003). Heart rate is affected by stress, fear, exertion, as well as intensity of the emotional response (Insko, 2003).

Eye-tracking has been shown to be a valid objective physiological measure of how people observe a landscape (Dupont, Antrop, & Eetvelde, 2014) and has been an analysis tool for the past 25 years in the fields of landscape science (Lucio, Mohamadian, Ruiz, Banayas, & Bernaldez, 1996), geography (Antonson, Mardh, Wiklund, & Blomqvist, 2009), and environmental psychology (Berto, Massaccesi, & Pasini, 2008). It has been suggested that eye movements are associated with the attention the viewer is giving to a scene (Berto, Massaccesi, & Pasini, 2008).

Another promising measure of physiological changes is GSR, the electrodermal activity is a measure of the skin's conductance. Eccrine (sweat) glands at specific locations, such as the palms of the hand or soles of the feet, respond to psychological changes and ones' GSR changes as a direct result of the eccrine glands (Nogueira, Rodrigues, Oliveira, & Nacke, 2011). GSR is composed of two signals, the skin conductance level and the skin conductance response. Skin conductance level or tonic activity is a slowly varying baseline that results in changes to hydration, skin moisture, or body regulation and is often not informative on its own (Terkildsen & Makransky, 2019). Skin conductance response or phasic activity has been shown to reflect the emotional arousal and typically occurs one to five seconds after the beginning of the event (iMotions, 2017). Research has shown that GSR levels are correlated to physiological wellbeing and arousal levels (Huanga, Yanga, Janea, Lia, & Bauerb, 2020), with arousal used as a proxy for assessing emotional activity (Mandryk, Inkpen, & Calvert, 2006).

Summary

A better understanding of how different visualization techniques can aid in the representation of a proposed landscape, particularly when communicating with those without a design background. To further understand responses to these 3D and 4D visualizations, a standard physiological measurement of human perception as it is related to the built and natural landscapes would be helpful. Empirical testing using physiological measures would improve our understanding of how people respond to greenspace. This research will focus on psychophysiological evaluation of responses to green space with and without sound using a combination of objective and subjective measures and three virtual environments.

Methods

Participants

To obtain subjective and objective measures of human presence and restorative effects of 3D and 4D visual and auditory simulation, we asked 39 participants to evaluate three different environments using two types of viewing hardware (VR HMD vs. computer screen) with and without sound in a controlled laboratory environment. Participants (27 women and 12 males), aged 19-74 years old (M = 24.77, SD 11.42). Our sample size is similar to previous studies examining the perception of aural-visual stimuli in a lab setting (Hong & Jeon, 2014; Joynt & Kang, 2010; Ren & Kang, 2015). Participants were recruited through the University of Michigan paid subject pool, and all were compensated $10 for their time. The study was a within-subject design and all participants received all treatments. The mean time to complete the experiment was 58.78 minutes, with a range from 28.78 to 112.30 minutes. All research conducted was approved by the appropriate IRB.

Apparatus and Materials

Visual and Aural Stimuli

A hypothetical 40 × 80-meter site was modeled using Lumion 7.5 (https://lumion.com/) and is representative of six contiguous parcels in Detroit, MI, USA. Three environments were created that varied in biodiversity and ecosystem services: a community garden (environment one), a playground (environment two), and a woodlot (environment three) (Fig. 1). A 4K resolution (3840 × 2160) at 60 frames per second animation was rendered for each of the three environments and edited to a total length of 30-seconds. Each of the environments had two sound treatments: no sound and point-specific sounds. Detailed soundscapes were created for each of the conditions using AVID Pro Tools (https://www.avid.com/pro-tools). Sound sources include local wooded areas, fields, and The Cornell Lab of Ornithology Macaulay Library (https://www.macaulaylibrary.org/). Recordings were made with a Sound Devices 702 audio recorder and a Sennheiser MKH 416-P48 Short Shotgun Microphone. The research team determined the congruency of the sounds with the environmental design conditions.

Figure 1: Environments: Community Garden, Playground, Woodlot

Questionnaire Design

A pre-experimental questionnaire was used to provide demographic information (age, gender) and to assess the participant's previous knowledge and use of 3D computer graphics.

A seven-point noise sensitivity scale questionnaire was also used to determine the subject's sensitivity towards noise. After each animation, participants were asked to indicate their ratings for: (i) realism, (ii) preference, (iii) perceived recreational value, and (iv) perceived biodiversity on a 5 item Likert-type scale. Perceived biodiversity was evaluated using the Biodiversity Experience Index (BEI) developed by Gyllin and Grahn (2005). Participants were asked to indicate how rich in plants and varied and wild an environment appears on a 1-5 Likert-type scale. The mean was then calculated for each combination of ratings. Questions derived from Slater, Usoh, and Steed (1994) and Lindquist (2014) will be used. The full questionnaire can be found in appendix A.

Apparatus and Procedure

To begin the experiment, participants were instructed to 1) read and sign the information and consent form, 2) answer pre-experiment user characteristics questions, 3) randomly assigned to an initial display type (VR or screen) for the experiment; and 4) aided in adhering the GSR measuring device. Participants were asked to sit at a desk 1 meter from the display screen, allowing them a 90-degree field of view (FOV) with the HMD having a 110-degree FOV, and instructed to place earphones over their ears for the screen experiment (Table 2). For the VR experiment, respondents were aided in placing a HTC Vive pro VR over their head and instructed on audio and visual calibration. Animations (n= 12) were repeated for both display type, with and without sound, and after viewing the visual stimuli respondents asked to answer a post-experiment questionnaire. The participants rated a total of 12 different conditions resulting in a 2 (display type) × 2 (sound) × 3 (environmental) factorial design. After the measurement devices were attached and the participant was ready, a 60-second gray screen with no sound was displayed to provide a baseline for the GSR date. The gray screen was followed by a 30-second animation at walking speed through each environment. After the animation, participants indicated responses on an Ipad via an online survey using Qualtrics XM (https://www.qualtrics.com/) (Figure 2) and were shown the same questions after each animation. Videos were passively viewed by participants using the VLC media player (https://www.videolan.org/) for the screen condition and GoPro VR Player (https://gopro.com/) for the VR condition.

