SOUNDSCAPE CATEGORISATION AND THE SELF-ASSESSMENT MANIKIN

Francis Stevens
AudioLab
Department of Electronic Engineering
University of York
York, UK
fs598@york.ac.uk

Damian T Murphy
AudioLab
Department of Electronic Engineering
University of York
York, UK
damian.murphy@york.ac.uk

Stephen L Smith
Intelligent Systems Group
Department of Electronic Engineering
University of York
York, UK
stephen.smith@york.ac.uk

ABSTRACT

This paper contains the results of a study making use of a set of B-format soundscape recordings, presented in stereo UHJ format as part of an online listening test, in order to investigate the relationship between soundscape categorisation and subjective evaluation. Test participants were presented with a set of soundscapes and asked to rate them using the Self-Assessment Manikin (SAM) and in terms of three soundscape categories: natural, human, and mechanical. They were also asked to identify the important sound sources present in each soundscape. Results show significant relationships between soundscape categorisation and the SAM, and indicate particularly significant sound sources that can affect these ratings.

1. INTRODUCTION

This paper presents the results of study investigating the relationship between soundscape preferences ratings made using the self-assessment manikin (SAM) [1] and three category ratings (natural, human, and mechanical). Following previous studies the SAM has now been established as an appropriate and powerful tool for the evaluation of soundscapes: for example in [2] where results from the SAM were compared with the use of semantic differential (SD) pairs; or in [3], where it was used to establish the ecological validity of stereo UHJ conversions of B-format soundscape recordings.

This paper presents additional results from the study presented in [3] exploring further the utility of the SAM in soundscape evaluation and research. Here the purpose was to investigate the relationship between soundscape preference ratings, and soundscape sound source identification and categorisation.

A soundscape can be considered as the aural equivalent of a landscape [4], and soundscape research is a field where environmental recordings are used and analysed to give an insight into a location's acoustic characteristics beyond noise level measurement alone. A soundscape can therefore be considered as being comprised of a set of individual sounds sources coming together in a particular context to form an environmental experience.

These sound sources can broadly be divided between three categories: natural, human, and mechanical. This test was designed in order to see how the presence of particular sounds belonging to each of these categories can affect the subjective rating of a soundscape in terms of emotional experience, and in terms of how the soundscape as a whole is perceived as belonging to each of these three categories.

It is hypothesised firstly that the soundscapes that are rated as being more mechanical will exhibit low valence and high arousal in the SAM results, and that highly natural soundscapes will exhibit high valence and low arousal. Soundscapes highly rated in the human category are expected to exhibit high arousal with valence determined by contextual cues from the other sound sources present.

In terms of the sound sources identified it is hypothesised that birdsong and traffic will be the most commonly identified sources, and that traffic noise and human activity (e.g. conversation or footsteps), when present, will have a significant effect on the category rating.

This paper starts with a presentation of the methods used in the study, including the collection of the soundscape data used in the test, the stereo UHJ conversion process, and the development of the test procedure including the SAM and category questions.

The results of the test are then presented, starting with a brief overview of the demographics of the test participants. The SAM results are then examined, after which a summary of the category ratings for each presented soundscape is presented alongside the sound sources identified. Correlational analysis is then used to indicate the relationships between the different metrics: firstly comparing the SAM results with the category ratings; then comparing category ratings with the percentages of the sound sources identified in each case that belong to each of the three categories. The paper concludes with a consideration of avenues for further research.

2. METHODS

This section begins with an examination of the soundscape data collected for this study, including the motivation behind the choice of locations where the recordings where made and the contents of those recordings. The conversion of the recorded B-format soundscapes to stereo UHJ format is considered before a presentation of the assessment methods used in the listening test: the SAM, and the soundscape categorisation and sound source identification questions, and the overall test procedure.

2.1. Data Collection

The data used in this study were collected from various locations around Yorkshire in the United Kingdom, including: Dalby forest, a natural environment; Pickering, a suburban/rural environment; and Leeds city centre, a highly developed urban environment. All of the soundscape recordings were made in B-format using a Soundfield STM 450 microphone [5].

Table 1 gives details of the sound sources present in each of the 16 clips used in the listening test. Each of these clips were 30 seconds long and extracted from the 10 minutes of soundscape recording made at each location. These clips were used in their original B-format in a previous study [2].

