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Tranquillity in the Scottish Highlands and Dartmoor National Park – the importance of soundscapes and emotional factors

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1. INTRODUCTION

For many, the chance to experience tranquillity is what makes the countryside so different from cities, and in a survey conducted by the UK's Department for Environment, Food and Rural Affairs [1], 58% of people questioned stated that for them tranquillity was the most positive feature of the British countryside. Furthermore, the provision of rural 'tranquil space' is also known to have significant economic benefits. A report published by the pressure group, the Campaign to Protect Rural England [2] lists the safeguarding of over 186,000 jobs and a boost to the UK rural economy of around £6.5 billion per annum, as two of the economic benefits of maintaining tranquil (restorative) areas. It is therefore probably not surprising that within the UK Government's Rural White Paper [3] that tranquillity features as an important element. In fact the UK has recently recognized the importance of tranquil spaces in the National Planning Policy Framework [4]. This policy framework places considerable emphasis on sustainable development with the aim of making planning more streamlined, localised and less restrictive. Specifically it states that planning policies and decisions should aim to "identify and protect areas of tranquillity which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason". This is considered by some (e.g. National Park Authorities) to go beyond merely identifying quiet areas based on relatively low levels of mainly transportation noise, as the concept of tranquillity implies additionally a consideration of visual intrusion of man-made structures and buildings into an otherwise perceived natural landscape.

Previous studies into modelling tranquil space [5,6] led to the development of the following Tranquillity Rating Prediction Tool (TRAPT), which can be used to predict the Tranquillity Rating (*TR*) of both urban and natural environments. It is important because for the first time it is possible to quantify the importance of natural features in the visual scene and of man-made noise. A practical formulation of the relationship is:

$$TR = 9.68 + 0.041 NCF - 0.146 L_{day} + MF \quad (1)$$

TR is the Tranquillity Rating on a 0 to 10 scale, where 0 is least tranquil and 10 is most tranquil, *NCF* is the percentage of natural and contextual features visible within the landscape and L_{day} is the equivalent constant A-weighted sound level of man-made noise during daytime hours (7:00am to 7:00pm). Contextual features include listed buildings, religious and historic structures, landmarks, monuments and elements of the landscape, such as traditional farm buildings, that directly contribute to the visual context of the natural environment. It is argued that when present, these visually cultural and contextual elements are as fundamental to the construction of ‘tranquil space’ as are strictly natural elements (e.g. grass, shrubs, trees, water, rock etc.). *MF* is a moderating factor that is added to the equation to take account of further factors such as the presence of litter and graffiti that would depress the rating, or sounds of flowing water that are likely to improve it. This is essentially a minor adjustment designed to take account of the actual environmental conditions at the time of assessment and is unlikely to influence the calculated *TR* by more than ± 1 scale point. The *MF* adjustment for litter and graffiti (-1 scale point) resulted from a study where the appearance of an outdoor environment being assessed for tranquillity was modified by adding litter under one condition and removing it under another [7].

The aim of this paper is to report the findings of a study that collected data in mainly unmanaged natural areas where natural features dominated the scenes and natural sounds dominated the soundscape. It extends beyond tranquillity studies of city parks and country parks [8,9,10] and includes wildland areas in the Scottish Highlands and Dartmoor National Park. It can be argued that these regions contain some of the most tranquil spaces in the UK. In this situation we wanted to test whether TRAPT was able to predict the tranquillity rating as successfully as for urban green spaces. A further important aspect of this study was to deepen an understanding of the tranquillity construct by determining how this relates to the emotional responses of pleasantness, calmness and control. Finally we wanted to test the effects of man-made noise on such pristine environments by introducing appropriate sounds that could possibly be heard in these contexts e.g. overflying aircraft in the Scottish Highlands and traffic passing over cattle grids in Dartmoor National Park, and also to

understand whether additional natural sounds could improve perceived tranquillity. It is anticipated that the findings of this study will be of use to those responsible for managing and conserving protected areas such as National Parks and planners and landscape architects involved in designing wild and tranquil spaces across a range of scales.