Table 2: Animation delivery apparatus

Display type	Discription	Resolution	Refresh Rate	Field of View	Audio
Screen	24" Dell IPS monitor	1920 × 1080	60 Hz	90˚	Sony over-ear
VR via HMD	HTC Vive Pro	2880 × 1200 (both eyes)	90 Hz	110˚	Sony over-ear

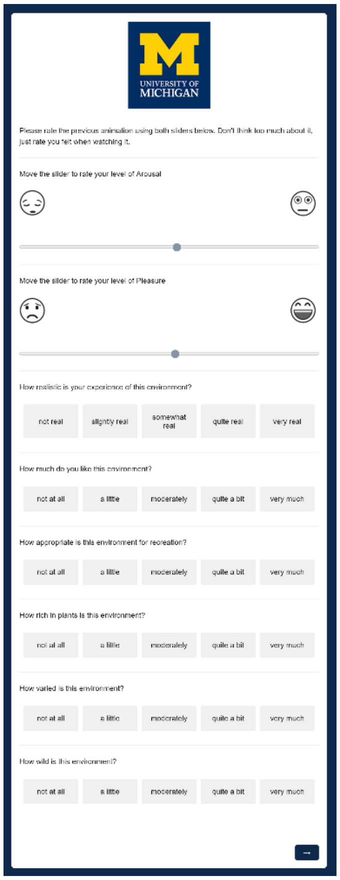

Figure 2: Qualtrics Survey

Raw GSR measurements were collected using a Shimmer3 GSR hardware module (https://www.shimmersensing.com/products/shimmer3-wireless-gsr-sensor) (Figure 3). The Shimmer3 records electrodermal activity at a sampling rate of 128Hz through a pair of bipolar electrodes., Two electrodes were placed around the first and second fingers of the participant's non-dominate hand to minimize noise and movement artifacts, with a shimmer optical pulse ear clip on the similar ear. ConsensysPRO (https://shimmersensing.com/products/consensys) (Figure 4), was used to record the GSR data and events. Data was recorded the entire time the participant was wearing the recorder with event markers manually placed at the start of each animation by the researcher.

Figure 3: Shimmer3 GSR Module

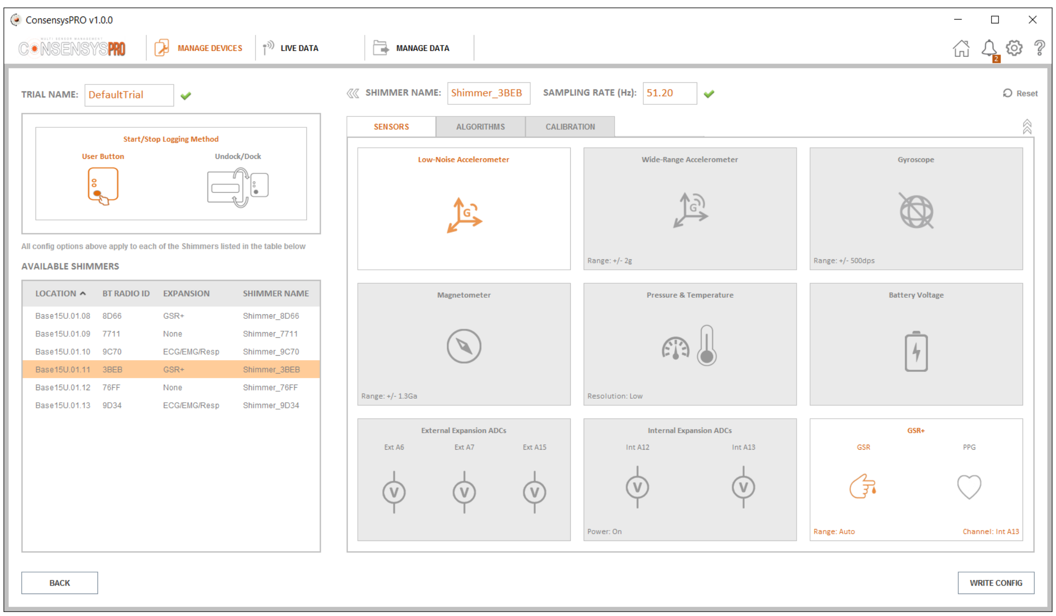

Figure 4: ConsensysPRO

A peak detection algorithm was run to calculate the GSR peaks. This applies a sliding window median filter [-4 s; +4 s] to the raw GSR signal to extract the phasic data from the tonic signal. A 5 Hz low-pass filter was then applied to the phasic data to remove any unwanted line noise. Peaks in the phasic data are then detected by identifying onsets (> 0.01 µS) and offsets (< 0 µS0). A set peak amplitude threshold of 0.005 µS above the GSR value on onset was used to categorize a peak, with anything larger than the set threshold being a peak. An artifact rejection method was set up within the peak detection algorithm with a signal jump threshold of 0.01 μS. This artifact rejection method is used to account for potential false positives from movement artifacts. After conducting the peak detection algorithm, the number of peaks for all participants were divided by the exact time that each participant spent viewing the animation in order to produce a comparable GSR peaks/min measure. Amplitudes of each GSR peak was averaged for each participant as a measure of overall peak intensity throughout the animation.

Data Analysis

A repeated-measures ANOVA was used to evaluate the effect of the within-subject independent variables and responses on realism, preference, perceived recreational value, and perceived biodiversity. Repeated ANOVA analysis enables comparisons across contrasting conditions (Screen vs VR, Sound vs. No Sound). We performed post-hoc tests with a Bonferroni correction to control the error rate (i.e significant interactions between the common scenes). Effect size is reported in partial eta squared (ηp^2), to allow for comparison with studies that use a similar design and is consistent with previous landscape preference research (Lakens, 2013).

GSR analysis was performed in Ledalab V3.4.9 (Figure 5) that runs in MATLAB (Matlab, 2020a). Raw shimmer data was first cleaned in excel to remove excess collected data and exported as a text file with UNIX timestamp, skin conductance data, and event marker in the first three columns. The cleaned data was then imported to Ledalab through text type three (manual definition) and not down sampled. Continuous decomposition analysis (Figure 6) was then performed to extract the phasic information underlying the EDA to have continuous phasic and tonic components (Benedek & Kaernbach, 2010). For each participant, four event-related activation text files were exported; A pre-event file (4-2 second average before the event) and post-event files at seconds one, 28, and an average export from seconds 1-28.