Location	Site	Clip A Sound Sources	Clip B Sound Sources
Dalby Forest (Rural/Natural)	1. Low Dalby Path	Birdsong, Owl Hoots, Wind	Birdsong and honking, Insects, Aeroplane flyby
	2. Staindale Lake	Birdsong, Wind, Insects, Single car	Insects, Birdsong, Water
North York Moors (Rural/Suburban)	3. Hole of Horcum	Birdsong, Traffic, Bleating	Birdsong, Traffic, Conversation
	4. Fox & Rabbit Inn	Traffic, Car door closing, Car starting	Traffic, Footsteps, Car starting
	5. Smiddy Hill, Pickering	Traffic, Car door starting, Conversation	Birdsong, Distant traffic
Leeds City Centre (Urban)	6. Albion Street	Busking, Footsteps, Conversation, Distant traffic	Workmen, Footsteps, Conversation, Distant traffic
	7. Park Row	Traffic, Buses, Wind, Busking	Busking, Footsteps, Conversation, Distant traffic
	8. Park Square	Birdsong, Traffic, Conversation, Shouting	Workmen, Traffic, Conversation, Birdsong

Table 1: Details of the sound sources present in the two 30 second long clips (labelled A and B) recorded at each of the eight locations.

2.2. Stereo UHJ Conversion

In order to present the recorded soundscape material online, the B-format signals had to be converted to a suitable two-channel format. It was decided to make use UHJ stereo format, where the $\mathbf{W}$, $\mathbf{X}$, and $\mathbf{Y}$ channels of a B-format recording are used to translate the horizontal plane of the soundfield into two-channel UHJ format [6].

This is a two channel format that can be easily shared online and reproduced over headphones, allowing the B-format recordings presented in a previous study to be used here with the spatial content of the $\mathbf{W}$, $\mathbf{X}$, and $\mathbf{Y}$ channels preserved in reproduction.

The following equations are used to convert from the $\mathbf{W}$, $\mathbf{X}$, and $\mathbf{Y}$ channels of the B-format signal to two stereo channels:

$$S = 0.9397\mathbf{W} + 0.1856\mathbf{X} \quad (1)$$
$$D = j(-0.342\mathbf{W} + 0.5099\mathbf{X}) + 0.6555\mathbf{Y} \quad (2)$$
$$L = 0.5(S + D) \quad (3)$$
$$R = 0.5(S - D) \quad (4)$$

where j is a $+90^\circ$ phase shift and L and R are the left and right channels respectively of the resultant stereo UHJ signal [7]. Note that the Cartesian reference for B-format signals is given by ISO standard 2631 [8], and the $\mathbf{Z}$ channel of the B-format recording is not used.

2.3. Assessment

This section will cover the assessment methods used in this study, starting with the SAM, followed by the category rating and sound source identification questions. This section concludes with a summary of the overall test procedure.

2.3.1. The Self-Assessment Manikin

A previous study [2] made a direct comparison between semantic differential (SD) pairs and the Self-Assessment Manikin (SAM) as methods for measuring a test participant's experience of a soundscape.

The use of SD pairs is a method originally developed by Osgood to indirectly measure a person's interpretation of the meaning of certain words [9]. The method involves the use of a set of bipolar descriptor scales (for example 'calming-annoying' or 'pleasant-unpleasant') allowing the user to rate a given stimulus. SD pairs are a well established aspect of listening test methodology in Soundscape research [10–17]. Whilst useful in certain scenarios, they can be time-consuming and unintuitive [2]. An alternative subjective assessment tool to use is the SAM.

The SAM is a method for measuring emotional responses developed by Bradley and Lang in 1994 [18]. It was developed from factor analysis of a set of SD pairs rating both aural [19, 20] and visual stimuli [1] (using, respectively, the International Affective Digital Sounds database, or IADS, and the International Affective Picture System, or IAPS). The three factors developed for rating emotional response to a given stimuli are:

- **Valence:** How positive or negative the emotion is, ranging from unpleasant feelings to pleasant feelings of happiness.
- **Arousal:** How excited or apathetic the emotion is, ranging from sleepiness or boredom to frantic excitement.
- **Dominance:** The extent to which the emotion makes the subject feel they are in control of the situation, ranging from not at all in control to totally in control.

These results were then used by Bradley and Lang to create the SAM itself as a set of pictorial representations of the three identified factors. The version of the SAM used in this experiment (as shown in Fig. 1) contained only the Valence and Arousal dimensions following results from a previous study [2].

2.3.2. Category Rating

The soundscape recordings used in this test (as detailed in Table 1) were selected in order to cover as wide a range of soundscapes as possible. In order to determine what such a set of soundscape recordings would contain, a review of soundscape research indicated that in a significant quantity of the literature [17, 21–25] three main groups of sounds are identified:

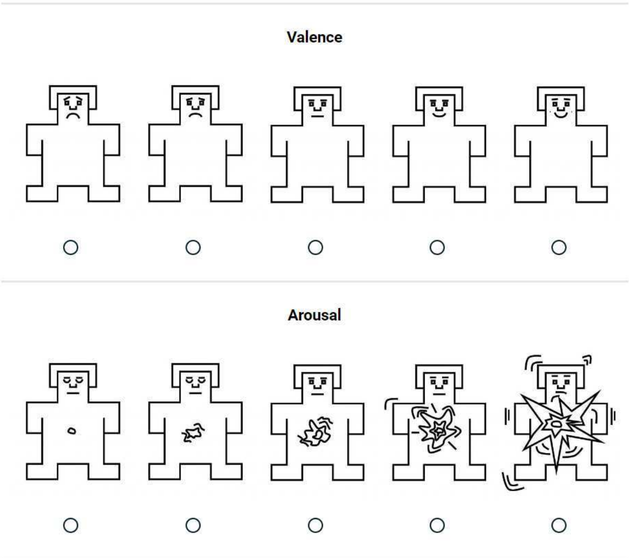

Figure 1: The Self-Assessment Manikin (SAM) as used in this study, after [18].

