Effects of exposure to rural soundscape on psychological restoration

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Summary
This study aims to explore and inform the connections between rural soundscape and psychophysiological well-being. Laboratory experiments were carried out in a virtual reality (VR) condition and a non-VR condition. For a VR condition, 360-degree videos were presented using a VR headset, while the videos were presented on a computer monitor screen in a non-VR condition. The experiments also consisted of two sessions: 1) audio-video combined session and 2) video only session. Participants first watched a stressful video clip and then were exposed to urban or rural scenes. Participants rated their perceived tranquillity/peacefulness, pleasantness, preference, and psychological restoration at the end of each session. During the laboratory experiments, physiological responses (heart rate: HR, electrodermal activity: EDA, respiratory rate: RR, and facial electromyography: fEMG) were measured. It was found that the rural area with water sound was most effective in psychological and physiological restoration. There were significant differences in subjective ratings and physiological responses between the VR and non-VR conditions. Furthermore, psychophysiological restorations in audio-video combined session were slightly better than those in video only session.

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1. Introduction[1]

A number of studies have reported the long-term health effects of noise, such as sleep disturbance and cardiovascular disease. Therefore, quietness has been considered critical to create a healthy environment. For example, practical suggestions were recently made to promote work towards improving tranquillity in open spaces in London [1]. In addition, legislation such as the European Union's noise directive (2002/49/EC) seeks to protect quiet areas from noise sources. Such legislation is based on evidence indicating the health benefits of quieter areas and the health costs of noisier areas.
Nowadays, there is an increasing interest in the hypothesis that a pleasant acoustic environment may have a positive impact on human well-being. In particular, restoration has been suggested as one of potential beneficial health effects of the soundscape. Psychological restoration is the recovery from attentional fatigue and reflection upon daily or life issues. Kaplan and Kaplan [2] examined the factors affecting a restorative experience and natural environments were then found to be the key factors in achieving restoration. Therefore, a number of studies have reported that being in or looking at natural environments are restorative when cognitively fatigued (e.g. [2, 3]). It was also found that natural settings led to a slightly better restoration than the urban environments and loud sound in urban settings was introduced as one of factors causing less restoration [3]. However, most studies in landscape field focused mainly on the visual perception (aesthetics) of the environment and restorative impacts of acoustic environment were rarely investigated.
Few studies have investigated the impacts of sound on restoration and cognitive performance but their targets were indoor settings such as open-

plan offices [4, 5]. Recently, there have been attempts to expand the knowledge on restoration into urban spaces using a combination of psychological methods and soundscape approaches. A scale for assessing perceived restorativeness in urban soundscape was developed through laboratory experiment based on the Attention Restoration Theory (ART) [6]. Another study introduced several conceptual models to explain a link between soundscape and health based on a literature review [7]. There is still a lack of evidence on impacts of sound on psychological restoration.

The aim of this study is to examine the effects of different acoustic and landscape settings on psychological and physiological restorations. Specifically, urban area was compared with rural areas in terms of perceived and measured restorations through laboratory experiments.

2. Methods

2.1. Participants

This study aimed to recruit more than 26 participants since this number of participants are required to obtain 0.8 of statistical power in correlation analysis. Any individuals with a history of hearing issues and who are currently taking medications for illness or suffering from or recovering from any illness were excluded from the recruitment. A total of 19 healthy adults have participated in the experiment so far and 11 will be further recruited. They included 9 males and 10 females aged between 21 and 39 (mean = 27.5, std. deviation = 5.2). Majority of them were in their 20s and 31.6% of them were in their 30s.

