DESIGNING 'TRANQUIL SPACES' – A PROPOSED LANDSCAPE MANAGEMENT PLANNING TOOL

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1 INTRODUCTION

In a world where sensory overload is becoming the norm the need to provide environments that enable us to recover our sense of well being is becoming increasingly important. Such restorative 'tranquil' environments need to comprise sufficient sensory stimulation to keep us engaged, whilst at the same time providing opportunity for reflection and relaxation[1]. However, despite still maintaining over 25,000 public parks and gardens[2], the United Kingdom has lost large tracts of green space both within the inner city and along the urban – rural fringe, due to development activity. This has resulted in the number of tranquil spaces that comprise the ingredients essential for cognitive recovery to become seriously compromised. As a consequence there has been increased research into tranquillity mapping[3, 4] along with attempts to define and characterize 'quiet areas' in response to the European Directive on the Assessment and Management of Environmental Noise (END) [5]. One essential aspect of safeguarding existing, or developing new 'tranquil space', is understanding the optimum relationship between the soundscape and the visual composition of a location and although considerable research has been undertaken by scientists on cross-modal interaction[6, 7, 8, 9,] and on the link between the perceived degree of noise annoyance and specific visual settings[10, 11, 12] their importance in constructing tranquil space has not yet been researched.

The aims of the 'Tranquillity and Noise in Urban and Rural Landscapes' project were to: (i) determine the link between objective measures and the subjective perception of tranquillity and soundscape quality and to establish acceptable noise level thresholds, (ii) to understand the combined effects on noise perception of acoustic and visual stimuli, which are typical of real rural and urban landscapes within the United Kingdom, (iii) to identify noise indices that best relate to perceptions of tranquillity and noise nuisance, and (iv) to establish unambiguous guidelines for the maintenance and construction of tranquil space.

By employing a systematic two stage experimental strategy, which presented subjects with single and bi-modal data, it has been possible to separate audio and visual stimuli in such a way that the effects on tranquillity can be measured. Throughout this project 'tranquillity' has been defined as 'how much individuals think a particular setting is a quiet, peaceful and attractive place to be, i.e. a place to get away from 'everyday life', and an assumption has been made that people prefer good weather when engaging with restorative environments. When making their assessments of tranquillity in response to both single and bi-modal stimuli the subjects were instructed to draw upon whatever value judgments they wished to characterize the various landscapes. Consequently the results of this study were not strongly dependent on anything other than the general description of tranquillity which was inherent to all of the volunteers taking part.

2 METHODOLOGY

2.1 Two stage experimental strategy

The first stage of the experimental strategy involved subjects ranking 100 photographs taken from across England during the summer of 2005 for their perceived tranquillity. By asking the subjects to rank the images from most to least tranquil it was possible to establish that the percentage of natural features within a scene, the extent to which is view can be considered open and the calmness of surface water were all key visual components of tranquil environments[13,14,15].

The second stage of the experimental strategy involved capturing audio and video footage from those locations ranked at ten percentile intervals during the photographic ranking exercise. These 10 locations, along with the one assessed as being 'most tranquil', gave 11 contrasting environments for use in the subjective assessment experiments. Place names, location designators and generic descriptions of each of the locations used in the Stage 2 experiments are presented in Table 1. The data was captured using a Canon XM 2 camcorder which was positioned on top of a mannequin's head with a binaural audio feed provided by two B&K condenser microphones that were situated inside the ear cavities. The video footage was taken from exactly the same position as the corresponding still image used in the photographic ranking exercise and the camcorder was swept from left to right over a 32 second recording period.

Location Code	Place name	Generic description
BSI	Bosigran Cliffs - Cornwall	Sea Cliffs
GS	Grasmere Lake – Cumbria	Lake
BCG	Baildon Community Garden – West Yorkshire	Community Garden
CR	Carrick Roads - Cornwall	Approaches to Falmouth Harbour
BB	Baildon Bank – West Yorkshire	Disused Quarry
SC	Sennen Cove - Cornwall	Coast
CC	Carland Cross - Cornwall	Wind Farm
CH	Chatsworth House - Derbyshire	Stately Home
HP	Hawksworth Pond – West Yorkshire	Rural Pond
OM	Otley Market – West Yorkshire	Market Town
BS	Building Site – West Yorkshire	Construction Site

