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Effect of odour on multisensory environmental evaluations of road traffic

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ABSTRACT

This study investigated the effect of odour on multisensory environmental evaluations of road traffic. The study aimed to answer: (1) Does odour have any effect on evaluations on noise, landscape and the overall environment? (2) How different are participants' responses to odour stimuli and are these differences influential on the evaluations? Experimental scenarios varied in three Traffic levels, three Tree screening conditions and two Odour presence conditions were designed, and presented to participants in virtual reality. Perceived Loudness, Noise Annoyance, Landscape Quality and Overall Pleasantness of each scenario were evaluated and the results were analysed. It shows that Odour presence did not have significant main effect on any of the evaluations, but has significant interactions with Traffic level on Noise Annoyance and with Tree screening on Landscape Quality, indicating the potential of odour to modulate noise and visual landscape perceptions in specific environmental content. Concerning participants' responses to odour stimuli, large differences were found in this study. However, the differences did not seem to be influential on environmental evaluations in this study. Larger samples of participants may benefit this study for more significant results of odour effect.

1. Introduction

Research in environmental psychology have shown the multisensory nature of human perception (Cassidy, 1997). The integration and interaction of physical environmental properties, including colour, light, tactile, temperature, humidity, sound, odour etc., can modulate human reactions to certain sensory stimuli as well as the overall human experience in the environment (Maffei, 2012).

Multisensory approach has been applied in many studies aiming to gain deeper understanding on environmental perception and develop human-centred methodologies for soundscape and landscape assessment. While some of these studies were based on or involved on-site experiments or observations (e.g., Southworth, 1969; Ge and Hokao, 2005; Anderson et al., 1983; Anderson et al., 1984; Mulligan et al., 1987; Jeon et al., 2011), most were based on laboratory experiments for better scenario control (e.g., Carles et al., 1999; Viollon et al., 2002; Pheasant et al., 2008, Hong and Jeon, 2013). Some of the recent studies have taken advantage of multi-media Virtual Reality (VR) for their laboratory experiments to enrich participants' experience and perception of the experimental scenarios (e.g., Joynt and Kang, 2010; Maffei et al., 2013a; Maffei et al., 2013b; Ruotolo et al., 2013). However, these studies were limited to only addressing audio and visual sensory modalities as influential factors, partly due to the prevailing effects of audio and visual inputs in environmental perception (Hong and Jeon, 2014), and partly due to technical challenges in presenting and controlling other sensory media (Washburn and Jones, 2004). The multisensory nature of human perception means it is possible that other sensory modalities would also have an effect on the audio and visual evaluations which was often eliminated in the controlled laboratory environment.

Among those unaddressed sensory modalities, odour can be a potentially influential one as people constantly listen, see and smell concurrently in the real environment. It has long been known that visual information can affect odour perception (Gottfried and Dolan, 2003; Morrot et al., 2001). Recent studies showed that on the other hand odour can also influence visual perception (Kuang and Zhang, 2014; Robinson et al., 2015; Seigneuric et al., 2010). There seems to be a lack of studies specifically on audio-olfactory interaction in current literature. Nevertheless, research has shown broadly that, due to links between olfaction and emotion, odours can influence behavioural performance such as attention, working memory, and reaction times to auditory and visual stimuli (Michael et al., 2003).

Given these findings, it seems promising that adding olfactory output to VR can help enhance user experience and achieve better applications of it including for human-centred environmental evaluations (soundscape, landscape, and/or the overall environment). However, most attempts to include sophisticated olfactory display in VR have been unsuccessful (Washburn and Jones, 2004). Moreover, some studies have explored the possible improvement of VR experience that olfactory output can make, but the results were inconclusive and mostly not encouraging. Dinh et al. (1999) conducted an experiment to investigate the effects of audio, visual, tactile, and olfactory output on participants' experience in a virtual environment. In their experiment, scent of coffee was used as the olfactory cue and was pumped to the

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participant via an oxygen mask in a scenario where coffee machine could be seen. The results showed that adding olfactory output did not increase the sense of presence in the virtual environment, but had significant effect on memory for the environment. Jones et al. (2004) tested the impact of olfactory media on human operator's sense of immersion into a virtual environment by comparing three scent condition groups, including no scent, ocean mint and maple syrup. In their experiment, the scents were presented by a hidden olfactory dispersion system attached on a headset. The results showed no significant enhancement of immersion by adding concordant olfactory media. Nevertheless, the between subject experimental design used in these studies might have introduced too much variation in ratings caused by individual difference.

Another challenge in involving odours as influencing factors in environmental evaluations is that odour perception differs greatly across individuals as well as within individuals. Research has shown that, not only different odours have different thresholds for detection and identification, but also threshold of the same odour varies across and within individuals (Kaye, 1999). In some cases, the variation within individuals can be as large as that across individuals (Stevens et al., 1988). Perceived Odour Intensity can also be unreliable as there is strong evidence that it is influenced by familiarity and hedonic strength (Distel et al., 1999).

This paper presents a case study, using road traffic as the source of environmental intrusions, to investigate the effect of odour on multisensory environmental evaluations. With evaluations on various audio, visual and olfactory scenarios made in virtual reality in a laboratory experiment, it was aimed to answer the following questions: (1) Does odour have any effect on evaluations on noise, landscape and the overall environment? (2) How different are participants' responses to odour stimuli and are these differences influential on the evaluations?