2. METHODOLOGY

2.1 Data collection

During the summer of 2012 audio-visual data were collected from 16 locations across England and Scotland using a Canon XM 2 camcorder to record the visual information, and a Bruel and Kjaer (B&K) 2250 Sound Level Meter (SLM), to record the acoustic data. The main locations chosen for the study were selected from the Scottish Highlands, Dartmoor National Park and moorland in West Yorkshire, as they provided a representative sample of environments that appeared to be free of any obvious human influence, though additionally a number of more managed landscapes together with one village centre were included for comparison purposes. During filming the camcorder was swept from left to right over a 1 minute recording period, 30 seconds of which settled on the central view. At the same time the associated soundscape was recorded as a WAV file on the B&K 2250 sound level meter that was calibrated in the field using a B&K 4231 94dB (1kHz) sound calibrator. The maximum, minimum and equivalent continuous A-weighted sound levels (i.e., L_{Amax} , L_{Amin} , L_{Aeq} respectively) were all taken at the same time as the audio data were recorded. L_{A10} , L_{A50} and L_{A90} , which are the percentage of time that the A-weighted sound level is exceeded for, were also calculated during the 30s sample period .

2.2 Data analysis

Once the visual and audio information was transferred to a PC it was edited using Adobe Premiere 6.5 software and each WAV file imported and reconciled with its corresponding visual scene. The

decision was then taken to either present each of the locations with just the 30 second central view or with the 120° panorama. The deciding factor lay in whether the peripheral visual information provided any additional contextual information to the central shot. Based on this criterion the final data set included 5 environments that covered 120° and 11 that used the central shot. In both cases the presented stimuli lasted for approximately 30 seconds (± 2) as per the exposure time reported in a previous study [5]. The bi-modal stimuli used within the pilot study consisted of 16 locations 9 of which were taken in the Scottish Highlands or Dartmoor National Park that had little or no human influence present. The remainder ranged from obviously managed countryside through to the urban fringe, with one urban scene (control) taken close to the main A379 in the village of Modbury near Plymouth. The three experimental conditions used in the study were:

A 'As is', i.e. as recorded in-situ

B With enhanced man-made noise added

C With enhanced natural sounds added

When each in-situ recording (A) was edited to either incorporate additional man-made noise (A+B) or natural sounds (A+C), every attempt was taken to ensure that the added components were in context with the environment in which they were being presented. All natural sounds were downloaded from the British Library and were originally recorded close to the location that they were added to. For example, the sounds of a golden eagle mewing that were added to the soundscape of Glen Etive in Scotland, were recorded close to where the footage for this study was taken, as were the sounds of birds and insects that were overlaid on the footage of mixed farmland within the Dartmoor National Park. A similar approach was taken when adding man-made noise to the original recordings.

Figure 1 shows a central view of the entrance to Glen Etive in Scotland taken from Rannoch Moor. The "As is" condition (A) contains sounds of running water and wind, the enhanced man-made noise track (B) contains running water, wind and the passage of a low flying helicopter, and the track with

enhanced natural sounds (C) includes running water, wind and the calls of a golden eagle plus moorland birds.



Figure 1: Glen Etive looking west from Rannoch Moor

Table 1 provides a description of each location used in the study and lists the soundscapes in each of the three associated experimental conditions (A, B and C). It also includes the latitude and longitude coordinates that were obtained using GPS at the time the field data were recorded. For simplicity the locations have been grouped into regions.

Table 1: Description of study locations and soundscapes

Location	Original soundscape (A)	Enhanced man-made (B)	Enhanced natural (C)	Latitude and longitude
<i>Scottish Highlands</i>				
Railway – Corroul	Very quiet	Train horn	Red deer	56° 45' 38" N 04° 41' 44" W
Long view - Corroul	Very quiet	High aircraft	Buzzard	56° 45' 24" N 04° 41' 44" W
Glen Etive	Running water	Helicopter	Eagle	56° 39' 17" N 04° 48' 06" W
Glen Nevis	Cars + people	Military jets	Birdsong	56° 46' 40" N 05° 00' 01" W
River Nevis	Running water	Hay bailing	Birdsong	56° 45' 38" N 04° 41' 31" W
<i>Dartmoor National Park</i>				
Farmland – Widecombe	Livestock	Tractor	Birdsong	50° 35' 22" N 03° 50' 58" W
Great Mis Tor*	Wind	Military gun fire	Birdsong	50° 34' 04" N 04° 01' 30" W
Moorland ponies	Light wind	Traffic	Birdsong	50° 32' 37" N 03° 50' 34" W
Hangershell Tor	Wind + birds	Distant siren	Water	50° 20' 05" N 03° 49' 23" W
Ancient stone cross	Light wind	Cattle grid	Birdsong	50° 31' 26" N 03° 52' 40" W
River Dart	Raging rapids	Low aircraft	Birdsong	50° 31' 03" N 03° 49' 23" W
Road below Hay Tor	Light traffic	Aircraft	Insects	50° 34' 46" N 03° 45' 04" W
<i>Adjacent to Dartmoor National Park</i>				
Modbury High Street	Urban traffic noise	N/A	N/A	50° 20' 55" N 03° 09' 26" W
Pylon in field by A38	Highway traffic noise	Chain saw	Birdsong	52° 25' 30" N 03° 48' 42" W
<i>West Yorkshire</i>				
Ovenden Moor	Wind turbines	Motor cycle	Water	53° 46' 38" N 01° 56' 63" W
Denholme pylons	Moderate traffic noise	Tractor	Bird + church bells	53° 47' 44" N 01° 53' 18" W