Table 1- Locations Used in the Stage 2 Experiments

The aims of the subjective assessment were for subjects to determine how tranquil they considered various locations to be, and how loud they estimated 5 generic soundscape components to be, when presented with both single and bi-modal stimuli. Using headphones and a plasma screen 44 subjects, with an average age of 35 (±14.1 yrs), were presented with audio only, video only and combined audio / video data streams and asked to score on a scale of 0 – 10 how tranquil they perceived each location to be. 0 = least tranquil and 10 = most tranquil. The data was presented to each subject four times per experimental condition in a balanced design to reduce order effects. Prior to commencing the last set of repeat data (i.e. tracks 34 - 44), the subjects were told that in addition to assessing the tranquillity of each location they were also to assess the loudness of each of the soundscapes based on the five generic soundscape descriptors listed. These were 1; human sounds (any sound made by people including musical instruments), 2; mechanical sounds (anything manmade excluding musical instruments and water features), 3; the weather, 4; water and 5; biological sounds. Loudness was assessed as being either quiet, moderately quiet, moderately loud or loud. When the subjects were assessing the perceived soundscape of video only data they were instructed to estimate the loudness of each component based only on the visual information presented.

3 DATA ANALYSIS

3.1 Subjective and objective measures

The results of the subjective assessments were collated and analyzed using SSPS and TableCurve2D software to determine the statistical significance of the data and the relationships between several independent or predictor variables. In this analysis the mean and standard deviation for the tranquillity rating, subjective and objective loudness and the proportion of the natural features present were used, together with the objectively measured noise indices L_{Amax}, L_{Aeq}, L_{Amin}, L_{A10} and L_{A90} for each of the 11 locations. Figures 1 - 3 show the mean tranquillity rating of each location for each of the experimental conditions, plotted against L_{Aeq} and L_{Amax}. It is convenient to discuss the results of the eleven locations using three groupings i.e. those with A-weighted values <55dB, those with values ranging from 55 – 75 dB and those above 75dB. These have been annotated as Groups A, B & C, respectively. It can be seen that once presented with bi-modal data the subjective assessments of tranquillity move to a position that approximates a mid-way value between those shown for the audio and video only responses.

Group A comprises tranquillity data plotted against the equivalent continuous sound pressure level below 55 dB. A high proportion of natural features (> 70%) are characteristic of this group, within which a relatively poor correlation between the mean tranquillity ratings and L_{Aeq} is observed. This can be attributed to the relatively small range of the independent variable and sample size. The landscapes which fall into Group C are characterized by relatively high maximum sound pressure levels (> 75 dB) and variable proportions of natural features. It can be seen from Figure 2 that the response of Group C to visual stimuli is greater than that of Group B in comparison to the audio only condition. However, this change is exaggerated by the fact that two of the locations, Chatsworth House (CH) and Hawksworth Pond (HP) both comprise a high percentage of natural features, i.e. 75% and 84%, respectively. In the case of Hawksworth Pond the auditory context is not easily determined due to the hidden nature of the dominant noise source.

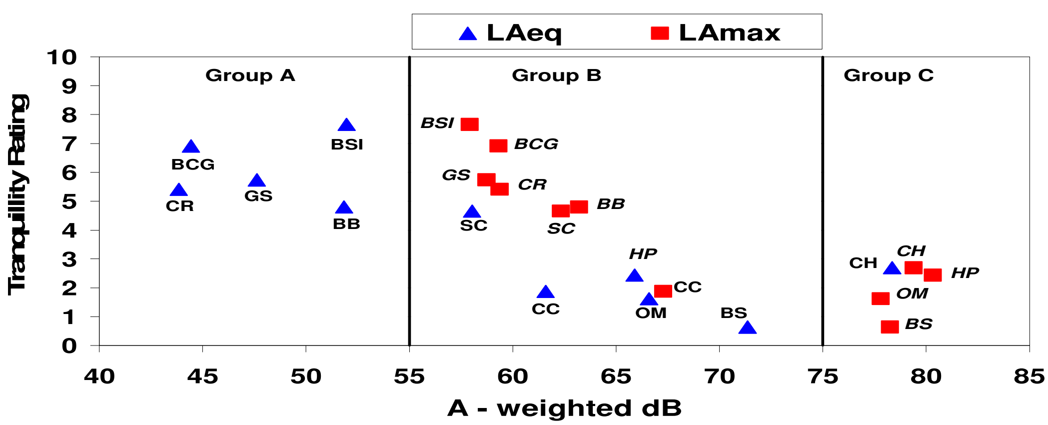

Figure 1 - Tranquillity Rating as a Function of L_{Aeq} and L_{Amax} (Audio Only Condition)