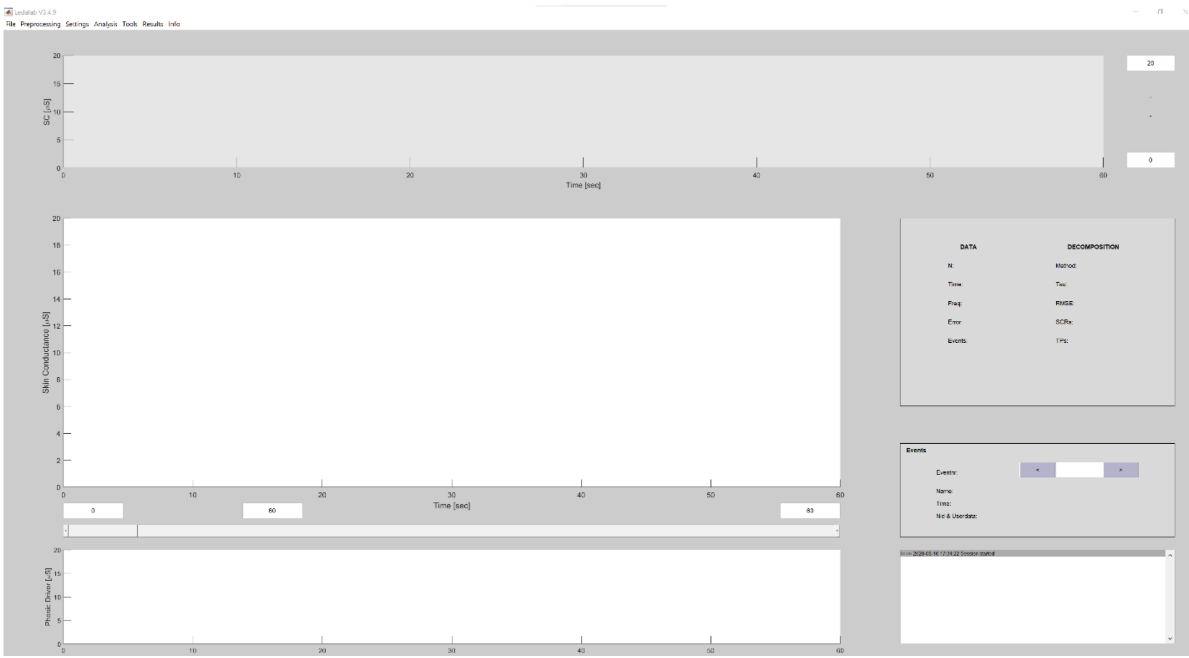

Figure 5: Ledalab start screen

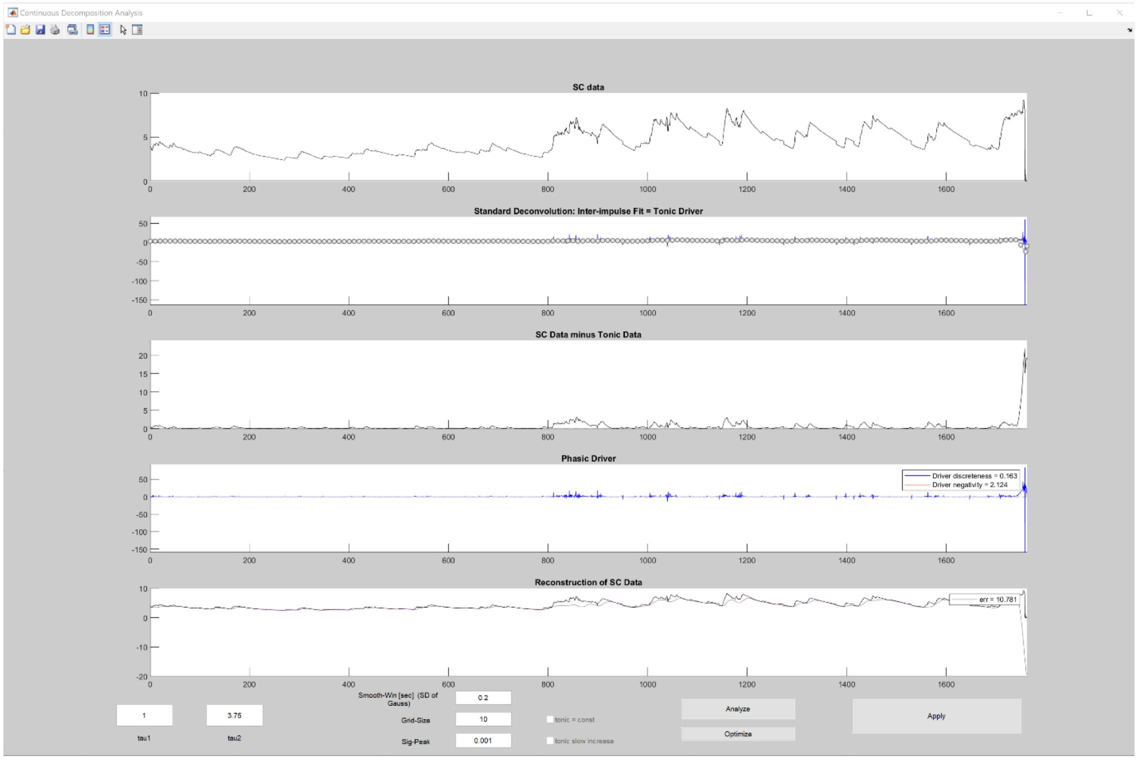

Figure 6: Ledalab - Continuous Decomposition Analysis

Statistical analyses were performed using IBM SPSS version 26.4.0. Normality was assessed by inspecting the absolute values for skew (< 2.0) and kurtosis (< 4.0) (West, Finch, & Curran, 1995). The Greenhouse-Geisser corrected values were used to control violations of sphericity and included in the results with the epsilon value (ε) when the sphericity test is significant.