* A “tor” is an exposed granite outcrop and is a common feature of the Dartmoor National Park

Each experimental condition was presented by means of a DVD player and large plasma screen to 21 subjects (average age 38, ± 15.7 years), in three randomized groups over a 90 minute assessment period. During the first presentation, which was considered a training session designed to expose the subjects to the full range of stimuli being used, the volunteers were given time to complete their assessment before the next location appeared on the screen. During subsequent presentations they were given ten seconds between each exposure to record their subjective assessments. After the

presentation of each full data set, which contained 46 stimuli (the control condition “Modbury High Street” was only shown in the ‘as is’ state, the other 15 stimuli were presented in each of the 3 conditions), the subjects were offered a ten minute comfort / refreshment break before proceeding with the experiment. For each condition the average assessments made on the second and third presentations of each dataset were used in the final analysis. All of the subjects that took part in the study were ‘naïve volunteers’ and each was rewarded with a £15 store voucher for taking part.

2.3 Subjective assessment

The experiment was conducted in the University of Bradford’s psycho-acoustic suite, where the volunteers sat in pairs and made their subjective assessments in response to the bi-modal stimuli presented via a Pioneer (PDP – 506XDE) plasma screen, a Samsung DVD – R125 player and two sets of ROLAND RH-300 headphones. The headphones had been calibrated using the calibration tone recorded in the field in order to ensure that the audio data were presented at the same sound pressure level as it was recorded.

Prior to commencing the experiment the following written information was provided: *‘This experiment uses audio-visual (video) information to determine how wild and tranquil 16 locations are perceived to be when responding to bi-modal sensory stimuli. You will be played a series of data streams that last for approximately 30 seconds followed by a 10 second period of silence, in order that you can make your assessments on the monitoring sheets provided. On each exposure you are asked to make an assessments of how wild, tranquil, natural and remote you perceive each location to be, by awarding a score of 0 – 10, with 0 being ‘least’ and 10 being ‘most’. In addition you should record your emotional reaction to the locations by annotating each of the three rows of Manikins (little men), with an “X” indicating how pleasant, excited and controlled, each location makes you feel. Note that you can place the “X” between Manikins if you wish to make an assessment that falls between categories. During the experiment you are to base your assessments on the fact that you are in each location by choice. No locational information is provided to steer you into making your*

subjective assessment of remoteness, instead you are asked to rate how remote each location feels to you based solely on the audio-visual information provided. You are to draw upon whatever value judgments you see fit to make your assessments. For each location you should assume that what you see is indicative of views in all directions and that the sounds you hear are typical of that location. Note that what you see and what you hear should both be taken into account when considering your ratings on all the scales provided. The data streams are presented to you in random order and will be repeated to obtain better precision’.

In previous landscape perception studies [11,12] it has not been uncommon for participants to struggle when assessing how remote a location is perceived to be, despite being provided with guiding information, such as distance to the nearest road or railway station. This is largely because these studies have used uni-modal stimuli, i.e. photographs to illicit a response rather than a more immersive auditory-visual input. This approach potentially prevented the subjects from being able to adequately contextualize the environment on the limited sensory information being provided. In this study we introduced the concept of ‘Felt Remoteness’ to the subjects, which is an adaptation of ‘Felt Intensity’, a measure that is often applied to explaining the intangible sensitivities to certain components of the urban environment [13] and provided an immersive set of stimuli for them to make their subjective assessments against.

