Towards a quantitative tool to assess the soundscape

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ABSTRACT

The aim was to develop a quantitative questionnaire that could easily be administered to assess people's perceptions of the current Soundscape. In a preliminary phase, a group of people identifying themselves as good writers were recruited and played recordings of natural, traffic, and human Soundscapes. As these were playing, participants were asked to write their impressions and responses to each for approximately twenty minutes. Qualitative analysis was used to extract themes from the writing. These themes were identified by key words and scalar (6-point) items were developed to form a short, 19-item questionnaire. This was then administered to 228 people in Auckland city centre, New Zealand. Respondents were able to use the questionnaire, and analyses showed that the items were not independent of each other. Factor analysis revealed patterns of responding, and comparisons between people reporting different levels of Noise Sensitivity and Noise Annoyance revealed that these were associated with the perception of the Soundscape as measured by our questionnaire. The questionnaire appears to be a useful tool, and further research will improve upon it.

Keywords: Soundscape, City, Quantitative I-INCE Classification of Subjects Number(s): 56.3

1. INTRODUCTION

The concept of the soundscape was developed by Schafer and is now important in research about the effects of perceived sound (1). Much of the research to date has been qualitative and descriptive. Compared to quantitative data, qualitative data are rich, however it may be more difficult to make comparisons between qualitative measures and can be harder to get quick, accurate responses at a population level, especially when seeking responses from less educated or literate people.

An issue with qualitative descriptors of soundscapes is that they may be limited by a person's vocabulary and ability to express themselves using language. Most people understand more words than they will actually use (2). This distinction between passive and active vocabulary means that providing people with a set of descriptors which can be rated may allow them to report on experiences for which their active vocabulary would be insufficient.

If, as seems likely, human perception of soundscapes has commonality, then it may be possible to generate a short and quantitative measure based on the responses of highly literate people. Members of the public should be able to use this to describe their perception of the soundscape and their responses to it.

2. METHOD

There were two phases to the research. Phase 1 involved recruiting literate people with an interest in descriptive writing and/or sounds. These participants wrote about their perceptions and responses to three different soundscapes and their writing was analysed thematically. A questionnaire was developed based on the themes identified. Phase 2 was a piloting of the questionnaire in a sample of people in Auckland City.

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2.1 Phase 1: Qualitative Study

2.1.1 Participants

Twenty five adult participants aged 20 – 38 years (mean 25.04, SD 4.71) participated; 52% were male (N=13). Recruitment was through advertisement in the form of posters, electronic flyers, and social media. It was desirable to attract participants who would be willing and able to provide rich written descriptions of their responses to different soundscapes, so advertising was targeted to students in creative-writing courses. All participants had hearing thresholds below 20 dBHL in their better ear for all tested frequencies.

2.1.2 Procedure

Three soundscape recordings were selected and purchased from a database of environmental sound recordings at www.shockwavesound.com. The three soundscape recordings were in 5.1 surround sound AC3 (dolby digital) file format, and a brief descriptions of each are as follows:

1. Traffic: Road traffic noise recorded at a town junction. Cars, mopeds, motorcycles, and occasional buses accelerating past in all four directions with some distant voices.
2. Human: Crowded pedestrian street in town. People walking by in all directions, distant sound of children playing.
3. Nature: Light surf with small birds chirping and tweeting to the front and rear.

The original soundscape recordings were looped to extend the presentation duration (longest 26:41 min; shortest 19:27 min) using Audacity® 2.0.0. For each of the six individual mono files of the 5.1 recording, four additional audio tracks were replicated and the ending of the previous track was overlayed with the start of the subsequent track. The recordings were also edited to fade in and out by 3 seconds to avoid startling participants.

Presentation order was randomized across participants.

Soundscape assessment was conducted at a The University of Auckland clinic booth. Dimensions of the booth are 221cm (width) x 248cm (length). The partially sound-proofed booth and lack of windows aided in reducing ambient noise, reverberation, and external sound influences e.g. rain and traffic.