Results

Experienced Biodiversity

No significant effect of display type was found, $F(1,38) = 0.665$, $p = 0.420$, $\eta p^2 = 0.017$. There was a significant main effect of environment, $F(2,76) = 76.656$, $p < 0.000$, $\eta p^2 = 0.669$, and sound, $F(1,38) = 32.476$, $p < 0.000$, $\eta p^2 = 0.461$. There was a statistically significant three-way interaction among display type, environment, and sound, $F(2,76) = 3.346$, $p =$

0.040, $\eta p^2 = 0.081$. A statistically significant two-way interaction was found between display and environment ($\varepsilon = 0.775$), $F(1.550,58.916) = 4.637$, $p = 0.021$, $\eta p^2 = 0.109$, and display and sound, $F(1,38) = 4.569$, $p = 0.039$, $\eta p^2 = 0.107$. There was no significant interaction between environment and sound ($\varepsilon = 0.853$) $F(1.706,67.579) = 0.401$, $p = 0.639$, $\eta p^2 = 0.010$.

A two-way ANOVA was run for each environment, finding display had no effect on environment one and three ($p > 0.050$), but had a significant effect on environment two, $F(1,38) = 6.465$, $p = 0.015$, $\eta p^2 = 0.145$. Sound had a significant effect on experienced biodiversity for environment one, $F(1,38) = 7.689$, $p = 0.009$, $\eta p^2 = 0.168$, environment two, $F(1,38) = 19.156$, $p < 0.001$, $\eta p^2 = 0.335$, and environment three, $F(1,38) = 9.158$, $p = 0.004$, $\eta p^2 = 0.194$. No interaction was found between display type and sound for both environment one and three, but a significant interaction between display and sound for environment two, $F(1,38) = 8.198$, $p = 0.007$, $\eta p^2 = 0.177$.

Analysis indicated that for environment two when viewing with no sound there was little difference between biodiversity assessment, $F(1,38) = 1.113$, $p = 0.298$, $\eta p^2 = 0.028$, while with the realistic sound viewing in VR was significantly higher experienced biodiversity than on screen, $F(1,38) = 1.113$, $p = 0.003$, $\eta p^2 = 0.204$. The marginal means for experienced biodiversity with sound score were 2.017 (SE = 0.075) for display type one (screen) and 2.410 (SE = 0.119) for display type two (HMD), a statistically significant mean difference of 0.393, 95% CI [0.138, 0.648], $p = 0.003$.

A two way repeated measures ANOVA was run for each sound conditions comparing display type and environment finding display had no effect on experienced bio diversity when no sound is present, $F(1,38) = 0.198$, $p = 0.659$, $\eta p^2 = 0.005$, or when realistic sound is present, $F(1,38) = 0.838$, $p = 0.084$, $\eta p^2 = 0.076$. Environment had a significant effect on experienced biodiversity in both no sound, $F(2,76) = 29.089$, $p < 0.001$, $\eta p^2 = 0.642$, and realistic sound, $F(2,76) = 58.083$, $p < 0.001$, $\eta p^2 = 0.605$, conditions. A significant two-way interaction was found between display type and environment for both no sound, $F(2,76) = 3.707$, $p = 0.029$, $\eta p^2 = 0.089$, and realistic sound, ($\varepsilon = 0.787$), $F(1.574,59.815) = 4.747$, $p = 0.019$, $\eta p^2 = 0.111$.

Preference

The effects of display type, environment and sound on preference was determined with a three-way repeated measures ANOVA. There was no significant effect on display type on preference, $F(1,38) = 1.096$, $p = 0.302$, $\eta p^2 = 0.028$. There was a significant effect on preference for environment, $F(2,76) = 17.978$, $p < 0.001$, $\eta p^2 = 0.321$, and sound, $F(1,38) = 56.276$, $p < 0.001$, $\eta p^2 = 0.597$. A pairwise comparison shows participants significantly preferred environment one more than environment two (Δmean = 0.782, $p < 0.001$) or three (Δmean = 0.596, $p < 0.001$) and realistic sound to no sound (Δmean = 0.496, $p < 0.001$).

There was no significant two-way interaction between display and environment, $F(2,76)$, $p = 0.832$, $\eta p^2 = 0.005$, display and sound, $F(1,38) = 2.481$, $p = 0.124$, $\eta p^2 = 0.061$ or environment and sound, $F(2,76) = 0.046$, $p = 0.955$ $\eta p^2 = 0.001$.

A significant three-way interaction was found between display type, environment, and sound, ($\varepsilon = 0.746$), $F(1.492, 56.699)$, $p = 0.041$, $\eta p^2 = 0.090$. A two-way repeated measures ANOVA was run for each environment comparing display type and sound. For environment one (community garden), there was a significant main effect of sound, $F(1,38) = 32.217$, $p < 0.001$, $\eta p^2 = 0.459$, as well as environment two (playground), $F(1,38) = 30.387$, $p < 0.001$, $\eta p^2 = 0.444$, and environment three (wood lot), $F(1,38) = 17.925$, $p < 0.001$, $\eta p^2 = 0.321$. Preference was significantly higher with sound than without (Δmean = 0.50, $p < 0.001$). A significant two-way interaction between display type and sound was found for environment two, $F(1,38) = 4.295$, $p = 0.046$, $\eta p^2 = 0.101$, and environment three $F(1,38) = 8.604$, $p = 0.006$, $\eta p^2 = 0.185$

Realism

A three-way repeated measures ANOVA was conducted to determine the effects of display, environment, and sound on perceived realism. Display type, environment, and sound all had a significant main effect: display type $F(1,38) = 11.218$, $p = 0.002$, $\eta p^2 = 0.228$, environment $F(2,76) = 4.891$, $p = 0.010$, $\eta p^2 = 0.114$, sound $F(1,38) = 27.809$, $p < 0.001$, $\eta p^2 = 0.423$, and no significant two or three-way interactions ($p > 0.05$ for all).

Pairwise comparisons indicated realism was significantly higher when viewing in VR over screen, (Δmean = 0.342, $p = 0.002$) and with realistic sound over no sound, (Δmean = 0.350, $p < 0.001$). Contrast also indicated that environment one was significantly higher in realism than environment three (Δmean = 0.224, $p = 0.011$).