2.2. Experimental design

It is firstly hypothesised that presentations of audio and video stimuli in virtual reality (VR) condition would lead to greater restorations than non-VR condition. Therefore, as listed in Table 1, the laboratory experiment consisted of two parts: VR and non-VR conditions. The 360-degree videos were presented via a VR headset (Oculus Rift) in a VR condition, whereas a monitor screen used to present the visual stimuli in a non-VR condition. Sounds were presented via a headphone (Sennheiser HD 518) for both conditions. All sound stimuli were presented diotically. Secondly, it is hypothesised that there would be audio-visual interaction in the restorations. Thus, both VR and non-VR conditions also had two separate sessions: 1) audio-video combined session and 2) video only session. Thirdly, it is hypothesised that rural area would lead to greater restorations than the urban space because natural features such as trees and stream are helpful to reduce stress level. For the VR conditions, one urban area and two rural areas were presented. For the non-VR condition, only the rural area with stream were presented with one urban area.

Before the presentations of urban or rural scenes, one minute of ‘baseline’ and one minute of ‘stressor’ were presented. One minute of presentation was adopted since physiological responses may habituate over one minute of presentation [8]. The ‘baseline’ contained a grey screen with a white noise at 40 dBA to make participants to rest and recover from a prior session or any stress. As the stressor, one of 10 horror videos were randomly presented in order to evoke stress. The presentation of horror movies is expected to increase each of the participants' psychological stress [9] so that the restoration evoked by urban or rural soundscapes can be clearly observed and compared.

2.3. Stimuli

An audio-video recording of the urban area (hereinafter ‘Urban’) was conducted in the city centre of Manchester with busy traffics, while two recordings of the rural areas were conducted in the

Table I. Outline of the laboratory experiment.

Conditions		Restorative visual stimuli	Time
Virtual reality (VR)	Audio-visual	One urban area and two rural areas	15-min
	Video only	One urban area and two rural areas	15-min
Non-virtual reality (VR)	Audio-visual	One urban area and one rural area	10-min
	Video only	One urban area and one rural area	10-min

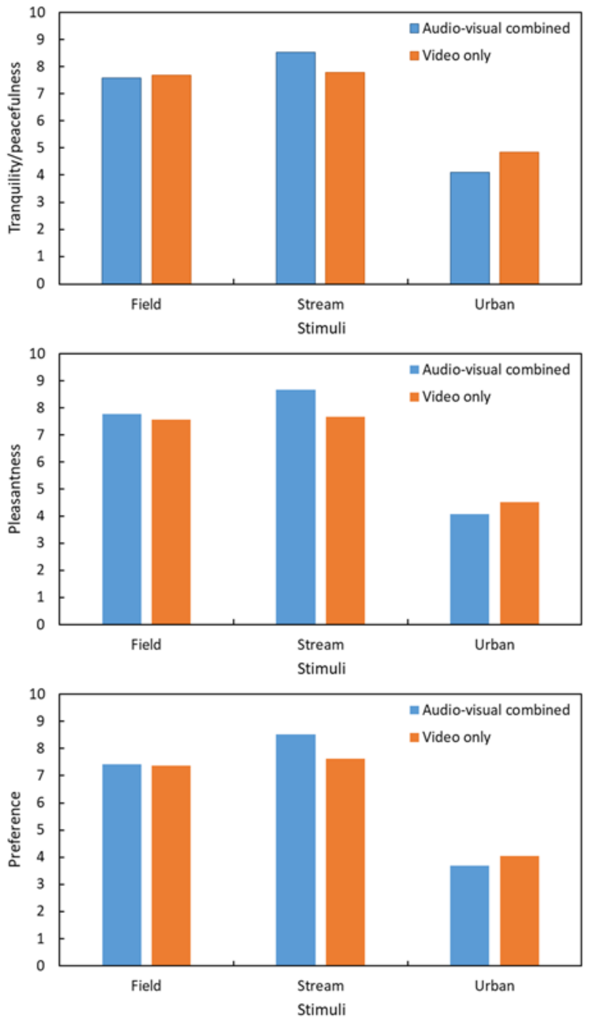

Figure 1. Comparison of audio-combined session and video only session in VR condition; tranquility/peacefulness (top), pleasantness (middle), and preference (bottom).