2. Methods

2.1. Experimental design

Three main factors were considered in this study:

- Traffic level;
- Tree screening;
- Odour presence.

Traffic level relates to both noise and visual intrusion of the traffic, and three Traffic levels were used in this experiment: low, medium and high. Tree screening concerns only the visibility of the traffic, and also had three levels: no screening, partial screening and total screening. Odour presence was used to compare human perceptions with and without a certain type of odour, and thus had two levels: with odour and without odour. A3 × 3 × 2 full factorial experimental design was made to present all possible combinations of the factors.

2.2. Audio, visual and odour stimuli

Audio signal of road traffic of various flows was recorded using a Zoom H6 recorder and a Soundfield SPS200 microphone at a distance of 50 m from a two-lane two-way road in a semi-rural area. The microphone was fixed on a tripod, facing perpendicularly to the road line at a height of 1.65 m above the ground. Two recordings were made and each lasted 10 min. On-site sound level at the recording position during the recording time was measured using a Solo 01 dB-Metravib sound level metre. Video recordings of the moving traffic were also made simultaneously with the audio recordings.

Three one-minute recording samples, each for one of the three Traffic levels, as well as a fourth sample of the background noise for the baseline scenarios without traffic (see Section 2.3), were extracted from the full recordings and processed for use with the 5.1 loudspeaker system (see Section 2.3). When choosing the recording samples, the video recordings were used to identify possible samples by traffic count in the initial stage. Then these candidate samples were analysed and the three samples that were representative to the low to high Traffic levels in terms of both sound level and vehicle number were selected. Lorry, bus, motorbike and any other vehicles other than cars were excluded from the selection to avoid dramatic differences in frequency spectrum across the samples. To produce single-channel audio files to feed the loudspeakers in the 5.1 configuration, the four-channel recording samples were rendered in Reaper with the SurroundZone2 plugin. Wide separation angles for both frontal channels L and R (90°) and rear channels LS and RS (120°) were used in the loudspeakers layout to better reproduce the effect of left–right movement of the sound source. Table 1 gives the description of the produced sound files. The playback was calibrated by means of a Solo 01 dB sound level metre and a CAL01 01 dB (94 dB/1 kHz) calibrator.

Based on the recording site, 3D models of the experimental scenarios were created using Google SketchUp and 3ds Max Design (Fig. 1). The viewpoints (receiver positions) in the models were set 1.65 m above the ground and 50 m away from the road, and located in a garden of a private house. Animations of moving vehicles on the road were made for each Traffic level and synchronised with the recordings. For the no-tree-screening scenario, there were no trees blocking the main part of the view to the traffic; for the partial-screening scenario, the traffic was partially screened by roadside plants; and for the total-screening scenario, the traffic was totally invisible behind a thick tree belt.

The audio files and 3D models were then uploaded into the virtual reality software WorldViz 4.0 to create virtual scenarios of the 3 Traffic levels × 3 Tree screenings, as well as the baseline scenarios without traffic.

For the odour stimulus, essential oil of rose was diffused by a quiet electric heater diffuser to generate ambient smell of rose for the with-odour scenario. The diffuser was switched on, with the participant within the closed room, 5 min before to start the test. Rose was also visually presented in the garden in the 3D models so the two sensory modalities were coherent in content. Traffic emission is not likely to be detected by people 50 m away from the road even with the highest Traffic level used in this study. So simulation of traffic emission was not considered.

2.3. Equipment and the test

The experiment was carried out in a 5 × 5 × 5 m anechoic chamber, equipped with a workstation (Intel Core i7 CPU 3.07 GHz processor, Nvidia GeForce GTX480 graphic card), and a 5.1 loudspeaker system (speaker: Dynaudio BM5A MKII; subwoofer: Dynaudio BM9S) driven by a multichannel soundcard MOTU 828 MKII (Fig. 2). Participants were seated at the “hot spot” listening area of the loudspeaker system, wearing an eMagin Z800 3D Visor through which the virtual scenarios were displayed. The visor presented stereoscopic images at 800 × 600 resolution, refreshed at 60 Hz and rendered by the workstation using the software WorldViz 4.0. Head movements (orientation and position) of the participants were tracked using the Polhemus Patriot six d.o.f. motion tracking system.

20 participants (11 males and 9 females), aged 21–47 (m = 29.3; SD = 7.3), with self-reported normal hearing and normal or adjusted to normal vision, were recruited for the experiment. Each participant

Table 1
Description of the produced sound files.

Traffic level	Traffic flow (cars)	On-site measured level $L_{A,eq}$	Played back level				
			$L_{A,min}$	$L_{A,90}$	$L_{A,eq}$	$L_{A,10}$	$L_{A,max}$
No traffic	0	40.8	27.4	40.8	41.7	43.5	46.4
Low	4	48.7	27.6	41.7	48.7	52.1	59.9
Medium	12	53.1	27.3	44.4	52.8	56.4	60.2
High	20	56.0	27.1	46.9	55.9	58.8	62.8