Recreation Value

A three-way repeated measures ANOVA was conducted to determine the effects of display, environment, and sound on perceived recreational value. There was no significant main effect of display type $F(1,37) = 0.702$, $p = 0.408$, $\eta p^2 = 0.019$, or sound $F(1,37) = 1.456$, $p = 0.235$, $\eta p^2 = 0.038$. There was a main effect of environment $F(2,74) = 22.803$, $p < 0.001$, $\eta p^2 = 0.381$.

There was a significant two-way interaction between display type and environment, $F(2,74) = 5.199$, $p = 0.008$, $\eta p^2 = 0.123$, and display type and sound, $F(1,37) = 10.496$, $p = 0.003$, $\eta p^2 = 0.221$. There was no statistically significant two-way interaction between environment and sound, $F(2,74) = 2.306$, $p = 0.107$, $\eta p^2 = 0.059$. There was no statistically significant three-way interaction between display type, environment, and sound, $F(2,74) = 0.708$, $p = 0.496$, $\eta p^2 = 0.019$.

Arousal

A three-way repeated measures ANOVA was conducted to determine the effects of display, environment, and sound on arousal. There were no two-way or three-way interactions between display type, environment, and sound ($p > 0.050$ for all). There was a significant main effect of display type, $F(1,28) = 9.005$, $p = 0.006$, $\eta p^2 = 0.243$, and sound, $F(1,28) = 31.993$, $p < 0.001$, $\eta p^2 = 0.533$. There was no statistically significant main effect of environment, $F(2,56) = 1.545$, $p = 0.222$, $\eta p^2 = 0.052$. A pairwise comparison indicated participants gave significantly higher arousal ratings when viewing the scenes in VR compared to the screen condition (Δmean = 5.592, $p = 0.006$) and with a realistic sound (Δmean = 9.420, $p < 0.001$).

Pleasure

A three-way repeated-measures ANOVA was conducted to determine the effects of display, environment, and sound on pleasure. There were no two-way or three-way interactions among display type, environment, and sound ($p > 0.050$ for all).

There was no significant main effect of display type, $F(1,33) = 1.206$, $p = 0.206$, $\eta p^2 = 0.035$. There was a significant main effect of both environment, $F(2,66) = 16.223$, $p < 0.001$, $\eta p^2 = 0.330$, and sound, $F(1,33) = 32.675$, $p < 0.001$, $\eta p^2 = 0.498$. A pairwise comparison indicated participants gave significantly higher pleasure ratings for environment one compared to environment two (Δmean = 9.930, $p < 0.001$) and environment three (Δmean = 7.340, $p < 0.001$). Pairwise comparison also indicated that participants gave significantly higher pleasure ratings when viewing scenes with sound compared to no sound (Δmean = 8.740, $p < 0.001$).

Galvanic Skin Response

GSR measures were calculated using the number of significant skin conductance events during the response window. A three-way repeated measures ANOVA was conducted to determine the effects of display, environment, and sound on GSR. There were no statistically significant main effects of environment, $F(2,40) = 0.266$, $p = 0.768$, $\eta p^2 = 0.013$, or sound, $F(1,20) = 0.142$, $p = 0.711$, $\eta p^2 = 0.007$, and no significant two-way interactions: display and environment, $F(2,40) = 0.154$, $p = 0.858$, $\eta p^2 = 0.008$, display and sound, $F(1,20) = 3.054$, $p = 0.096$, $\eta p^2 = 0.132$, environment and sound $F(2,40) = 2.532$, $p = 0.092$, $\eta p^2 = 0.112$. No significant three-way interaction were found, $F(1.438,28.766) = 1.282$, $p = 0.289$, $\eta p^2 = 0.060$. There was a significant main effect of display type, $F(1,20) = 9.852$, $p = 0.005$, $\eta p^2 = 0.330$. A pairwise comparison indicated that participants had more significant GSR peaks while viewing animations in VR vs. screen (Δmean = 119.959, $p = 0.005$).

Table 3: ANOVA results for experienced biodiversity, preference, realism, recreation value, arousal, and pleasure for each combination of display type, environment, and sound, N = 39