A SONY 6.1 surround speaker system consisting of left (L), centre (C), right (R), left surround (Ls), right surround (Rs), centre back (Cb) speakers and a subwoofer (Sub) was used for this study. The speaker system was treated as a 5.1 surround system, and no input was received at the Cb speaker for the 5.1 soundscape recordings file format. All speakers were facing the listener and mounted on adjustable stands, with the exception of the subwoofer. The speakers were amplified with a SONY digital audio/video (Model STR-DG500 6.1 Channel) amplifier.

The 6.1 surround system was set up as follows:

- C speaker was positioned straight ahead of the listener at 0° azimuth.
- L and R speakers were positioned at each corner of the front of the booth, approximately 45° left and right respectively to the horizontal. The speakers were raised slightly above ear level.
- Ls and Rs speakers were positioned at each corner of the back of the booth, approximately 45° left and right respectively to the horizontal. The speakers were aligned at ear level.
- (Non-functioning) Cb speaker was positioned directly behind the listener.
- Subwoofer was positioned at the front between speakers C and L.

A calibration spot approximately 150 cm from each of L, R, Ls, and Rs speakers to the middle of the room was marked with masking tape. A comfortable chair on which participants were seated was positioned over the calibrated spot, and a large table was situated in front of the chair where the SONY amplifier and a laptop were placed.

Soundscape recordings were delivered through the surround sound speakers using VLC media player on a 13’ inch Macbook OS X. Coupling of the laptop with the SONY amplifier was carried out with a Creative Labs Sound Blaster THX® TruStudio Pro external USB soundcard and an optical audio cable.

Output levels of the three soundscape recordings were calibrated using a Brüel & Kjær Hand-held Analyzer Sound Level Meter (Type 2250) with a ½ inch microphone. The sound level meter was mounted on a Manfrotto 804RC2 tripod at participants’ ear level when seated over the calibrated spot.

The average sound pressure level (SPL) of traffic sounds was set to 75 dBA (LAeq,4min). Austroad Facts 2000 indicated that the average sound pressure level of traffic noise taken from major Australian cities ranges between 55dB – 75dB. The upper limit of this range was taken because the intersection was very busy. The average SPL of human sounds was set to 65 dBA (LAeq,4min), and the average SPL of nature sounds was set to 55 dBA (LAeq,4min), both based on the researchers' subjective experience of the sounds.

Each participant was seated and briefed of the context of the soundscapes before commencement of each recording. While listening to each recording, participants were instructed to write about their soundscape experience. Participants were given the option of manually writing their responses with pen and paper or typing on a laptop, but all preferred the latter. A blank Microsoft Word document was created headed with an open-ended question:

"Please describe the soundscape you have just heard, and the feelings, emotions, and impressions it may have evoked in you (for example, positive or negative reactions you may have)"

Participants were instructed to write as freely as possible in response to the question. For each of the soundscape recordings, participants were informed that the minimum writing time was eight minutes. However, they were encouraged to write as much as they could, and allowed as long as they required. A count-up timer was set up in the top right-hand corner of the laptop screen to notify participants when eight minutes had passed to avoid premature halting of HRV recording.

During the experiment, the researcher waited outside the sound-proofed booth in order not to interfere with the soundscape experience and to preserve the anonymity of participants' writings. Participants were asked to remove mobile phones. Lights of the sound-proofed booth were dimmed during the experiment.

2.1.3 Data treatment

Participants' subjective writings in response to the open-ended question were analysed using NVivo Software. Thematic analysis of the writings was conducted, and a set of themes and concepts within the data was identified. These categories were organised in a hierarchical manner, illustrating the emergence of more specific themes from general concepts.

2.1.4 Questionnaire Development

The themes identified were adapted to items in a questionnaire (Appendix). There were 19 items in total, and each item consisted of a 6-point visual analogue bipolar rating scale. As the aim was to create a questionnaire that could be distributed and completed by members of the public, focus was placed on reducing the number of items where possible. Preliminary versions of the questionnaire were trialled among a small group of people. An iterative process allowed for refinement of the questionnaire.