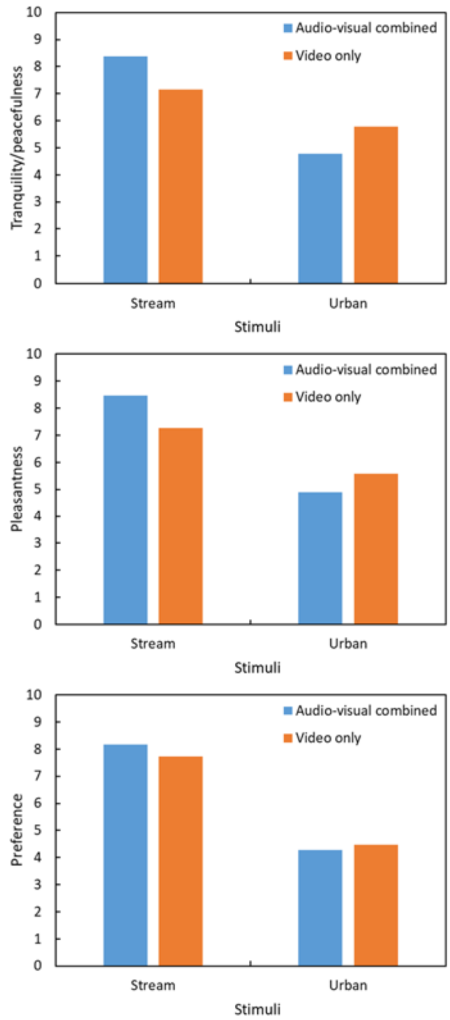

Figure 2. Comparison of audio-combined session and video only session in non-VR condition; tranquility/peacefulness (top), pleasantness (middle), and preference (bottom).

Lake District National Park (LDNP). Videos were recorded using a 360-degree camera (Samsung Galaxy Gear) at a resolution of 3840×2160 and sounds were recorded using a half-inch free field microphone (Behringer ECM8000) attached to a portable sound recorder (Zoom H4n). One of the rural areas shows an open space surrounded by hills (hereinafter ‘Field’) and the other includes stream and trees (hereinafter ‘Stream’). In addition, two VR videos of rural area were downloaded from the YouTube website and sounds were extracted from the VR videos. These videos are one open space (‘Field’) and one stream (‘Stream’), respectively. As a stressor, 10 horror videos were downloaded from the YouTube website. All horror videos were cautiously chosen and edited not to contain any violent scenes; they only contained startle effect of sounds or visual images. All the sounds and video were edited to be one minute in duration. A-weighted equivalent sound pressure levels (L_{Aeq}) of the horror videos were fixed at 65 dBA, while sounds of the urban and rural areas were presented at 55 dBA.

2.4. Psychophysiological measurements

Restoration was evaluated by using physiological measurements as well ass a questionnaire. During the laboratory experiment, several physiological responses were recorded: 1) heart rate (HR), 2) electrodermal activity (EDA), 3) respiration rate and 4) facial electromyography (fEMG). The physiological signals were acquired using the Biopac MP150 physiological data acquisition system and analysed using AcqKnowledge 4.4 (BIOPAC Systems). Firstly, a