Source	SS	df	MS	F	Sig.	ηp^2	ε
Experienced Biodiversity							
Main Effects							
Display	0.243	1,38	0.243	0.665	0.420	0.017	
Environment	112.321	2,76	56.160	76.656	**< 0.001**	0.669	
Sound	4.787	1,38	4.787	32.476	**< 0.001**	0.461	
Two-way Interactions							
Display*Env.	2.892	1.550,58.916	1.865	4.637	**0.021**	0.109	0.775
Display*Sound	0.642	1,38	0.642	4.569	**0.039**	0.107	
Env.*Sound	0.129	1.706,67.579	0.075	0.401	0.639	0.010	0.853
Three-way Interactions							
Display*Env.*Sound	0.932	2,76	0.466	3.346	**0.040**	0.081	
Preference							
Main Effects							
Display	0.855	1,38	0.855	1.096	0.302	0.028	
Environment	52.081	2,76	26.041	17.978	**< 0.001**	0.321	
Sound	28.752	1,38	28.752	56.276	**< 0.001**	0.597	
Two-way Interactions							
Display*Env.	0.209	1.737,65.990	0.121	0.184	0.802	0.005	0.868
Display*Sound	0.419	138.000	0.419	2.481	0.124	0.061	
Env.*Sound	0.030	2,76	0.015	0.046	0.955	0.001	
Three-way Interactions							
Display*Env.*Sound	2.363	1.492,56.699	1.584	3.773	**0.041**	0.090	0.746
Realism							
Main Effects							
Display	13.675	1,38	13.675	11.218	**0.002**	0.228	
Environment	3.953	2,76	1.976	4.891	**0.010**	0.114	
Sound	14.368	1,38	14.368	27.809	**< 0.001**	0.423	
Two-way Interactions							
Display*Env.	0.850	2,76	0.425	1.338	0.268	0.034	
Display*Sound	0.214	1,38	0.214	1.000	0.324	0.026	
Env.*Sound	1.107	2,76	0.553	2.226	0.115	0.055	
Three-way Interactions							
Display*Env.*Sound	0.261	2,76	0.130	0.463	0.631	0.012	
Recreation							
Main Effects							
Display	0.561	1,37	0.561	0.702	0.408	0.019	
Environment	74.544	2,74	37.272	22.803	**< 0.001**	0.381	
Sound	1.482	1,37	1.482	1.456	0.235	0.038	
Two-way Interactions							
Display*Env.	6.386	2,74	3.193	5.199	**0.008**	0.123	
Display*Sound	5.930	1,37	5.930	10.496	**0.003**	0.221	
Env.*Sound	1.281	2,74	0.640	2.306	0.107	0.059	
Three-way Interactions							
Display*Env.*Sound	0.491	2,74	0.246	0.708	0.496	0.019	
Arousal							
Main Effects							
Display	2720.486	1,28	2720.486	9.005	**0.006**	0.243	
Environment	593.293	2,56	296.647	1.545	0.222	0.052	
Sound	7719.313	1,28	7719.313	31.933	**< 0.001**	0.533	
Two-way Interactions							
Display*Env.	202.695	2,56	101.348	0.551	0.579	0.019	
Display*Sound	214.164	1,28	214.164	3.150	0.087	0.101	
Env.*Sound	181.385	2,56	90.693	0.899	0.413	0.031	
Three-way Interactions							
Display*Env.*Sound	179.845	2,56	89.922	0.797	0.456	0.028	
Pleasure							
Main Effects							
Display	463.787	1,33	463.787	1.206	0.280	0.035	
Environment	7211.784	2,66	3605.892	16.223	**< 0.001**	0.330	
Sound	7791.885	1,33	7791.885	32.675	**< 0.001**	0.498	
Two-way Interactions							
Display*Env.	56.529	1.648,54.368	34.312	0.213	0.766	0.006	0.824
Display*Sound	48.728	1,33	48.728	0.561	0.459	0.017	
Env.*Sound	74.255	2,66	37.127	0.301	0.741	0.009	
Three-way Interactions							
Display*Env.*Sound	51.059	2,66	25.529	0.287	0.751	0.009	
GSR							
Main Effects							
Display	906582.105	1,20	906582.105	9.852	0.005	0.330	
Environment	36077.678	2,40	18038.839	0.266	0.768	0.013	
Sound	2673.789	1,20	2673.789	0.142	0.711	0.007	
Two-way Interactions							
Display*Env.	13970.971s	2,40	6985.486	0.154	0.858	0.008	0.824
Display*Sound	70362.134	1,20	70362.134	3.054	0.096	0.132	
Env.*Sound	106491.514	2,40	53245.757	2.532	0.092	0.112	
Three-way Interactions							
Display*Env.*Sound	43469.293	1.438,28.766	21734.646	1.282	0.289	0.060	0.719

Discussion

The present study sought to investigate the how VR and sound impact participant's perceived biodiversity, preference, realism, recreation potential, arousal, and pleasure when viewing animations of three different environments, as well as the potential of GSR to serve as an objective measure of engagement. The results will be discussed for each dependent variable in the next sections.

Experienced Biodiversity

Environment type played a significant role in the experienced biodiversity of the user. Participants perceived environment one (community garden) to have significantly more biodiversity than both environment two (playground) and environment three (woodlot). Participants also found environment three to be significantly more diverse than environment two. This result shows that as the landscape becomes more varied and diverse, users are better able to identify biodiverse landscapes. This finding is in line with other research on the richness of vegetation and its perceived biodiversity (Lindquist et al. 2020; Qiu, Lindberg, & Nielsen, 2013).

Preference

Preference significantly increased with the addition of sound for all three environments ($p < 0.001$). This finding is consistent with other research (Lindquist, Lange, & Kang, 2016; Liu & Schroth, 2019) that found the presence of sound that matched visuals increased preference compared to viewing visuals alleParticipants significantly preferred environment one to environments two and three, possibly due to the increased natural features and variation found in that environment, This corroborates other research (Kaplan & Kaplan, 1982; Hagerhall, Purcell, & Taylor, 2004), One interesting finding is that the participants least preferred environment two (playground). It was thoguht that because a playground is familiar, participants would prefer that environment as indicated by past research (Nessauer, 1988; Cosgrove, 1998). Another point of interest found was that display type did not have a significant influence on preference ($p = 0.302$).

Realism

The findings of this research are in line with other research that found an increase in user realism when viewing a virtual landscape in an HMD (Rockstroh et al., 2020; Lindquist et al., 2020). Environment one was found to be significantly more real than environment three ($p = 0.011$). This finding is believed to be due to the vivid variation found in environment one compared to environment three, which consisted mainly of large and similar trees on a generic ground. Realistic sound increased perceived realism which is in line with previous research by Lindquist et al, (2016) that demonstrated congruency between sounds and sight as a vital factor for perceived realism in a virtual environment. In general, as the levels of detail increased (environment three, woodlot with few detailed trees to environment one, community garden with dense and detailed vegetation), so does the preseived level of realism. This is a similar finding to a 2003 study by Appelton and Lovett, who found that increased detail in still images increased preceived realism. It is important to note that those with prior experience with 3D and 4D visualizations and in VR may have an increased expectation of realism in a virtual environment.

Recreational Value

The recreational values of the three animations were consistent with other research (Bjerke et al., 2006; Lindquist et al., 2020) in that environments with recreational elements are perceived as having a higher recreational value. With this expectation, it is not surprising that environment two had a significantly higher recreational value than environment three ($p < 0.001$) and environment one ($p = 0.002$) while environment one had a higher recreational value than environment three ($p = 0.008$). Another explanation of the woodlot being so low in recreational value is the perceived danger from the enclosed feeling and limited sightlines found in the woodlot (Herzog & Kutzli, 2002).

Arousal and Pleasure

This study used arousal as a proxy for presence in a virtual landscape to be consistent with prior research (Gatti et al., 2018; Terkildsen & Makransky, 2019). It was anticipated that skin conductance levels would vary more in an HMD, indicating a higher perceived sense of presence. This assumption was based on previous work by Terkildsen and Makransky (2019) that used peaks in GSR to compare the user's sense of presence between two groups. The present study did not notice any significant changes in the number of peaks in GSR when comparing between environments. Unlike a previous study that found a consistent boost in user presence while using an HMD (Birenboim, et al., 2019), this study found sound and environment to have a more significant impact on presence than display type.