- **Natural sounds:** These include animal sounds (bird song is an oft-cited example), and other environmental sounds such as wind, rustling leaves, and flowing water.
- **Human sounds:** Any sounds that are representative of human presence/activity that do not also represent mechanical activity. Such sounds include footsteps, speech, coughing, and laughter.
- **Mechanical sounds:** Sounds such as traffic noise, industrial and construction sounds, and aeroplane noise.

The aim of this test is to see how subjective assessments of soundscapes made using the SAM relate to the categorisation of those soundscapes into these three groups. Fig. 2 shows the category ratings question as presented to the test participants. They were asked to give a rating in each category for each of the sixteen soundscapes. They were also given a free text entry field alongside each one where they were asked to identify the sound sources present. Participants were required to enter at least one sound source into this field in order to progress, but no further requirements were in place. This was done in order to identify the sound sources that were most noticeable to test participants and dominated their perception of the aural scene.

2.4. Test Procedure

The listening test in this study was presented online using Qualtrics [26], and the overall procedure was as follows:

1. An introductory demographics questionnaire including questions regarding age, gender, nationality, and profession. From the results of previous studies [2, 3] it is not expected that any of these demographic factors will have an effect on the results.
2. An introduction to the questions accompanying each soundscape, covering the SAM, the categorisation question, and the sound source identification entry field. Two example questions (using soundscape clips 1A and 7B) are presented in order to get baseline results for the participant. After listening to the first clips the participant was instructed not to change the playback volume.
3. The 16 soundscape recordings were then presented to the individual in a random order. After listening to each one they were asked to rate their experience of the soundscape using the SAM, to categorise it, and to identify the sound sources present. They were also given the opportunity to add any comments they had in an optional text entry field.

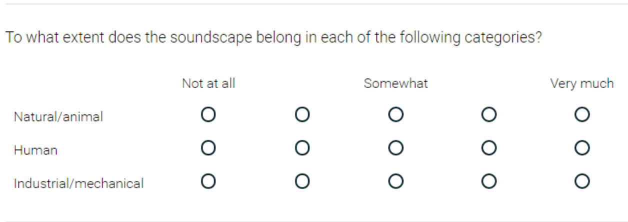

Figure 2: The category ratings question as presented to test participants.

3. RESULTS

This section presents the results of this study, with a discussion following in Section 4. Following a summary of the SAM results, the category ratings are examined. An overview of the identified sound sources is then shown, after which the sound sources identified for each soundscape clip are categorised themselves and the percentage of these sources that belong to each of the three categories is presented. Correlational analysis is then used to examine the relationships between these metrics.

3.1. SAM Results

Fig. 3 shows a summary of the SAM results gathered in this test. As can be seen in this figure, the clips presented in this study cover a wide range of arousal and valence ratings. A full analysis of these results can be seen in [3]. A comparison of these results with the categorisation results can be seen in Section 3.4.1.

3.2. Category Ratings

Fig. 4 shows a summary of the category ratings results. As with the SAM results it is clear from this plot that the selected soundscapes cover a wide range of ratings in each category.

3.3. Sound Source Identification

Fig. 5 shows a pie chart of all of the sound sources identified by test participants. In total there were 1369 sound source instances identified which contained 24 unique sound sources (as listed in Fig. 5). The overall breakdown of these instances between the three categories is as follows: 38.9% natural, 26.9% human, and 34.2% mechanical.

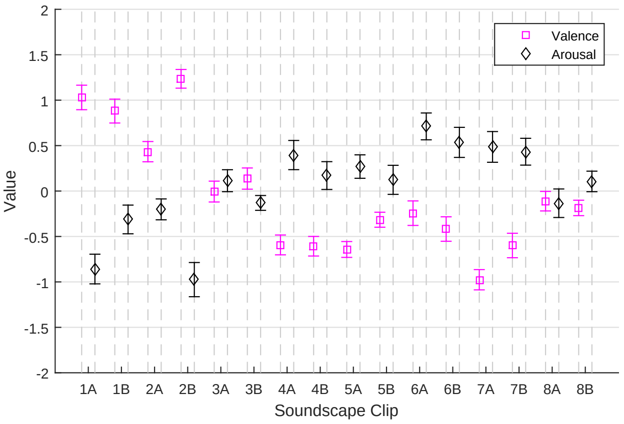

Figure 3: Summary of SAM results from this listening test, showing the mean valence and arousal ratings, and the standard error associated with each mean, for each of the 16 clips.