2.2 Quantitative Study in Auckland City

Adults were stopped in the street and asked if they would be willing to answer the questionnaire. Of these, 228 completed it and these data are presented here. This was done in four different locations within the central city: a park, a quiet shopping street with mixed pedestrian and vehicular use, a busy main shopping street with a mixture of pedestrian and vehicular traffic, and a street heavily used by buses and other vehicles. Factor analysis was conducted and Factor Scores generated. These values were compared between those responding in a park and in the streets, and between different types of street using t-tests and GLM depending upon the number of comparisons made.

Alongside the soundscape questionnaire, two six-point scale were used by respondents to rate their Noise Sensitivity generally and their Noise Annoyance in the current environment.

3. RESULTS

3.1 Qualitative Results

Responses fell into two broad classifications: those about the sounds, and those about the feelings and impressions that were evoked by the soundscapes.

3.1.1 Sounds

Level, or the impression of loudness was a theme:
"The blood that runs in the city's veins is harsh and loud…"

Pace was perceived as present in the soundscapes. It manifested as a sense of urgency:
"The brakes stop abruptly, signifying that time is short, and nobody has time to spare in their busy schedule. Nobody has time to spare, everyone minding their own business."

Or leisureliness:
"Time slows down to an almost standstill."

Clarity was about the apparent signal-to-noise ratio. In some soundscapes, sounds were distinct with a clear source:
"It is not difficult to separate the sounds of the ocean versus the bird calls."
Whereas in others they were not:
"People's footsteps and voices are drowned out by the constant hum of traffic."

Complexity of the soundscapes was perceived:
"...there are more people speaking at once and several other background noises competing against each other for attention."

There was a sense of space provided by the soundscape:
"There is also a sense of a large expanse of the ocean, the beach (perhaps) and because there are birds there would be places that they can fly off away to."
Or of congestion:
"There is a distant clanging of cutlery, babies crying [...], everything that exists in a densely populated space."

A tonality was perceived. In some soundscapes it was harmonious:
"The chorus the sea sings as the wind encourages its wave to crash. What other melody can compare to that?"

Whereas others were discordant, jangling, or harsh:
"There are a range of voices of different pitches that I can hear. The higher pitched voices – children and women – seem easier to pick out as they move around. But occasionally a man's voice stands out. Sounds such as babies crying are suddenly quite startling."

Stability was the idea that a soundscape could be still and unchanging or varied and changing:
"The surf is always rushing but it's the intensity that changes. The birds tweet but the rhythm and speed changes. You feel like you could sit for hours and never tire of hearing the same sounds over and over."

A Pattern was observed in some soundscapes which had predictability:
"The ocean waves are rhythmic and predictable and quickly become part of a soothing background."

But others were irregular and unpredictable:

"Sounds such as babies crying are suddenly quite startling and immediately noticeable, as are short claps"

3.1.2 Feelings and emotions

Stimulation was experienced as a result of perceiving the soundscapes. This had the effect of either soothing people:

"I like the sound of the ocean waves. The repetitive white noise has a kind of calming, hypnotic effect that could put me to sleep at night."

Or of arousing them:

"I enjoy myself. It's not every day I get to go to such a busy and exciting place. The clatter of shoes, the banter of people, the merchants having welcoming and, sometimes sly, smiles, it's to be an eventful afternoon."

Within the arousal responses to the soundscapes were two types: either excitement, as above, or being overwhelmed by the level of stimulation:

"I can sense urgency in the air. My heart is starting to race. [...] Why can't I relax? I need to breathe."

There may be a perception of connection to the soundscape:

"But this is no kind of loneliness, for there is the connexion with the greener beings."

Or alienation from it:

"I feel isolated from them. This is their everyday [...] I feel invisible, lost, lonely even. It's as though they are alien to me."

Stress, and its opposite, relaxation, were felt in response to some soundscapes:

"I feel at rest, worrisome thoughts I may once have had are long forgotten, and I pause to enjoy the sound of nature."

A sense of Familiarity is evoked by some soundscapes

"I feel that this is a very normal, everyday environment to be in."

But the secondary response to this Familiarity may either put people at ease:

"I feel like I'm in my comfort zone and I know where I'm going."

Or it may seem dull and boring:

"We are all following a pattern designed by something larger than ourselves, all moving, busy ants picking up a little lump of the bigger sugar pile, picking it up, carrying it and dropping it somewhere, only to be picked up and moved again by a fellow ant. I want out. This is not me."