Galvonic Skin Response

The present study aimed to evaluate the use of GSR as an indication of presence in a virtual 4D landscape visualization. While it was hypothesized that there would be more significant peaks in VR and with sound, only VR had significantly more peaks. Previous research suggests that presence does not directly influence arousal intensity, and thus is not a good indicator of presence (Reeves, Detenber, & Steuer, 1993). This research was based on changes in visual fidelity and did not include the manipulation of media factors which do significantly affect physiological arousal levels (Reeves, Detenber, & Steuer, 1993; Terkildsen & Makransky, 2019). It is also argued that for a measured physiological response from a mediated environment to be accurate to a real world, the stimuli must represent the same level of stress or emotion-inducing characteristics as the non-mediated version (Slater, 2018). For these reasons that it is believed that the choice of stimuli in the present experiment was not stressful or emotion inducing enough to properly reveal a consistent and measurable physiological response. Prior research in presence using GSR utilized a horror video game to induce the physiological response (Terkildsen & Makransky, 2019). It is interesting to note that only display type had a significant effect on GSR peaks. If GSR peaks can be used to indicate presence as prior research suggests (Terkildsen & Makransky, 2019), and sound increases users presence (Lindquist, 2014), then it would be expected that both sound and display type would have a significant impact on GSR peaks. It is thought that sound did not have a impact on GSR owing to the calming nature of the sounds.

Limitations and Future Research

The findings of this study show the potential of using GSR as an indication of presence in a virtual landscape; However, some limitations of this study should be considered in future research. This study used BEI as a means of evaluating perceived biodiversity. This index was not validated on moving images or multisensory stimuli, and thus may not be a reliable measure of perceived biodiversity. Future work should find an alternative measure of perceived biodiversity that has been validated for multisensory stimuli. GSR can be limited to stimuli that elicits a strong emotional response and the stimuli in the present research was not startling enough to create a strong emotional response. Future work should focus on limiting the stimuli to that can elicit a strong emotional response, such as a jump scare (Terkildsen & Makransky, 2019).

Conclusion

In this study, the perception of three different environments was compared with two sound conditions when viewed on screen and via VR HMD. While there was no main effect of display type on all measures but participants preference, realistic sound significantly influenced participants perceived levels of experienced biodiversity, preference, realism, arousal, and pleasure ($p < 0.001$ for all). Environment also had significant influence on participants perceived experienced biodiversity, preference, realism, recreation, and pleasure.

While this study has limitations, the findings indicated that display type and multisensory stimulation significantly increased participants engagement with the experiment material. As new technologies are further adapted by practitioners and researchers, special consideration should be made to display type and multisensory stimuli as they have a significant impact on user’s experience. GSR is a promising measure of participants experience in these immersive environments and should be carefully considered in future works.

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Appendix A

GSR survey

Start of Block: Participant ID (Researcher filled out)

Q1 Please select participant ID

▼ 01 (1) ... 70 (70)

Q2 First screen type

○ Screen (1) ○VR (2)

Q3 Experimental condition

○ A (1) ○ B (2) ○ C (3) ○ D (4) ○ E (5) ○ F (6)

End of Block: Participant ID

Start of Block: Demographics (Participant filled out)

Q4 What's your age?

▼ 18 (1) ... 100 (83)

Q5 Do you consider yourself Male or Female?

○ Male (1)

○ Female (2)

○ Other (3) ____

○ Prefer not to say (4)

Q6 Is English your first langauge?

○ Yes (1)

○ No (2)

Q7 In which country have you lived the majority of your life?

▼ Afghanistan (1) ... Zimbabwe (1357)

Q8 Did you live in or grow up in an ...?

○ urban environment (1)

○ suburban environment (2)

○ rural environment (3)

Q9 Do you enjoy spending time more in cities or in natural environments, or both?

○ cities (1)

○ natural environments (2)

○ both (3)

End of Block: Demographics

Start of Block: NSS

Q10 Please answer the following question about your sensitivity to noise.

Q11 I am sensitive to noise

- Agree strongly 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 (5)
- Disagree strongly 6 (6)

Q12 I find it hard to relax in a place that's noisy

- Agree strongly 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 (5)
- Disagree strongly 6 (6)

Q13 I get mad at people who make noise that keeps me from falling asleep or getting work done

- Agree strongly 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 (5)
- Disagree strongly 6 (6)

Q14 I get annoyed when my neighbors are noisy

- Agree strongly 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 (5)
- Disagree strongly 6 (6)

Q15 I get used to most noises without much difficulty

- Agree strongly 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 (5)
- Disagree strongly 6 (6)

End of Block: NSS

Start of Block: Next part

Q16 Please let the researcher know that you're ready to begin the experiment.

End of Block: Next part

Start of Block: GSR DV 01`

Q17 Please rate the previous animation using both sliders below. Don't think too much about it, just rate you felt when watching it.

Q18 Move the slider to rate your level of Arousal

- 0	

Q19 Move the slider to rate your level of Pleasure

- 0	

Q20 How realistic is your experience of this environment?

○ not real (1) ○ slightly real (2) ○ somewhat real (3) ○ quite real (4) ○ very real (5)

Q21 How much do you like this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q22 How appropriate is this environment for recreation?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q23 How rich in plants is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q24 How varied is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q25 How wild is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

End of Block: GSR DV 01`

Start of Block: GSR DV 02

Q26 Please rate the previous animation using both sliders below. Don't think too much about it, just rate you felt when watching it.

Q27 Move the slider to rate your level of Arousal

- 0	

Q28 Move the slider to rate your level of Pleasure

- 0	

Q29 How realistic is your experience of this environment?

○ not real (1) ○ slightly real (2) ○ somewhat real (3) ○ quite real (4) ○ very real (5)

Q30 How much do you like this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q31 How appropriate is this environment for recreation?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q32 How rich in plants is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q33 How varied is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q34 How wild is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

End of Block: GSR DV 02

Start of Block: GSR DV 03

Q35 Please rate the previous animation using both sliders below. Don't think too much about it, just rate you felt when watching it.

Q36 Move the slider to rate your level of Arousal

- 0	

Q37 Move the slider to rate your level of Pleasure

- 0	

Q38 How realistic is your experience of this environment?

○ not real (1) ○ slightly real (2) ○ somewhat real (3) ○ quite real (4) ○ very real (5)

Q39 How much do you like this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q40 How appropriate is this environment for recreation?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q41 How rich in plants is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q42 How varied is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q43 How wild is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

End of Block: GSR DV 03

Start of Block: GSR DV 04

Q44 Please rate the previous animation using both sliders below. Don't think too much about it, just rate you felt when watching it.