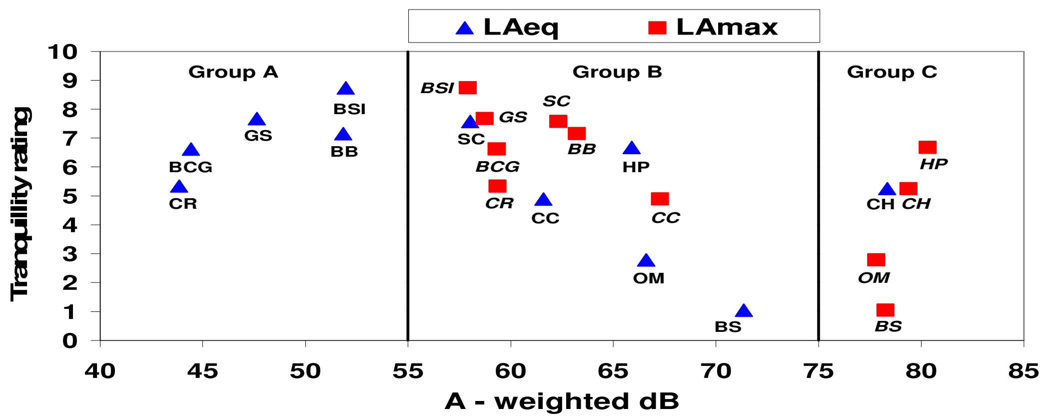

Figure 2 - Tranquillity Rating as a Function of L_{Aeq} and L_{Amax} (Video Only Condition)

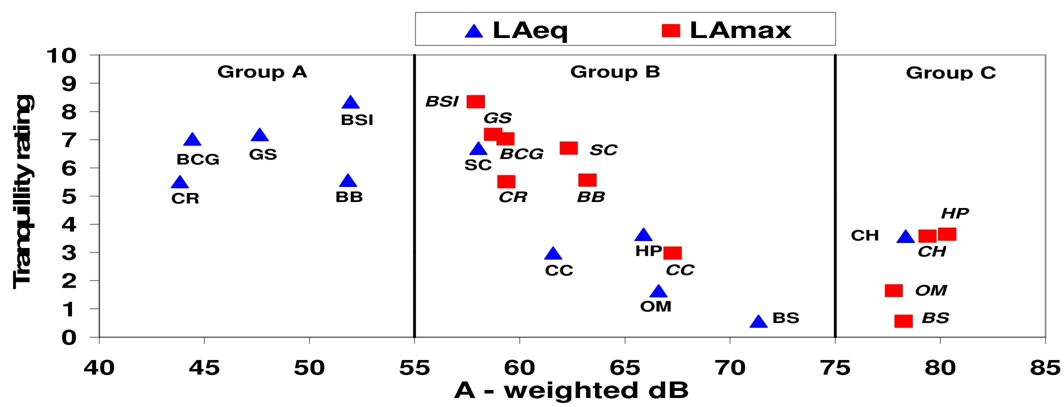

Figure 3 - Tranquillity Rating as a Function of L_{Aeq} and L_{Amax} (Audio-Visual Condition)

Of the eleven locations used in the experiment Chatsworth House, which is considered something of a national treasure by the 650,000 visitors it attracts each year, could also be viewed as an outlier. We note that the quoted A-weighted maximum level of 79 dB was recorded 1m from the water edge, however, given the linear extent of the water channel one can argue that a 3 dB reduction to this level per doubling the distance could be expected if the recordings were to be taken further away from the running water. Sound pressure level measurements taken at 12 meters away from the water channel, i.e. where the public like to sit and enjoy the view, suggest that the L_{Amax} can reduce to 61 dB. Therefore, the subjective tranquillity rating for this specific location would depend on the proximity to the water feature and may become comparable to that obtained in the cases of Sennen Cove (SC) and Baildon Bank (BB).

This confirms how subjects like to spatially distance themselves from directed attention, preferring instead the feeling of relaxation that remaining in acoustic range of the water feature provides. The aircraft noise which is the source of L_{Amax} at Hawksworth Pond (HP) however, is omni-present and therefore not escapable within the considered landscape. The other two locations, Otley Market (OM) and the Building Site (BS), comprise a low proportion of natural features, 0% and 8%, respectively, and high levels of mechanical noise. The tranquillity rating of these sites is low and consistent for all three combinations of audio and video stimuli presented in the subjective assessment experiment (see Figures 1 - 3).