2.4 Self-Assessment Manikin (SAM)

The Self-Assessment Manikin (SAM) is a non-verbal pictorial assessment technique devised by Hades et al [14] that directly measures the pleasure, arousal, and dominance (PAD) associated with a person's affective reaction to a wide variety of stimuli. These three emotional dimensions are known to be pervasive in organising human judgements [15]. The advantage of using SAM as opposed to Semantic Differential (SD) for example, is that it requires only 3 judgements using ranked pictures that can be quickly interpreted with little error across a wide range of age groups and cultures (Figure 2). It therefore fitted well with the limited time that the subjects had available to make their

assessments. In this study arousal was measured using the polar opposites, excited and calm, which referred to how various components within the presented stimuli, raised levels of alertness and arousal. Control was used as a proxy for dominance and referred to how participants felt they were in control of the situation in various landscapes. For example, if they felt threatened because of the presence of animals (e.g. ponies or flying insects) or gun fire, it would be expected that they would tend to rate their situation as more “controlled” rather than “in control”. Pleasantness, simply measured how agreeable the subjects felt the environment was. For analysis purposes a 5 point scale was used with the least favourable emotion in each category being scored 1 and the most favourable 5. Figure 2 illustrates how the SAM scales were presented:

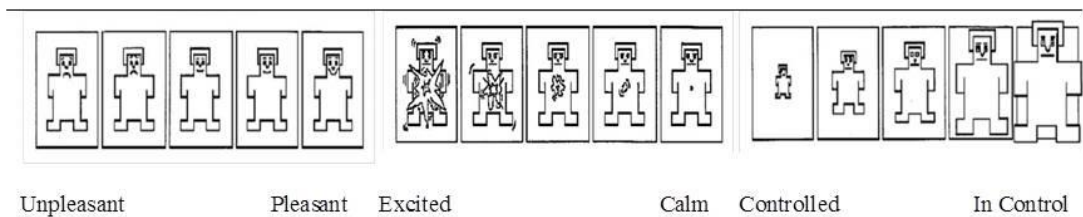


Figure 2 – Self-Assessment Manikins (SAM) used to rate emotional response [14]

2.5 Objective measures

The WAV files used to introduce enhanced mechanical and enhanced biological soundscape components to each of the locations used in the study were analysed by a specially written Matlab

code that enabled their A-weighted sound levels (average and statistical noise indices) to be calculated. This was achieved by comparing them against the calibration tones that were recorded onto the sound level meter in the field. During this process the in-situ acoustic data were also analysed in order that the values obtained using the Matlab code could be cross checked with those obtained at the time of recording. This process showed a maximum error of ± 0.5 dB(A), thereby giving confidence in all of the A-weighted measurements used. It was also possible to extract the psycho-acoustic measures loudness (sone) and sharpness (acum) [16] using analysis software loaded on the B&K 2250 sound level meter and then to convert loudness to loudness level (phon). The sharpness measure has been found to be related to changes in tranquillity rating when studying water sounds [17] and past studies of the reaction to vehicle noise emissions have demonstrated the slight advantage of the loudness level over the A-weighted level in predicting subjective noisiness [18].

The percentage of natural and contextual features (*NCF*) within the visual scene was also obtained as described in Pheasant et al [5]. These were derived by pasting the landscape images into PowerPoint and overlaying a 10x10 grid. The areas covered by natural and contextual features or wild land, were estimated by counting the number of squares occupied by each and interpolating where necessary. The area of sky above the horizon was not used in the calculation of *NCF*. If *N* is the area with natural features and *M* the total area of man-made features then *NCF* is given by:

$$NCF = 100 N/(N + M) \tag{2}$$

2.6 Analysis

Microsoft Excel 2010 was used to collate the subjective assessments made by the 21 subjects to each of the stimuli presented and also to determine mean values for tranquillity, wildness, naturalness, felt remoteness, calmness, pleasantness and control. It was then used to determine the effect that the added man-made and natural sounds had on the perception of each variable and to carry out a detailed statistical analysis in order that the results could be understood and the main hypotheses tested. In the

first instance a two-tailed *t*-test was carried out to determine that the means obtained in each experimental condition were significantly different. Once confidence had been gained as to the overall quality of the raw data a correlation analysis between each pairs of variables (both objective and subjective) was conducted. The results gained from the correlation analysis informed the choice of variables to be included within a multiple regression analysis.

3 RESULTS

3.1 Initial analysis

The results of the correlation analysis identified that tranquillity is well related to naturalness and remoteness, but much more so to the emotional reactions of pleasantness, calmness and control, and strongly negative to the acoustic index $L_{Aeq_26dB(A)}$ which is explained below. The results of the correlation analysis are contained in Table 2.