Q45 Move the slider to rate your level of Arousal

- 0	

Q46 Move the slider to rate your level of Pleasure

- 0	

Q47 How realistic is your experience of this environment?

○ not real (1) ○ slightly real (2) ○ somewhat real (3) ○ quite real (4) ○ very real (5)

Q48 How much do you like this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q49 How appropriate is this environment for recreation?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q50 How rich in plants is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q51 How varied is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q52 How wild is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

End of Block: GSR DV 04

Start of Block: GSR DV 05

Q53 Please rate the previous animation using both sliders below. Don't think too much about it, just rate you felt when watching it.

Q54 Move the slider to rate your level of Arousal

- 0

Q55 Move the slider to rate your level of Pleasure

- 0

Q56 How realistic is your experience of this environment?

○ not real (1) ○ slightly real (2) ○ somewhat real (3) ○ quite real (4) ○ very real (5)

Q57 How much do you like this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q58 How appropriate is this environment for recreation?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q59 How rich in plants is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q60 How varied is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q61 How wild is this environment?

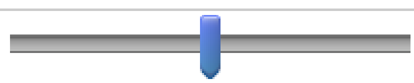
○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

End of Block: GSR DV 05

Start of Block: GSR DV 06

Q62 Please rate the previous animation using both sliders below. Don't think too much about it, just rate you felt when watching it.

Q63 Move the slider to rate your level of Arousal

- 0	

Q64 Move the slider to rate your level of Pleasure

- 0	

Q65 How realistic is your experience of this environment?

○ not real (1) ○ slightly real (2) ○ somewhat real (3) ○ quite real (4) ○ very real (5)

Q66 How much do you like this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q67 How appropriate is this environment for recreation?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q68 How rich in plants is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q69 How varied is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q70 How wild is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

End of Block: GSR DV 06

Start of Block: Switch format

Q71 Please tell the researcher you are ready to switch presentation formats

End of Block: Switch format

Start of Block: GSR DV 07

Q72 Please rate the previous animation using both sliders below. Don't think too much about it, just rate you felt when watching it.

Q73 Move the slider to rate your level of Arousal

- 0	

Q74 Move the slider to rate your level of Pleasure

- 0	

Q75 How realistic is your experience of this environment?

○ not real (1) ○ slightly real (2) ○ somewhat real (3) ○ quite real (4) ○ very real (5)

Q76 How much do you like this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q77 How appropriate is this environment for recreation?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q78 How rich in plants is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q79 How varied is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q80 How wild is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

End of Block: GSR DV 07

Start of Block: GSR DV 08

Q81 Please rate the previous animation using both sliders below. Don't think too much about it, just rate you felt when watching it.

Q82 Move the slider to rate your level of Arousal

- 0	

Q83 Move the slider to rate your level of Pleasure

- 0	

Q84 How realistic is your experience of this environment?

○ not real (1) ○ slightly real (2) ○ somewhat real (3) ○ quite real (4) ○ very real (5)

Q85 How much do you like this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q86 How appropriate is this environment for recreation?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q87 How rich in plants is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q88 How varied is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q89 How wild is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

End of Block: GSR DV 08

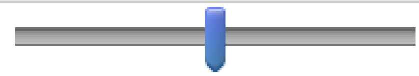
Start of Block: GSR DV 09

Q90 Please rate the previous animation using both sliders below. Don't think too much about it, just rate you felt when watching it.

Q91 Move the slider to rate your level of Arousal

- 0	

Q92 Move the slider to rate your level of Pleasure

- 0	

Q93 How realistic is your experience of this environment?

○ not real (1) ○ slightly real (2) ○ somewhat real (3) ○ quite real (4) ○ very real (5)

Q94 How much do you like this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q95 How appropriate is this environment for recreation?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q96 How rich in plants is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q97 How varied is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q98 How wild is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

End of Block: GSR DV 09

Start of Block: GSR DV 10

Q99 Please rate the previous animation using both sliders below. Don't think too much about it, just rate you felt when watching it.

Q100 Move the slider to rate your level of Arousal

- 0	

Q101 Move the slider to rate your level of Pleasure

- 0	

Q102 How realistic is your experience of this environment?

○ not real (1) ○ slightly real (2) ○ somewhat real (3) ○ quite real (4) ○ very real (5)

Q103 How much do you like this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q104 How appropriate is this environment for recreation?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q105 How rich in plants is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q106 How varied is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q107 How wild is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

End of Block: GSR DV 10

Start of Block: GSR DV 11

Q108 Please rate the previous animation using both sliders below. Don't think too much about it, just rate you felt when watching it.

Q109 Move the slider to rate your level of Arousal

- 0	

Q110 Move the slider to rate your level of Pleasure

- 0	

Q111 How realistic is your experience of this environment?

○ not real (1) ○ slightly real (2) ○ somewhat real (3) ○ quite real (4) ○ very real (5)

Q112 How much do you like this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q113 How appropriate is this environment for recreation?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q114 How rich in plants is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q115 How varied is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q116 How wild is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

End of Block: GSR DV 11

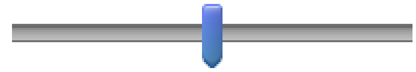
Start of Block: GSR DV 12

Q117 Please rate the previous animation using both sliders below. Don't think too much about it, just rate you felt when watching it.

Q118 Move the slider to rate your level of Arousal

- 0	

Q119 Move the slider to rate your level of Pleasure

- 0	

Q120 How realistic is your experience of this environment?

○ not real (1) ○ slightly real (2) ○ somewhat real (3) ○ quite real (4) ○ very real (5)

Q121 How much do you like this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q122 How appropriate is this environment for recreation?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q123 How rich in plants is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q124 How varied is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

Q125 How wild is this environment?

○ not at all (1) ○ a little (2) ○ moderately (3) ○ quite a bit (4) ○ very much (5)

End of Block: GSR DV 12

Start of Block: End of survey

Q126 Please let us know any comments you have about the survey

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Page Break

Q127 Thank you for taking our survey. Your participation is appreciated.

End of Block: End of survey