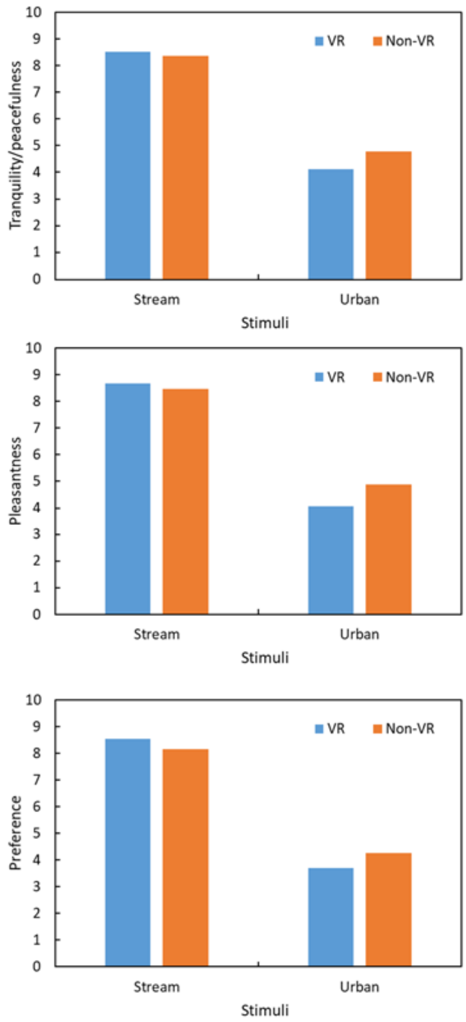

Figure 3. Comparisons of VR and non-VR conditions in audio-video combined session; tranquility/peacefulness (top), pleasantness (middle), and preference (bottom).

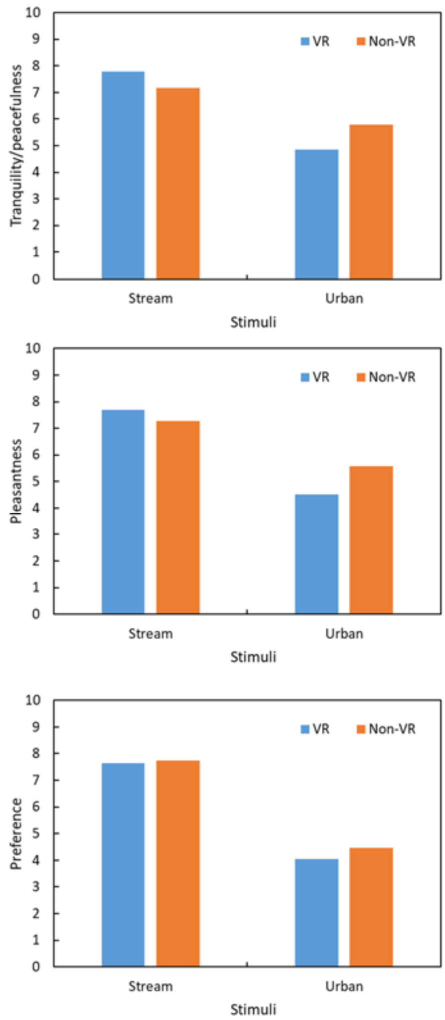

Figure 4. Comparisons of VR and non-VR conditions in video only session; tranquility/peacefulness (top), pleasantness (middle), and preference (bottom).

photoplethysmography (PPG) sensor was attached to one finger for measuring heart rate. Secondly, two electrodes were attached to other adjacent fingers for measuring EDA. Thirdly, in order to measure respiration rate, a transducer belt was worn around the chest. Finally, fEMG was measured using five electrodes placed over facial muscles, associated with different emotion expressions. Specifically, it was expected happy expressions to activate zygomaticus major, which pulls up the cheek, while fear expressions were expected to activate the medial frontalis (corrugator supercilii muscle), which raises the inner eyebrow [10]. In addition, based on previous findings about physiological responses (e.g. EDA and RR) to building noise, physiological restoration was expected to be shown by decreases in EDA and RR [8, 11].

After each presentation of the stimulus, the questionnaire was shown on the screen. The participant responded to each question and the researcher outside the booth listened to his/her responses via a headphone. This method was chosen instead of using a hard-copied questionnaire to minimise the time of taking on and off the VR headsets. The questionnaire contained questions about tranquillity/peacefulness, pleasantness, preference, and psychological restoration. In particular, psychological restoration was measured by using six items from a Perceived Restorativeness Soundscape Scale (PRSS) [6]. Three items are related to 'Fascination' and others are about 'Being-away-to', 'Being-away-from' and 'Compatibility'. These six items from the PRSS were used only in audio-video combined sessions for VR and non-VR conditions.