Table 2: Correlation coefficients

	<i>Tranquillity</i>	<i>Wildness</i>	<i>Naturalness</i>	<i>Felt Remoteness</i>	<i>Pleasantness</i>	<i>Calmness</i>	<i>Control</i>	<i>LAeq</i>	<i>LAeq_26dB(A)</i>	<i>LN</i>	<i>Sones</i>	<i>Sharpness</i>	<i>NCF</i>
<i>Tranquillity</i>	1.00												
<i>Wildness</i>	0.76	1.00											
<i>Naturalness</i>	0.86	0.96	1.00										
<i>Felt Remoteness</i>	0.86	0.94	0.95	1.00									
<i>Pleasantness</i>	0.97	0.73	0.85	0.81	1.00								
<i>Calmness</i>	0.97	0.63	0.76	0.73	0.97	1.00							
<i>Control</i>	0.96	0.65	0.78	0.75	0.98	0.99	1.00						
<i>LAeq</i>	-0.74	-0.40	-0.47	-0.53	-0.69	-0.79	-0.75	1.00					
<i>LAeq_26dB(A)</i>	-0.89	-0.66	-0.79	-0.77	-0.90	-0.87	-0.89	0.64	1.00				
<i>LN</i>	-0.74	-0.44	-0.50	-0.58	-0.67	-0.75	-0.71	0.96	0.63	1.00			
<i>Sones</i>	-0.66	-0.30	-0.36	-0.40	-0.63	-0.74	-0.68	0.91	0.58	0.80	1.00		
<i>Sharpness</i>	0.35	0.21	0.29	0.26	0.33	0.30	0.30	-0.18	-0.36	-0.30	-0.08	1.00	
<i>NCF</i>	0.31	0.52	0.51	0.38	0.30	0.28	0.29	-0.13	-0.22	-0.08	-0.14	-0.03	1.00

Within Table 2 the scales of tranquillity, wildness, naturalness and felt remoteness are all assessed on a 0 to 10 scale. Pleasantness, Calmness and Control are the variables measuring emotion using the SAM manikins and later scored on a 1 to 5 scale.

L_{Aeq} is the average sound level whereas $L_{Aeq_26dB(A)}$ is used in order to reflect the level of man-made noise present and is the level used in predicting the tranquillity rating *TRAPT*. A default value of 26 dB(A) is assumed for all environments where only natural sounds are perceptible. This value was based on the very low noise level that produces a predicted Tranquillity Rating of 10 (i.e. the highest

possible level with 100% *NCF* present), using equation (1). It also relates closely to the lowest L_{Aeq} observed during the field studies when no man-made noises were perceived and wind speeds were $<5\text{m/s}$. Note that for all other environments, i.e. those to where man-made noise predominates, the value of $L_{Aeq_26\text{dB}(A)}$ is set to the average level that is measured i.e. L_{Aeq} . In this study L_{Aeq} was always found to be greater than 26 dB(A).

L_N is the average loudness level calculated from the value in sones and *NCF* is the percentage of natural and contextual features (see equation (2)).

As expected it can be seen that the level of man-made noise present ($L_{Aeq_26\text{dB}(A)}$) is more closely related to tranquillity rating than L_{Aeq} and is in fact superior to all the loudness and sharpness measures used.

In this study the *NCF* variable is weakly related to tranquillity unlike earlier studies because the value of this variable did not vary widely in the present study as most landscapes were almost entirely natural. In fact the average value of *NCF* was very high at 91%.

3.2 Tranquillity and wildness

The relationship between tranquillity and wildness ratings is examined in Figure 3 where the broken line shows a 1 to 1 relationship for comparison purposes. It can be seen that the relationship is not close ($R^2 = 0.58$) and indicates that the two constructs are substantially different.

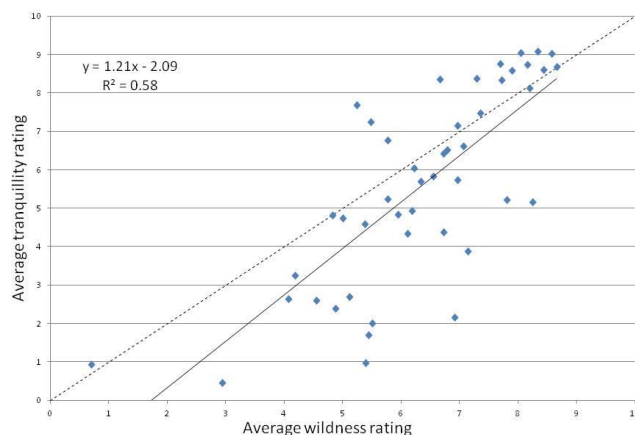


Figure 3 – Relationship between average tranquillity and wildness ratings

Table 2 shows that tranquillity is more closely related to emotional scales of pleasantness and calmness than wildness. As was expected tranquillity is more closely related than wildness to the acoustic variables and especially the measure of man-made noise $L_{Aeq_26dB(A)}$ while wildness is more closely related than tranquillity to ratings of felt remoteness and naturalness. Further difference between tranquillity and wildness constructs are examined in the sections below.