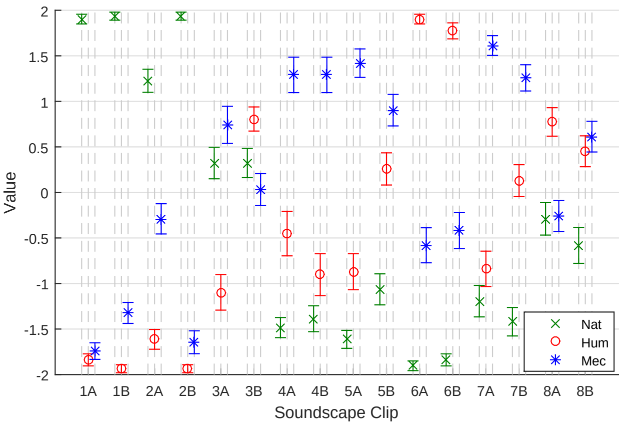

Figure 4: Summary of category ratings results from this listening test, showing the mean ratings for each category, and the standard error associated with each mean, for each of the 16 clips.

3.3.1. *Percentages*

In order to make a comparison between the sound sources identified and the categorisation of each clip, it was decided that the sound sources identified for each clip should be grouped by category and then the number of sound sources instances in each of these categories should be expressed as a percentage of the total number of sound source instances in each case. Fig. 6 shows the sound source category percentage break down for each soundscape recordings.

3.4. Correlational Analysis

Having now presented a brief summary of the SAM and categorisation results, and having made use of the sound sources identified to create a data set suitable for comparison with those result, correlational analysis can be used to compare these three sets of variables to identify relationships between them. First the SAM and categorisation results will be compared, after which the category ratings will be compared with the percentage breakdown of the sound sources identified.

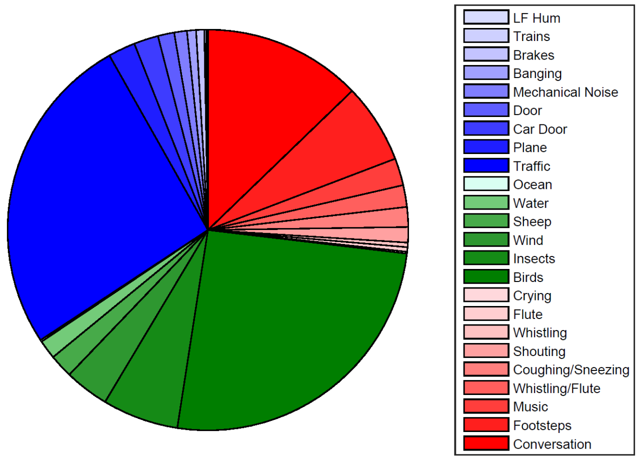

Figure 5: Pie chart indicating all of the unique sound sources identified, shown colour-coded into categories by colour where blue is mechanical, green is natural, and red is human.

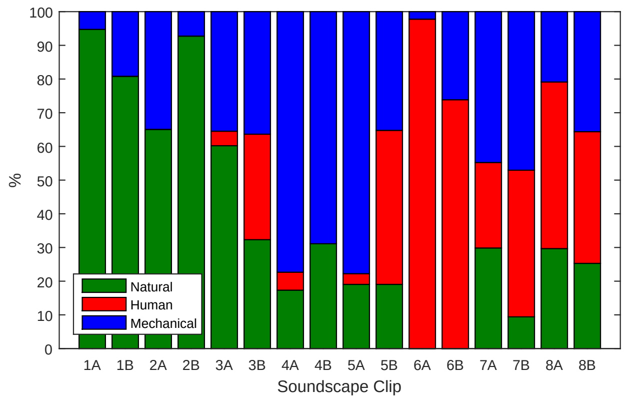

Figure 6: Sound source identification instances for each clip split into categories and expressed as a percentage.

3.4.1. *SAM and category ratings*

Fig. 7 shows scatter plots of the mean category ratings against the mean valence and arousal ratings. The result of a Pearson's correlation analysis [27] of the data presented in these plots can be seen in Table 2.

Table 2: Correlation coefficient and p-values comparing the valence results with category ratings.