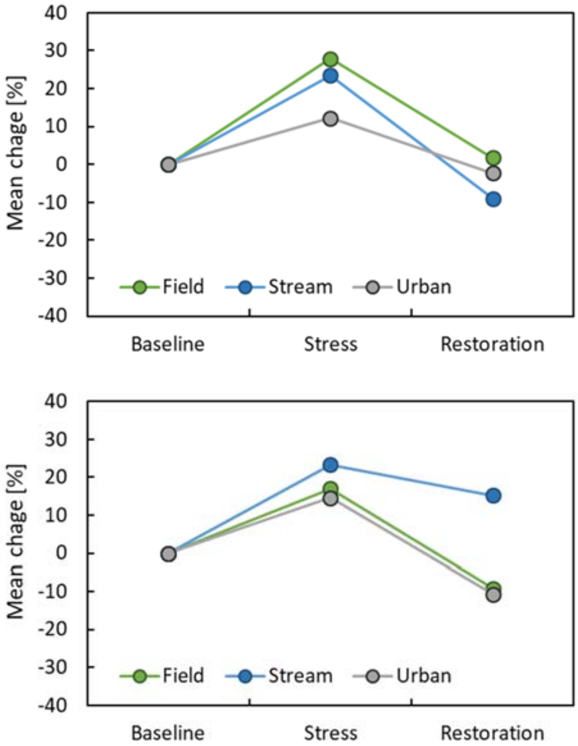

Figure 5. Mean changes of corrugator supercilii muscle responses in VR condition; audio-video combined session (top) and video only session (bottom).

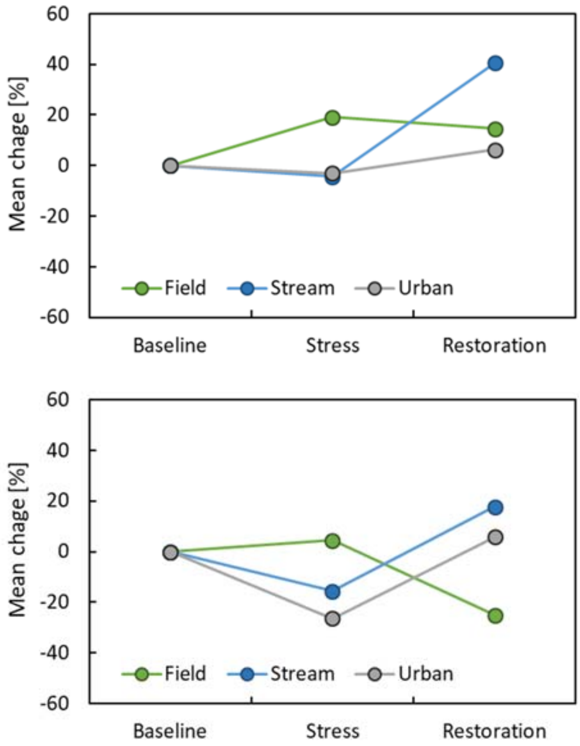

Figure 6. Mean changes of zygomatic muscle responses in VR condition; audio-video combined session (top) and video only session (bottom).

2.5. Procedure

The participants were asked to avoid staying up late and drinking alcohol the night before the experiment and to avoid drinking any caffeinated drinks on the day of the experiment. The experiment was carried out in an experimental chamber where the background noise level was approximately 25 dBA. All the electrodes were attached to the participants' face, chest, and fingers once the participant finished reading the information sheet regarding the experiment and gave their consent to participate. The participant was then helped to be seated comfortably on a chair. The participants wore a VR headset (Oculus Rift) and headphone (Sennheiser HD 518) during the experiment. The participants used the VR for five minutes to get accustomed to the headset and each participant then took part in a test session at the beginning which lasted five minutes. The room temperature and humidity were kept constant throughout the experiment to avoid their effects on the physiological responses [12].