A sense of the Cognitive Load or burden places on the mind by experiencing the soundscapes was given. Sometimes this load was heavy and crushing:

"Too many things, too many noises surround me it's hard to hear your own thoughts."

And sometimes it was refreshing:

"I can feel my mind coming alive, as if a blanket of responsibility that has been smothering me has been removed."

A feeling of safety was felt at times:

"I feel a sense of control – I can move close to the birds or the waves and interact with it if I want to and only if I want to. Nothing in this environment is going to move in a way that may threaten my safety. I don't have to be on my guard the whole time."

There was a reinforcement of Spiritual and/or religious feelings:

"I want to find discover new things, and learn about the answers of life. I feel like I have so many questions and very little in the way of answers so far. Some questions I cannot even express, but I have a feeling of curiosity and hope that that feeling will take me somewhere should I act upon it."

Soundscapes could make people feel Wellbeing:

"I feel healthy – I'm awake early enough to hear the birds. […] I'm breathing fresh, unpolluted, virgin air."

Or else a sense of affliction:

"I cannot get through, for there are too many people. The wait is giving me lines, a tight forehead, and I feel tired, very tired and a little short of breath."

A sense of comfort and contentedness was associated with some soundscapes:

"Overall it's pretty warm and cosy …"

Whereas other soundscapes produced discomfort and the desire to escape from it

"The motorbikes/scooters are particularly painful. They scream at me stabbing at my brain."

3.2 Quantitative Results

Principle axis factoring with obliminal rotation was used to assess the 19 soundscape items. Patterns of association emerged most clearly using a four-factor solution. Absolute loadings >0.3 were used to characterize each factor.

The Level, Pace, and Complexity items loaded negatively and Clarity positively on a factor that was labelled 'Quietness', combining as it did, soft, slowly changing, simple, and clear sounds.

Stimulation, Stress, and Cognitive Load loaded negatively and Space, Tone, Connection, Spirit, Wellbeing, and Comfort on a factor that was labelled 'Pleasantness'.

Connection and Familiarity loaded together and positively on a factor labelled 'Belonging'.

Safety, Spirit, Wellbeing, and Comfort loaded positively on a factor labelled 'Protection'

Stability and Pattern did not produce large enough loadings on any of the factors to be considered in the naming of factors. The factor scores associated with both items were however included in generating the Factor Scores.

Follow-up items: 'Type of Arousal' which sought to operationalize the difference between feeling aroused in the sense of being excited and aroused in the sense of being overwhelmed; and 'Feeling about familiar sounds' which tried to operationalize the difference between comfortably familiar sounds and boring sounds were dropped from this analysis because they were conditional on prior items and this made interpretation difficult as well as having many missing data points.

Factor Scores were generated and the scores were compared between those who completed the questionnaire on city streets and those who completed it in a park (Figure 1).

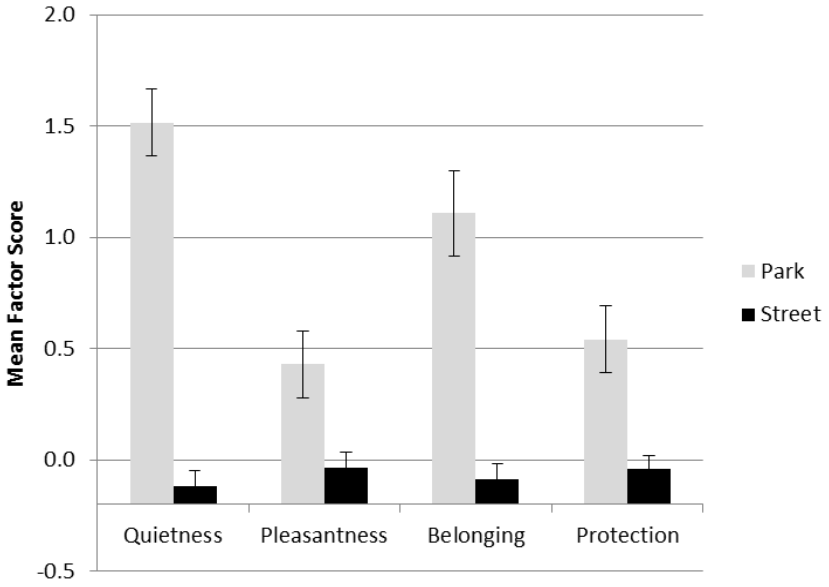

Figure 1: Mean Factor Score for people responding in either a city street or city park. Error bars represent one standard error of the mean.