	Natural	Human	Mechanical
		R-values	
Valence	0.93	−0.51	−0.90
Arousal	−0.91	0.65	0.70
		p-values	
Valence	2×10^{-7}	0.04	2×10^{-7}
Arousal	9.4×10^{-7}	0.006	0.002

The R-values indicate the degree of correlation between two variables, and the p-values indicate the statistical significance of this

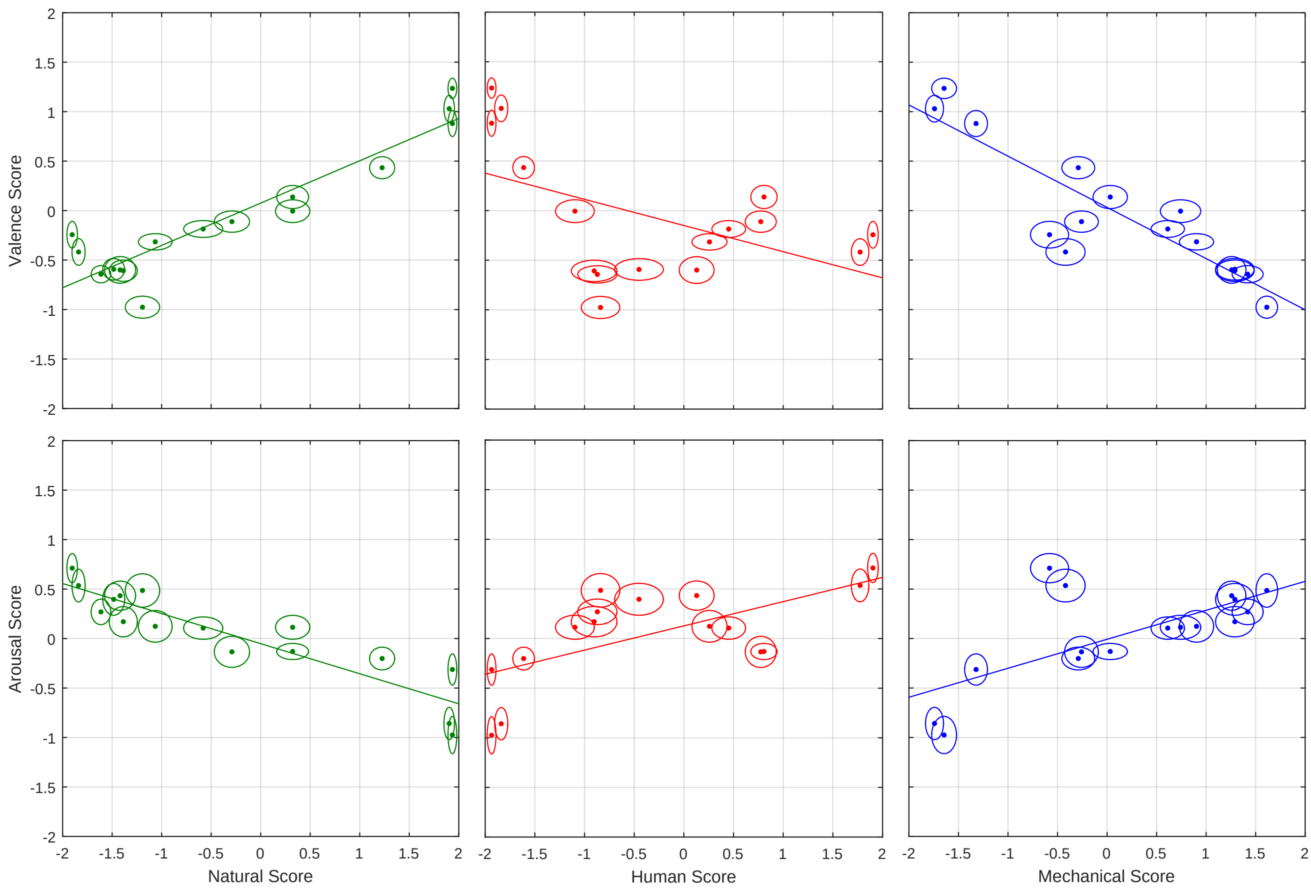

Figure 7: Scatter plots showing the mean category and SAM ratings for each clip. The ellipses surrounding each data point indicate the standard error associated with each mean value. Trend lines have been included to reflect the correlation results shown in Table 2.

relationship where $p \leq 0.05$ it indicates a statistically significant correlation [27].

The natural and mechanical category ratings show a very strong set of correlations with the SAM results, where the Natural category is shown to have a highly significant positive correlation with the valence dimension, and a highly significant negative one with the arousal dimension. The mechanical category exhibits the opposite relationship with each dimension. From this it can be said that the locations rated as highly natural are typically rated as pleasant and relaxing, and locations that are rated as highly mechanical are unpleasant and invoke feelings of stress and anxiety. These are the emotions indicated by these SAM results when considering the circumplex model of affect [28].