3. Results

3.1. Perceived tranquillity/peacefulness, pleasantness, and preference

Figures 1 and 2 represent the comparisons of audio-combined session and video only session in VR and non-VR conditions, respectively. As shown in Figure 1, in VR condition, significant differences were found in Stream and Urban, whereas there was no difference between the sessions in Field. It may be because sounds of the Field (such as wind and leaves rustling) were less dynamic in evoking positive emotions. Audio-video combined sessions led to greater ratings in Stream; however, opposite tendencies were found in Urban. This implies that adding sounds to 360-degree videos significantly changed positive and negative perception in rural and urban areas, respectively. Similar tendencies were found in non-VR condition. As shown in Figure 2, audio-video combined sessions resulted in greater and less ratings than video only session in Stream and Urban, respectively.
Comparisons of VR and non-VR conditions are plotted in Figures 3 and 4 for audio-video combined and video only sessions. As shown in Figure 3, in audio-video combined sessions, the differences between VR and non-VR are quite

small in Stream. In contrast, subjective ratings of VR were relatively lower than those of non-VR in Urban. This might because the videos of Urban were more dynamic than Steam; thus, VR is more effective to produce realistic situation of urban areas than non-VR. Similar tendencies were found in video only sessions (Figure 4). The differences between VR and non-VR in Urban were greater than those in Stream.

3.2. Perceived Restorativeness Soundscape Scale (PRSS)

Mean PRSS ratings for VR and non-VR conditions are listed in Table II. It was found that rural areas are more effective than urban area in psychological restoration in VR and non-VR conditions. Stream showed the greatest PRSS ratings, followed by Field and Urban. In particular, Urban showed much lower ratings across all the factors of PRSS than two rural areas (Field and Stream). This result confirms that visiting rural areas or countryside is quite effective to reduce stress levels.
Contrary to expectation, VR condition showed similar PRSS ratings with non-VR condition except 'Fascination' raring of Stream. It might because VR condition had poorer video quality than non-VR condition.

3.3. Physiological responses

Analysis of physiological responses is still ongoing so only initial result from five participants is available. Figure 5 shows mean changes of corrugator supercilii muscle response in VR condition. In general, corrugator supercili muscle responses increased during stressor presentations then decreased with presentations of rural and urban areas. In audio-video combined session, the change of Stream was most rapid, indicating that water sound is most effective in physiological restoration. On the other hand, in video only session, the change with Stream was less than others without sounds.
Mean changes of zygomatic muscle responses in VR condition are plotted in Figure 6. For Stream and Urban, zygomaticus responses decrease due to a stressor and increased with presentations of rural and urban areas. Field showed an unexpected tendency here but it is expected that it will show a similar tendency after the analysis of whole data. Again, Stream showed the most rapid changes in audio-video combined and video only sessions and the change in audio-video combined session was greater than that in video only session.

4. Conclusions

The present study investigated psycho-physiological responses after presentations of urban and rural soundscapes. In particular, the stimuli were presented in VR and non-VR conditions. It was found that rural soundscape with strong water sound was most effective in terms perceived tranquillity, pleasantness, and preference in both VR and non-VR conditions. There was a significant difference in subjective ratings between VR and non-VR conditions. It was also observed that the rural area with water sound showed the greatest psychological restoration, followed by the rural area with open space and urban area. Furthermore, the rural area with water sound showed the most physiological restoration in terms of corrugator supercilii muscle and zygomatic muscle response. This study is still ongoing so more detailed analysis will be presented at the conference.

Acknowledgement

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Table II. Mean PRSS ratings for VR and non-VR conditions

PRSS	VR condition			Non-VR condition	
	Field	Stream	Urban	Stream	Urban
'Fascination'	6.4	7.9	3.2	7.8	3.5
'Being-away-to'	5.8	7.4	3.1	7.6	3.3
'Being-away-from'	6.3	8.1	2.4	8.3	3.0
'Compatibility	6.4	8.3	2.7	8.3	3.3

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