Group B comprises the tranquillity data plotted against the maximum sound pressure level in the range of 55 – 75 dB. The data in this group show a very good correlation between the tranquillity rating and the L_{Amax}. Within this group the Baildon Community Garden (BCG) and Carrick Roads (CR) were rated slightly lower in the visual condition than they were in the audio only condition. In the case of the Community Garden (the location with the lowest standard deviation in all three experimental conditions), the dominant noise source was birdsong, which at 59dB, and with an averaged loudness assessment of moderately quiet, the subjects evidently found pleasing. The urban nature of the location, which is situated on the site of an old Victorian primary school close to the village centre, accounts for its lower rating in the visual only condition.

The dominant noise source at Carrick Roads came from people speaking; however, it was clear from what they were saying that they were involved in some sort of sight-seeing activity. This provided the subjects' with enough locational context on which to make their tranquillity assessments. Once presented with the visual context of the environment, which included a red brick World War 2 gun emplacement overlooking the sea, the perceived value of the location dropped slightly. This compares starkly with Carland Cross (CC) wind farm which more than doubled its audio only tranquillity rating once the visual data had been provided.

3.2 Results

In order to identify the correlations that existed between the subjective and objective variables involved in this research the subjects' mean assessments of tranquillity for each location and each experimental condition, were contrasted against a range of independent variables utilizing the SPSS (version 14.0), Linear Regression (Stepwise) analysis tool. These included L_{Amax}, L_{Aeq}, L_{A90}, L_{A10}, the percentage of natural features present within each location, and the perceived loudness of the corresponding soundscape components. In each condition only those variables which could have noticeably influenced the subjects' assessment of tranquillity were included. For example, in the audio only condition variables that relied on visual information such as the percentage of natural features occupying each scene, or the number of people present, were not included. Likewise in the video only condition L_{Amax} and L_{Aeq} were omitted. However, the perceived levels of loudness for the five generic soundscape categories were included as it was felt that these could reasonably influence how tranquil a particular environment was felt to be by providing an element of acoustic context.

When assessing the impact of environmental noise it is usual within the EU to use L_{den} which relies on the L_{Aeq} scale. However, the World Health Organization (WHO) advises in their Guidelines for Community Noise[16], that measurements based solely on L_{Aeq} values do not fully characterize most noise environments and do not adequately assess the health impacts on human-beings. Their guidance also states that it is important to measure the maximum noise levels and the number of noise events when deriving guideline values. When proposing guideline values for specific environments in[16] the WHO states that the critical health effect of allowing the ratio of intrusive noise to exceed the background noise in parks and conservation areas, is a disruption of tranquillity. Given these factors it has been deemed appropriate to examine L_{Amax} in addition to L_{Aeq}. This will be achieved by first looking at the relationship between L_{Aeq} and the tranquillity rating before establishing how L_{Amax} influenced the subjective responses.

3.2.1 L_{Aeq} Groups A & B

Group A, which is widely distributed below 55dB does not show any systematic dependency between L_{Aeq} and tranquillity, which is determined largely in response to visual stimuli alone. When analyzing both the audio only, and the combined audio-visual conditions, no meaningful correlation existed between tranquillity and any of the independent variables. In the video only condition the number of people present in the scene and the perceived loudness of mechanical noise, were the two variables identified in the regression analysis. However, with an R^2 value of 0.20 this correlation was considered extremely weak. In Group B a weak correlation existed between L_{Aeq} and the perceived loudness of biological noise in the audio only condition. In this group the video only condition showed the best result with the percentage of natural features being the single variable that influenced the tranquillity rating. Stepwise analysis of the combined audio-visual condition showed L_{Aeq} as being the sole influencing factor. The one-dimensional regression analysis of the data within this group suggests that the tranquillity rating (TR) depends strongly on the L_{Aeq} and can be closely approximated by the following linear equation for which the coefficient of determination was $R^2 = 0.80$.

$$TR = 29.7 - 0.41L_{Aeq} \quad (1)$$

3.2.2 L_{Amax} Groups B & C

Audio Only Condition Group B

When responding to audio only data subjects made their tranquillity assessments of Group B based on L_{Amax} and the perceived loudness of human noise. Within this experiment subjects showed that they were well capable of applying auditory scene analysis, i.e. the ability to automatically partition incoming sounds with similar regularities[17], to each of the 32 second data streams played to them. It was by applying this technique that they were able to generate, and subsequently categorize, a number of 'auditory streams' that corresponded to a single sound source. This information then enabled them to make reasonably consistent assessments of the soundscape and not only identify which of the five generic components were present, but also allocate them a loudness score. The fact that the perceived level of loudness of human noise correlated so well suggests that when working on hearing alone individuals place significant value on information relating to other people.