The human category rating results also show a (just-significant) negative correlation with valence, and a positive correlation with arousal. This is perhaps due to the fact that most of the soundscapes that include human sounds also contain mechanical sounds, particularly traffic noise. Examining the top middle plot in Fig. 7 gives an indication of why the relationship between the human category ratings and valence is only just significant. Whilst the lowest human category ratings corresponding to high valence, as the human category rating increases there is a 'dip' where the valence values for human ratings around 1 are in fact lower than those for higher human ratings. This is due to a disproportionate number of the soundscapes containing very few or no human sounds (i.e. clips 1A-2B, as seen in Fig. 6).

The results shown in Table 2 support the hypotheses laid out in Section 1 detailing the expected relationships between the three category ratings and the SAM.

3.4.2. Category ratings and categorised sounds source percentages

Table 3 shows the correlation results indicating the relationships between the category ratings and the sound source percentage results. The following section includes a discussion of the results and the other results presented in this section.

4. DISCUSSION

This section contains a discussion of the correlation results presented in Table 3, considering the following three areas of the correlation results in turn:

- Comparison of categorisation results.
- Comparison of the categorised sound sources.
- Comparison of categorisation results with the categorised sounds sources.

Table 3: Correlation results for the category ratings and sound source percentage results. Indicated here are the *R* values. The numbers in boldface indicate correlation results where $p \leq 0.05$ (a significant result); and the presence of an asterisk indicates $p \leq 0.01$ (a highly significant result).

	Natural	Human	Mechanical	Nat%	Hum%	Mech%
Natural	-	-	-	-	-	-
Human	$\mathbf{-0.69}^*$	-	-	-	-	-
Mechanical	$\mathbf{-0.73}^*$	0.19	-	-	-	-
Nat%	$\mathbf{0.95}^*$	$\mathbf{-0.83}^*$	$\mathbf{-0.64}^*$	-	-	-
Hum%	$\mathbf{-0.58}$	$\mathbf{0.92}^*$	0.01	$\mathbf{-0.71}^*$	-	-
Mech%	$\mathbf{-0.52}$	-0.08	$\mathbf{0.84}^*$	-0.41	-0.35	-

Following this discussion, the key sound sources and soundscapes that explain these results are identified and examined in further detail.

4.1. Category Ratings

There is significant negative correlation between natural and human, and natural and mechanical ratings, indicating that where soundscapes were rated as more natural they were also rated as less human and less mechanical. Perhaps surprisingly there is not a significant relationship between the human and mechanical category ratings.

4.2. Sound source percentage results

The correlation results comparing the sound source category percentage results in Table 3 show that the only significant relationship is the negative correlation between the percentage of sound sources identified that are in the natural category, and those belonging to the human category.This is indicated by the sound source categorisation results for clips 6A and 6B as shown in Fig. 6.

For both of these clips the overwhelming majority of sound sources identified ($> 70\%$) were in the human category, with the remaining sound sources belonging to the mechanical category and no identified sounds in the natural category. Likewise the results for clips 1A-2B contain very high percentages of natural sound sources, some mechanical sources, and no human ones.

4.3. Categories and percentages

There is a significant correlation between the category ratings and percentage of identified sound sources for each of the three categories. This gives some indication that the percentage breakdown of the identified sound sources into each category is a valuable metric that in some way reflects the overall categorisation of a soundscape.

The natural category rating shows significant negative correlation with the human and mechanical sound source percentage metric, as does the natural sound sources percentage metric with the human and mechanical category ratings. The two pairs of variables that show no significant correlation in this group are human category rating and mechanical percentage metric, and the mechanical category rating and the human percentage metric.

4.4. Key Sound Sources

As identified in Fig. 5, the three most commonly identified sound sources were traffic noise, birdsong, and conversation; sound sources belonging to the mechanical, natural. and human categories respectively. This section will consider each one in turn and see how the presence of these sound sources in the soundscapes has impacted on the SAM and category ratings of those soundscapes.

4.4.1. Birdsong

Table 1 indicates that the soundscape clips recorded in Dalby Forest contain many instances of birdsong. As can be seen in Fig. 4, these soundscapes (clips 1A-2B) were rated as most belonging to the natural category, and, as shown in Fig. 3, received the highest valence and lowest arousal ratings of all the soundscape clips. This result is in accord with the correlation results presented in Table 2 that indicate the same relationship between higher natural category ratings and the SAM results.

It is also interesting to note the difference in category rating between clips 7B and 8A. These clips were recorded at two nearby locations in Leeds: clip 7B was recorded next to a busy road, and clip 8A was recorded in the middle of a small park. These two clips are fairly similar, but the presence of birdsong in the latter is partly responsible for a significant difference in the natural category rating, which contributes to the relative increase in valence rating (and decrease in arousal rating) as seen in Fig. 3.