3.3 Effects of man-made and natural sounds

A greater understanding into how these environments were perceived in relation to the variables being assessed can be obtained by examining Table 3, which shows how the added man-made noise and natural sounds influenced the overall rating of each category in a negative or in a positive way.

Table 3: Mean influence of enhanced man-made and natural sounds

	Tranquillity	Wildness	Naturalness	Felt remoteness	Pleasure	Calmness	Control
Man-made	-3.5	-0.9	-1.7	-1.9	-1.3	-1.4	-1.3
Natural	-0.1	0.2	0.1	0.0	0.0	0.0	0.0

For example the addition of man-made noise on average decreased ratings of wildness by 0.9 of a scale point ($p < 0.001$), whereas a much greater effect was observed on the perception of tranquillity, where ratings reduced by -3.5 points. However the addition of natural sounds had no significant effect on tranquillity ratings (-0.1, $p = 0.54$) but produced a small but significant increase in wildness ratings of 0.2, ($p < 0.01$). Note that the emotional measures of pleasantness, calmness and control all reduced significantly with the addition of man-made noise but were unaffected by the natural sounds. This was expected as these measures are very closely related to tranquillity, which as mentioned only changed slightly.

The reduction in tranquillity produced by the addition of man-made noise was predicted (see Equation (1)). The reduction was consistently large i.e. ≤ -1.5 scale points except for one location where a high flying aircraft producing little noise (40.7 dB(A)) reduced tranquillity by just 0.5 scale point. Interestingly a cattle grid, used on many lanes in Dartmoor to stop livestock and wild ponies leaving the moors, produced a large decrement of -4.0. However, the largest decreases were found for a loud train horn and automatic gunfire in an army training area (-6.7 and -6.2 respectively).

It was expected that the addition of natural sounds would tend to improve tranquillity as it has been shown previously that some water sounds improve it [17]. Two water sounds were introduced in the current study where there was a small increase of 0.22 in one case and a decrease of 0.30 in the other case. The effect was too small to be significant but tending to confirm that the choice of water sound may be important in this respect. Overall the largest decrease in tranquillity rating (-1.83) was found when the sound of a stag recorded during the rutting season, was introduced into a highland scene. It is thought that this sound might not have been readily identified by many and possibly perceived as a wild animal that could potentially inflict harm. Another factor is that it was clearly audible in an otherwise quiet environment. Note that as expected the average rating of wildness in this landscape increased slightly (0.13). If this outlying case is removed the average effect on tranquillity of adding natural sounds would become slightly positive at 0.04. The addition of bird sounds in 10 landscapes ranged from 0.46 to -0.43 indicating a mixed but small effect. There was only one case where an insect sound was introduced and this again produced a very small effect which was positive (0.24).

3.4 Tranquillity and emotional measures

Figure 4 shows the close relationship between rated tranquillity (TR) and a linear combination of ratings on the emotional scales (SAM) of Pleasantness (P) and Calmness (C).

$$TR = 1.375 (P + C) - 4.345 \quad (3)$$

The constants were derived by first taking into account the fact that the emotional scales were scored from 1 to 5 and the tranquillity scale from 0 to 10 and then fine adjusting to ensure the intercept was zero and slope unity.

It should be noted that both pleasantness and calmness ratings have equal weighting in the prediction equation (3). The addition of the emotional scale of control had only a minute effect on the degree of fit and was not considered further for this reason. A previous study has indicated a minor role for the influence of Control when compared with Pleasantness and Calmness [15].

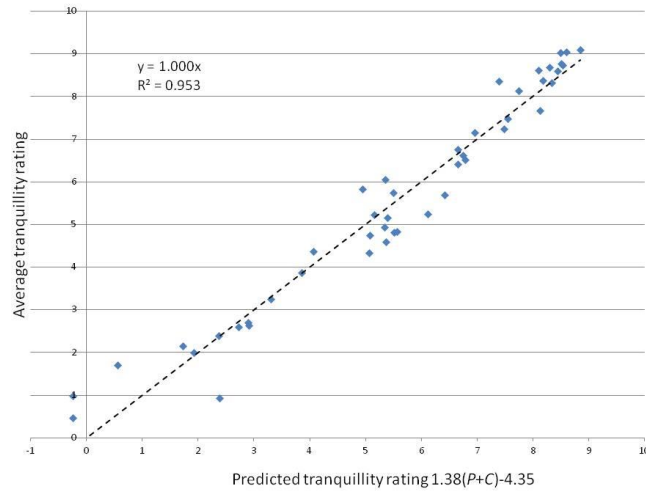


Figure 4: Relationship between emotional ratings of pleasantness and calmness and tranquility