Audio Only Condition Group C

Once above 75dB the results became ambiguous and no significant correlation existed between the variables in the audio only condition for Group C. This may be due to the combined affects of the small sample size of the group, and the potentially negative impact on tranquillity of variables such as the perceived level of human and mechanical noise, the number of people present, and the objectively measured L_{Amax}. Combined these factors make it difficult to draw any coherent conclusions and more data are required to determine under what conditions tranquil space could exist in either natural or built environments with a soundscape greater than 75dB. Such work would build on the findings of Yang and Kang[18], who identified an L_{Aeq} of 76dB as being the level at which people find the soundscape of urban spaces noisy.

Video Only Condition Group B

The regression analysis of the video only condition identified the perceived level of mechanical noise and the number of people present in a scene to be the key correlates. This shows that when attempting to gauge how tranquil an environment is in response to visual only data, individuals utilize the same hierarchy of influencing factors that they did in the audio only presentation. In this condition L_{Amax} is replaced by the perceived loudness of mechanical noise and the perceived loudness of human noise is replaced by the actual number of people present.

Video Only condition Group C

When the locations that comprise Group C were shown to the subjects in a video only data stream the variables that correlated were: the perceived levels of mechanical, biological and human noise. All other factors were excluded from the models. This suggests that for environments above 75dB estimating the acoustic context is more important when assessing tranquillity than the overall visual quality of the environment.

Combined Condition Groups B and C

Once presented with bi-modal information that provided as much visual and acoustic context as was technically possible, the subjects were able to make a judgment based on near sensory certainty. The key variables which control the tranquillity rating of the locations falling within these groups were L_{Amax} and the percentage of natural features present in the scene. These variables predominated through a complex synthesis of auditory scene analysis, visual congruence provided by scene perception, mankind's deep affiliation with nature, which Wilson describes as biophilia[13] and preference for a particular environment[14]. All of which allowed the subjects to take what began as undifferentiated space and endow it with a lesser or greater degree of value. A more detailed investigation of the experimental data reveals that the effect of the percentage of natural features on the perceived tranquillity of the scene is relatively small in comparison with that of the L_{Amax}.

Linear regression analysis of this data suggests the following approximation to the tranquillity rating for 55 dB < LAmax < 75 dB

$$TR = 34.0 - 0.46\ L_{Amax},\ 55\ \text{dB} < L_{Amax} < 75\ \text{dB}. \qquad (2)$$

Above the level of 75 dB (Group C) the percentage of natural features present in the scene was the only variable that correlated with the measured tranquillity rating data.

By using audio-visual tranquillity ratings across all 11 sites it has been possible to establish a reasonably robust linear expression that once fully validated could form the basis of a landscape management planning tool. The variables L_{Amax} and the percentage of natural features were the two independent variables found to explain the greatest degree of variance in the dependent variable and were statistically significant at the 0.1% level. The R^2 value of the analysis was 0.52 which is considered acceptable for this area of work. The following expression enables a tranquillity rating to be determined:

$$TR = 13.93 - 0.165\ L_{Amax} + 0.027\ NF,\ (40\ \text{dB} < L_{Amax} < 85\ \text{dB}) \qquad (3)$$

Where TR is the tranquillity rating NF is the proportion of natural features (%).

In the case when the L_{Aeq} needs to be used instead of L_{Amax} equation (3) becomes

$$TR = 8.57 + 0.036NF - 0.11\ L_{Aeq} \qquad (4)$$

The coefficient of determination in this case was found to be 0.49.

4 CONCLUSIONS

This research represents the first step in understanding the effects of audio-visual interaction on the perception of tranquillity when responding to single and bi-modal stimuli. The reliance of acoustic information, both actual and perceived, in the decision making process, can be interpreted as an imperative when we consider that six out of the eight correlations identified in the regression analysis included as an independent variable, either L_{Amax} or the perceived loudness of one or more of the generic soundscape categories.

From the regression analysis it has been possible to propose approximate linear expressions for tranquillity using L_{Amax}, L_{Aeq} and the percentage of natural features within an environment, as the coefficients. This research has indicated that given the right combination of natural features and soundscape components, tranquil space can be engineered and created within an urban environment.

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