4.4.2. Traffic

The correlation between the mechanical category ratings and the SAM results (negative for valence, positive for arousal), as indicated by Table 2, is shown clearly in the difference between SAM results and category ratings for clips 2A and 2B. These two clips were recorded in the same location next to a lake in a forest: Clip 2A contains the recording a single car driving on a nearby road where clip 2B does not. As shown in Fig. 4 the presence of this car is responsible for big increase in the mechanical category ratings, and a big decrease in the natural category rating, for clip 2A relative to clip 2B.

Fig. 3 shows the effect of this car on the SAM ratings for this clip. It is interesting to note how big a difference the presence of a single car can make. This same pattern can be seen to a lesser extent in the results for clips 1A and 1B. These were both recorded at different positions in the forest next to a footpath away from any roads. In this case it is the presence of an aeroplane passing overhead in clip 1B that is not present in clip 1A that results in a similar pattern of differences between the two clips.

It is also worth noting that the clips recorded at roadside location were rated as having the lowest valence levels (clips 4A-5A and 7A-7B), and that these clips were also rated as most belonging to the mechanical environment category.

4.4.3. Conversation

The most significant sound source identified as belonging to the human category was conversation. It's presence in clip 3B and absence in clip 3A, whilst not responsible for any appreciable difference in SAM results, produced a big change in category ratings resulting in a much higher human category rating for clip 3B.

Fig. 6 also indicates the perceptual dominance of conversation when present in a soundscape recording - clips 6A and 6B are the only soundscapes for which no natural sound sources were identified by test participants, despite some birdsong and wind noise being present in those recordings.

5. SUMMARY

This paper has shown the results of an online listening test presenting stereo UHJ renderings of B-format soundscape recordings. Test participants were asked to describe the emotional state evoked by those soundscapes using the SAM, rate the extent to which each soundscape belonged in three environmental categories, and identify the key sound sources present in each one.

The purpose of this test was to identify any relationships between the subjective assessment of a soundscape and the extent to which that soundscape is perceived to be natural, human, and mechanical. A secondary aim was to use the sound sources identified by test participants to sound sources that are the most important to soundscape perception, both in terms of subjective experience and category rating.

Correlational analysis indicated strong relationships between the natural and mechanical category ratings and the valence and arousal dimensions of the SAM. The natural category ratings were shown to be positively correlated with valence, and negatively correlated with arousal. The mechanical category ratings showed the opposite correlations in each case. The human category ratings showed similar but less strong correlation results to the mechanical category ratings with some ambiguity in the relationship between the human category ratings and the valence dimension of the SAM. These results support the study's hypotheses which predicted a negative emotional response to highly mechanical soundscapes, and a positive emotional response to highly natural soundscapes. The hypothesis regarding emotional response to soundscape rated as highly human was also suggested with a clear correlation between human rating and arousal and a more ambiguous relationship with valence.

These results indicate that more natural soundscapes invoke a relaxation response (low arousal, high valence), and that more mechanical soundscapes invoke a stress response (high arousal, low valence). The human category rating result's relative lack of significance indicate a contextual dependence where human sounds are not necessarily disliked or stressful, but are mainly present in soundscapes where traffic noise (i.e. mechanical sounds) are also present.

An analysis of the sound sources identified by test participants has presented, which indicated a key sound source for each category: conversation, birdsong, and traffic. The identification of these sources supports the hypothesis predicting which sound sources would be most commonly identified, and as such would be the most useful predictor of soundscape categorisation. The presence and absence of these sources in the soundscapes presented was examined by studying particular examples. This examination demonstrated where these sound sources in particular produced differences in the SAM and category ratings that exhibited with correlational relationships previously identified.

Future work will include a listening test presenting the same soundscapes used in this study alongside spherical panoramic images of the recordings sites. Test participants will again be asked rate their experience of the environment using the SAM, to categorise the environment, and to identify the key aural and visual features. This test should produce results that answer the following questions:

- Will the presence of different visual features change the SAM results, indicating a change in the evoked emotional states?
- Will the key visual feature identified be the same as the aural features?
- Will the presence of visual features change which aural features are identified by test participants?
- Will the presence of visual elements change the category ratings for the presented environments?

This results presented in this paper certainly confirm the SAM as being a powerful tool for soundscape analysis, with soundscape categorisation and sound source identification offer suitable methods to pair with the SAM to offer further insight into which aural features can most dramatically affect emotional responses to environmental sound.

6. ACKNOWLEDGMENTS

This project is supported by EPSRC doctoral training studentship: reference number 1509136.

7. REFERENCES

[1] M. Bradley, B. Cuthbert, and P. Lang, "Picture media and emotion: Effects of a sustained affective context," *Psychophysiology*, vol. 33, no. 6, pp. 662–670, 1996.

[2] F. Stevens, D. T. Murphy, and S. L. Smith, "Emotion and soundscape preference rating: using semantic differential pairs and the self-assessment manikin," in *Sound and Music Computing conference, Hamburg, 2016*, 2016.