3.5 Predicted and rated tranquility

The prediction equation for tranquillity rating TRAPT has been described above (equation 1) and was used to examine the fit with the current dataset. Note that for the purposes of this study L_{day} was replaced by $L_{Aeq_26dB(A)}$ for the reasons given in section 3.1. Figure 5 shows the predicted and actual average ratings given by participants in the current study. The strength of the relationship ($R^2 = 0.78$) is lower than similar studies carried out in urban parks ($R^2 = 0.88$) and a country park on the urban fringe ($R^2 = 0.88$).

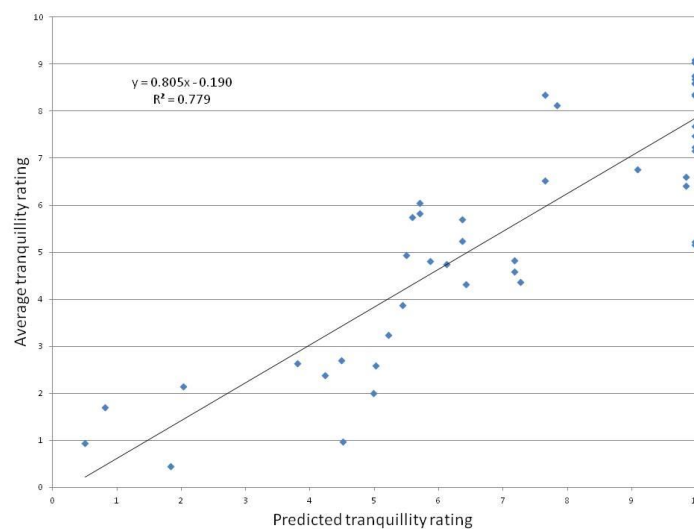


Figure 5: Relationship between predicted tranquility ratings from TRAPT and average ratings given by participants

It can be seen that there are a number of outliers and if these locations are examined in detail it appears that perceived personal threat may be a reason. An example are rapids on the river Dart shown in Figure 6 where the viewing position is very close to high flows of turbulent water and the average rating of tranquillity was low ($TR = 5.2$).



Figure 6: Rapids on the river Dart with $TR = 5.2$

The predicted TR value would be the highest possible i.e. $TR = 10$ as there is a 100% natural features ($NCF=100$) and no perceptible man-made noise, though natural sound sources due to flowing water were high ($L_{Aeq} = 71$ dB(A)). Further examples are the sound of an approaching train, police siren, automatic rifle fire and wild ponies close to the viewing position. There were 11 such locations which could be identified as posing a potential threat to personal safety. In a previous study it was found that prediction precision could be improved by taking into account those situations where there was perceived to be a measure of personal threat by applying a 1 scale point penalty i.e. MF in equation (1) is -1. If these data in the current study were adjusted the resulting relationship is closer ($R^2 = 0.82$) as can be seen in Figure 7. Interestingly there are few points above an average rated TR value of 9 and this may be because of the range effect a consequence of adaptation to the limited range of stimuli presented [19]. A part from the village centre scene all the video clips showed mainly natural environments. It could be argued that participants were therefore adapted to a relatively high level of

tranquillity and therefore didn't often consider awarding top ratings to any of the scenes as they were likely to be judged as not particularly outstanding compared with the perceived average of the stimulus set.

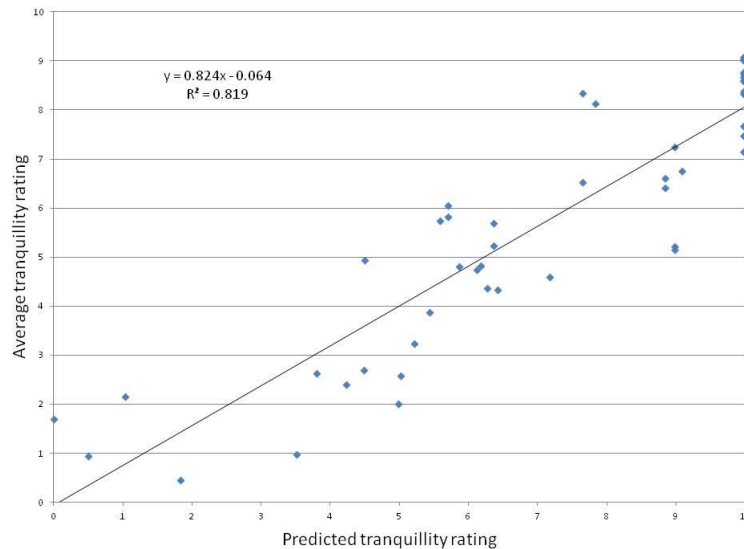


Figure 7: Relationship between predicted tranquility ratings from TRAPT and average ratings given by participants with adjusted ratings where personal safety was judged to be an issue