Factor scores were significantly higher in the park than the street for three of the factors (Quietness:

t(167)=6.43, p<0.001; Belonging: t(167)=4.80, p<0.001; Protection: t(167)=2.56, p=0.011), and were marginally higher for Pleasantness (t(167)=1.83, p=0.068).

Further analysis was conducted to compare the responses to the different types of street and the park. This used GLM with the four types of area (street dominated by vehicles, mixed, street dominated by pedestrians, and park) as the independent variable and the four Factors as dependent variables. The Quietness (F(3,165)=18.55) and Belonging (F(3,165)=13.50) factors were both significantly different between areas (p<0.001); Protection differed marginally (F(3,165)=2.18, p=0.093); and Pleasantness did not differ (F(3,165)=1.30, p=0.277). Figure 2 shows the results for these analyses combined; clearly the park soundscape received higher ratings than all of the streets, though the street with the fewest vehicles had slightly higher scores on Quietness and Belonging than the other streets

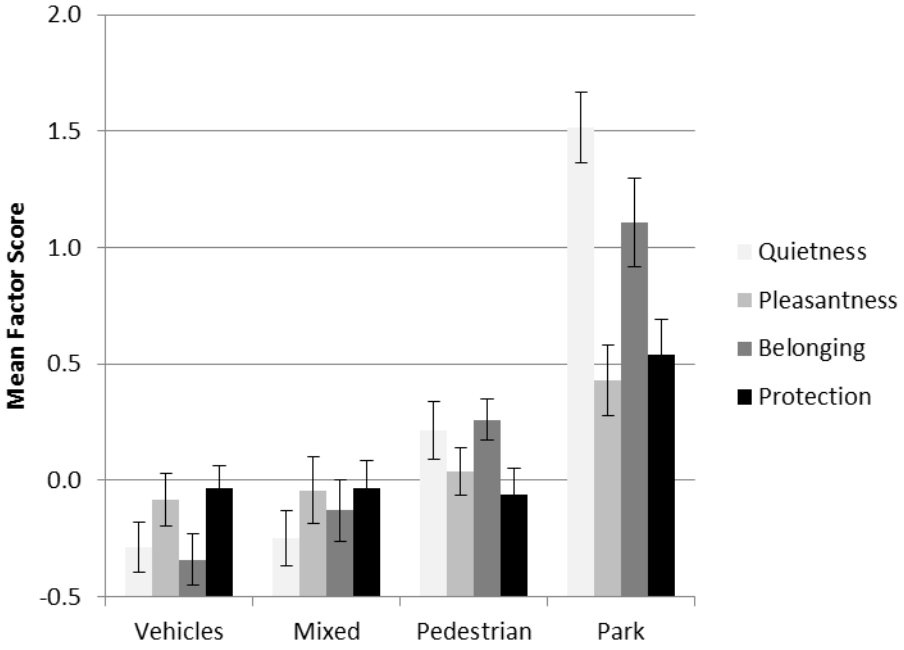

Figure 2: Mean Factor Scores obtained in the four different types of area. Error bars represent one standard error of the mean.

It was of interest to assess whether self-rated general noise-sensitivity and noise-annoyance in the current environment were associated with ratings of the soundscape. Rated Soundscape Quietness was correlated negatively with both (r=-0.228 (p=0.006) and -0.457 (p<0.001) respectively), as was Soundscape Pleasantness (r=-0.196 (p=0.018) and -0.294 (p<0.001) respectively). Feeling of Belonging to the Soundscape did not correlate with Noise Sensitivity (r=-0.108, p=0.196) but it did, negatively, with noise annoyance (r=-0.395, p<0.001). Feeling Protection from the Soundscape did not correlate with either Noise Sensitivity (r=-0.042, p=0.616) or Noise Annoyance (r=-0.080, p=0.342)

4. CONCLUSIONS

Our questionnaire was useable by the general public and showed patterns in the results. It was able to detect differences in the soundscape associated with differing observable environments and with personal variables known to influence the perception of sound. It was not very good at distinguishing between soundscape associated with different types of city street however. Further development may render it more sensitive.