[3] ——, "Ecological validity of stereo uhj soundscape reproduction," in *In Proceedings of the 142nd Audio Engineering Society (AES) Convention*, 2017.

[4] R. Schafer, *The Soundscape: Our Sonic Environment and the Tuning of the World*. Inner Traditions/Bear, 1993. [Online]. Available: http://books.google.co.uk/books?id=ltBrAwAAQBAJ

[5] E. Benjamin and T. Chen, "The native b-format microphone," in *Audio Engineering Society Convention 119*. Audio Engineering Society, 2005.

[6] R. Elen, "Ambisonics: The surround alternative," in *Proceedings of the 3rd Annual Surround Conference and Technology Showcase*, 2001, pp. 1–4.

[7] M. A. Gerzon, "Ambisonics in multichannel broadcasting and video," *Journal of the Audio Engineering Society*, vol. 33, no. 11, pp. 859–871, 1985.

[8] ISO, *Mechanical Vibration and Shock: Evaluation of Human Exposure to Whole-body Vibration. Part 1, General Requirements: International Standard ISO 2631-1: 1997 (E).* ISO, 1997.

[9] C. Osgood, "The nature and measurement of meaning." *Psychological bulletin*, vol. 49, no. 3, p. 197, 1952.

[10] J. Kang and M. Zhang, "Semantic differential analysis of the soundscape in urban open public spaces," *Building and environment*, vol. 45, no. 1, pp. 150–157, 2010.

[11] W. Davies, N. Bruce, and J. Murphy, "Soundscape reproduction and synthesis," *Acta Acustica United with Acustica*, vol. 100, no. 2, pp. 285–292, 2014.

[12] S. Viollon and C. Lavandier, "Multidimensional assessment of the acoustic quality of urban environments," in *Conf. proceedings "Internoise", Nice, France, 27-30 Aug*, vol. 4, 2000, pp. 2279–2284.

[13] A. Zeitler and J. Hellbrück, "Semantic attributes of environmental sounds and their correlations with psychoacoustic magnitude," in *Proc. of the 17th International Congress on Acoustics [CDROM], Rome, Italy*, vol. 28, 2001.

[14] T. Hashimoto and S. Hatano, "Effects of factors other than sound to the perception of sound quality," *17th ICA Rome, CD-ROM*, 2001.

[15] B. Schulte-Fortkamp, "The quality of acoustic environments and the meaning of soundscapes," in *Proc. of the 17th international conference on acoustics*, 2001.

[16] M. Raimbault, "Qualitative judgements of urban soundscapes: Questionning questionnaires and semantic scales," *Acta acustica united with acustica*, vol. 92, no. 6, pp. 929–937, 2006.

[17] S. Harriet, "Application of auralisation and soundscape methodologies to environmental noise," Ph.D. dissertation, University of York, 2013.

[18] M. Bradley and P. Lang, "Measuring emotion: the self-assessment manikin and the semantic differential," *Journal of behavior therapy and experimental psychiatry*, vol. 25, no. 1, pp. 49–59, 1994.

[19] M. Bradley and P. J. Lang, *The International affective digitized sounds (IADS): stimuli, instruction manual and affective ratings*. NIMH Center for the Study of Emotion and Attention, 1999.

[20] M. Bradley and P. Lang, "Affective reactions to acoustic stimuli," *Psychophysiology*, vol. 37, no. 02, pp. 204–215, 2000.

[21] A. Léobon, "La qualification des ambiances sonores urbaines," *Natures-Sciences-Sociétés*, vol. 3, no. 1, pp. 26–41, 1995.

[22] S. Viollon, L. C., and C. Drake, "Influence of visual setting on sound ratings in an urban environment," *Applied Acoustics*, vol. 63, no. 5, pp. 493 – 511, 2002. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0003682X01000536

[23] W. Yang and J. Kang, "Acoustic comfort and psychological adaptation as a guide for soundscape design in urban open public spaces," in *Proceedings of the 17th International Congress on Acoustics (ICA)*, 2001.

[24] L. Anderson, B. Mulligan, L. Goodman, and H. Regen, "Effects of sounds on preferences for outdoor settings," *Environment and Bevior*, vol. 15, no. 5, pp. 539–566, 1983.

[25] G. Watts and R. Pheasant, "Tranquillity in the scottish highlands and dartmoor national park–the importance of soundscapes and emotional factors," *Applied Acoustics*, vol. 89, pp. 297–305, 2015.

[26] J. Snow and M. Mann, "Qualtrics survey software: handbook for research professionals," 2013.

[27] K. Pearson, "Note on regression and inheritance in the case of two parents," *Proceedings of the Royal Society of London*, vol. 58, pp. 240–242, 1895.

[28] J. A. Russell, "A circumplex model of affect," *Journal of Personality and Social Psychology*, vol. 39, no. 6, pp. 1161–1178, 1980.