4. DISCUSSION AND CONCLUSIONS

The correlational analysis revealed that the average rated tranquility rating is very closely associated with both the emotional scales of Pleasantness and Calmness but slightly less so with Control. A linear combination of Pleasantness and Calmness was able to closely match average ratings of tranquility. Previous studies using principle component analysis of soundscape quality [20] showed that outdoor soundscape quality may be represented by their position in a two-dimensional space defined by the two main components Pleasantness and Eventfulness. The authors note that it was plausible that “eventful soundscapes would be more arousing and activating than uneventful soundscapes” which links well with the calmness dimension examined here. Further they found that the tranquil attribute was clearly in the quadrant of pleasant/uneventful.

Tranquillity was correlated negatively with a measure of man-made noise $L_{Aeq,26dB(A)}$ and less well to the overall sound level L_{Aeq} as found in previous studies where TRAPT was used to predict tranquillity rating. Interestingly the overall A weighted sound level L_{Aeq} is as well related to tranquillity as the loudness measure L_N . In a previous study by the author of the noisiness of vehicle sounds it was found that loudness level and A-weighted level also gave very similar correlations with subjective noisiness across a wide range of vehicle types and operating conditions [18]. Since the A-weighted level can be accurately predicted for major noise sources i.e. road, rail and aircraft there is no incentive to substitute loudness level in predicting tranquillity.

Where man-made noises were introduced into the soundscape (except for one case of a high flying aircraft creating little noise) there was a consistently large and statistically significant drop in tranquillity rating averaging 3.5 scale points. As an example worth highlighting the cattle grids to control the movement of grazing animals along access roads on Dartmoor produce high levels of “rumble” as vehicles pass over with noise peaking at 61 dB(A) at 20m in the case examined but such sounds can be perceived at much larger distances due to generally low levels of background noise. Tranquillity rating dropped by an average of 4 scale points so methods to control this noise need to be considered to restore the tranquillity of neighbouring areas of moorland. Figure 8 shows a typical cattle grid on Dartmoor where the individual bars are spaced at 150mm and the bars are 20mm thick.



Figure 8: Typical cattle grid in Dartmoor National Park at Dartmeet

At 50 km/h the dominant frequency produced as each wheel passes over the bars would be approximately 100 Hz and perceived as a low rumble though higher frequencies would also be generated.

The grid in Figure 8 was 2.6m long and since the wheel base of a midsize saloon is of similar dimensions the duration of the noise pulse would be of the order of 0.4 sec.

Attempts to improve the tranquillity rating by introducing natural sounds, which were mainly birdsong, were largely unsuccessful. If natural sounds are perceived as being loud, this also has an effect on tranquillity. However, it is not taken into account in TRAPT as only the level of man-made sounds feature. An example of this was the low tranquility ratings of 5.2 given for the river Dart where predictions would be for a *TR* value of 10. However as argued above the personal safety aspect is probably a major factor in contributing to the low score. Further work is required to determine what natural sounds can usefully be introduced to improve tranquillity.

The equation TRAPT was successful in predicting rated tranquility in these mainly wildland areas and extends the range of validation from urban and country parks previously studied [9,10]. It was found that precision could be improved by taking into account those situations where there was perceived to be a measure of personal threat. This was noted in a previous study where some parks were perceived as less safe than others and these were also spaces where litter and graffiti were in evidence. By adjusting for these environments by applying a 1 scale point penalty point a significantly better fit was obtained [9]. The 1 scale point adjustment was taken from a study where an open space was deliberately littered under one condition and then compared with the same space without litter [7].

Finally, the findings of this study underline the fact that the characterization of landscapes cannot be based on purely visual descriptors since the soundscape quality needs to be considered as an integral part of this assessment process. Man-made noise sources and levels will vary depending on location so advice on noise mitigation needs to be on a case by case basis. However, the approach adopted and the findings will be of interest to those responsible for managing, conserving and improving protected areas such as National Parks and should inform future improvements to visitors' experience of these valued landscapes.

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