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APPENDIX: Soundscape questionnaire.

This questionnaire aims to assess the sound environment (soundscape).

Your Gender (tick) **Your Age (in years)**

Male ❑ Female ❑ _____

Please indicate how much the following types of sound contribute to the total sound environment.

Nature sounds	**None**	**1**	**2**	**3**	**4**	**5**	**6**	**Entirely**
People sounds	**None**	**1**	**2**	**3**	**4**	**5**	**6**	**Entirely**
Machine sounds	**None**	**1**	**2**	**3**	**4**	**5**	**6**	**Entirely**

Please listen to the sounds around you and rate the sound environment and your response(s) towards it by circling a number (1-6) on the following scales. If the scale is irrelevant to you, tick the 'not applicable' box beside it.

Soundscape feature/ your response								**Not applicable (tick)**
Overall level	**Very soft**	**1**	**2**	**3**	**4**	**5**	**6**	**Very loud** ❑
Pace	**Leisurely**	**1**	**2**	**3**	**4**	**5**	**6**	**Fast** ❑
Clarity	**Clear/ distinct**	**1**	**2**	**3**	**4**	**5**	**6**	**Unclear/ blurred/ disorderly** ❑

Complexity	**Simple sounds**	**1**	**2**	**3**	**4**	**5**	**6**	**Complex sounds**	❑
Stimulation	**Soothing/ hypnotic**	**1**	**2**	**3**	**4**	**5**	**6**	**Arousing**	❑
Arousal	**Vibrant/ exciting**	**1**	**2**	**3**	**4**	**5**	**6**	**Overwhelming/ intense**	❑

(Please tick the N/A box if it is not arousing in any way)

Space	**Spacious/ liberating/ vast**	**1**	**2**	**3**	**4**	**5**	**6**	**Congested/ claustrophobic/ enclosed**	❑
Tone	**Harmonious/ melodious**	**1**	**2**	**3**	**4**	**5**	**6**	**Discordant/ harsh**	❑
Stability	**Dynamic/ changing/ up-and-down**	**1**	**2**	**3**	**4**	**5**	**6**	**Monotonous/ in the same manner/ flat**	❑
Pattern	**Rhythmic/ predictable**	**1**	**2**	**3**	**4**	**5**	**6**	**Irregular/ random**	❑
Your connection to the soundscape	**A sense of belonging**	**1**	**2**	**3**	**4**	**5**	**6**	**A sense of alienation**	❑

	Relaxation/ tranquillity/ peace						**Stress/ anxiety annoyance/ anger**	
Relaxation/ stress		**1**	**2**	**3**	**4**	**5**	**6**	❑
	Familiar/ usual						**Novel/ unusual**	
Familiarity		**1**	**2**	**3**	**4**	**5**	**6**	❑
	In comfort zone/ at ease						**Mundane/ dull/ boring**	
Your feeling about these familiar sounds		**1**	**2**	**3**	**4**	**5**	**6**	❑

(Please tick the N/A box if it is not familiar in any way)

	Refreshed/ rejuvenated						**Distracted/ mentally overloaded**	
Cognitive load		**1**	**2**	**3**	**4**	**5**	**6**	❑
	Safe/ a sense of control						**Threatened/ fearful**	
Your safety		**1**	**2**	**3**	**4**	**5**	**6**	❑
	Uplifted/ meditative/ transcendent						**Oppressed/ depressed**	
Spirit		**1**	**2**	**3**	**4**	**5**	**6**	❑
	Healthy/ wholesome						**Affliction/ infirmity**	
Your well-being		**1**	**2**	**3**	**4**	**5**	**6**	❑
	Contented/ comfortable						**Desire to escape/ uncomfortable**	
Comfort		**1**	**2**	**3**	**4**	**5**	**6**	❑