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The importance of auditory-visual interaction in the construction of ‘tranquil space’

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Abstract

In a world of sensory overload, it is becoming increasingly important to provide environments that enable us to recover our sense of well-being. 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. One essential aspect in safeguarding existing, or developing new 'tranquil space', is understanding the optimum relationship between the soundscape and the visual composition of a location. This research represents a first step in understanding the effects of audio-visual interaction on the perception of tranquillity and identifies how the interpretation of acoustic information is an integral part of this process. By using uni and bi-modal auditory-visual stimuli in a two stage experimental strategy, it has been possible to measure the key components of the tranquillity construct. The findings of this work should be of particular interest to those charged with landscape management, such as National Park Authorities, Regional Councils, and other agencies concerned with providing and maintaining public amenity.

Keywords: Tranquillity, Uni-modal stimuli, Bi-modal stimuli, Loudness, Soundscape.

1. Introduction

The ability of individuals to take respite from the periods of sustained ‘directed attention’ that characterize modern living has been shown to reduce stress and contribute to the overall feeling of well-being (Hartig, 1997). In developing their Attention Restoration Theory (ART), Kaplan and Kaplan (1989) proposed that recovery from cognitive overload could be best achieved by engaging with natural restorative environments, that are away from daily distractions and have the extent and mystery that allows the imagination to wander, thereby enabling individuals to engage effortlessly with their surroundings. The theory works on the principle that the amount of reflection possible within such an environment depends upon the type of cognitive engagement, i.e. fascination; that the environment holds. ‘Soft fascination’ is deemed to occur when there is enough interest in the surroundings to hold attention but not so much that it compromises the ability to reflect. In essence, soft fascination provides a pleasing level of sensory input that involves no cognitive effort other than removing oneself from an overcrowded mental space.

For our ancient ancestors, impaired performance, brought about by prolonged periods of directed attention, would potentially have had fatal consequences. Therefore, in order to survive they must have developed a series of mechanisms that enabled them to cope with constantly living in a state of ‘tense arousal’ that came from the fear of predation (Thayer, 1989). Essential to their survival would have been the ability to take periods of cognitive respite that were facilitated by social cooperation and a reliance on the environment to provide important safety information. Thus wide open views with lush vegetation, where grazing herbivores could act as bio indicators of impending danger, and glassy water surface textures that when broken would elevate the state of arousal (Coss, 1990), may well have been the ancient components of soft fascination that Kaplan and Kaplan (1989), identify as underpinning modern day restorative environments.

Motivated by ART, from which they took ‘tranquillity’ as a reasonable term to describe soft fascination, Herzog and Bosely (1992) and Herzog and Barnes (1999), attempted to distinguish empirically between the constructs of tranquillity and preference as affective qualities of natural environments. By defining tranquillity as “how much you think this setting is a quiet, peaceful place, a good place to get away from everyday life”, and preference as “how much you like this setting for whatever reason”; they asked subjects to score a range of contrasting natural environments for each target variable in response to still images (colour slides).

Both these studies showed that despite tranquillity and preference being positively correlated they are in fact individual constructs, thus giving an extremely useful insight into the complex relationship that exists between sensory input (in this case a visual stimulus), environmental schemata and scene coherence. In addition they effectively built on other studies into the role of vision within landscape characterization, most notably that of ‘prospect-refuge theory’ (Appleton, 1975). This reductionist theory, which was developed to explain habitat selection of early hominids, argues that a pleasurable response will be elicited from an environment that has the appearance of satisfying survival needs. For these savannah dwellers the perception of three-dimensional landscape features, their form, spatial arrangements and animation, would have acted as sign stimuli of the environmental conditions favourable or otherwise to safety and survival. In negotiating this wilderness landscape the response to the likelihood of predation was the ability to see (prospect), whilst at the same time remaining unseen (refuge).

Prospect-refuge theory was developed by Appleton as a response to those who looked at landscape paintings and inferred human preference in terms of aesthetic quality i.e. beauty, rather than in functional terms, where primitive stimuli were fundamental to survival. In explanation of why an aesthetic experience of landscape is pleasurable today, Appleton argues, "it is derived from the observer experiencing an environment favourable to the satisfaction of their biological needs". An assessment of landscape attributes is for most people no longer essential to their physical survival. However, a remnant primitive reaction must still be part of our landscape preference, even though it is now satisfying instead an inner, restorative need for well-being that is delivered by a tranquil space.

It can be seen that significant emphasis has been placed on understanding the role of vision in the perception of natural environments, and this is probably not surprising considering that upon first viewing a scene its configurational coherence can be established with incredible speed. Indeed scene information can be captured in a single glance (Oliva & Torralba, 2006) and the gist of a scene determined in as little as 100ms (Dobel, et al, 2006). The speed of processing of a complex natural image was tested by Thorpe et al (1996), using colour photographs of a wide range of animals (mammals, birds, reptiles and fish), in their natural environments, mixed with distracters that included pictures of forests, mountains, lakes, buildings and fruit. During this experiment, subjects were shown an image for 20ms and asked to determine whether it contained an animal or not. The electrophysiological brain responses obtained in this study showed that a decision could be made within 150ms of the image being seen, indicating the speed at which cognitive visual processing occurs.

However, audition, and in particular the individual components that collectively comprise the soundscape, a term coined by Schafer (1977), to describe the ever present array of sounds that constitute the sonic environment, also significantly inform the various schemata used to characterize differing landscape types. For our ancient ancestors whilst the need to find fresh water for example, would frequently have been met by visual stimuli, it would have been the case that rivers, streams, waterfalls and cascades would all have provided auditory cues that signalled their presence (Hudson, 2000). Other indicative elements of the soundscape would have been the characteristic sounds of potential quarry animals, or their movement heard but unseen in complex vegetated landscapes. When the following are added to the soundscape mix - birdsong, territorial, courtship and mating calls; along with the forewarning to take shelter from advancing thunder storms; and the need for security on hearing the cooperative calling between predators as they search out new prey - it becomes apparent how important audition is in landscape perception. This interpretation is supported by the auditory reaction times, which are 50 to 60ms faster than that of the visual modality (Jaśkowski, et al, 1990).

It is known that sound can alter visual perception (Shams, et al, 2002) and that under certain conditions areas of the brain involved in processing auditory information can be activated in response to visual stimuli (Calvert, et al, 1997). Despite considerable research being undertaken into audio-visual interaction (McGurk & Macdonald, 1976, Marks, 1987 and Heron & Whitaker, 2004) and linkages between the perception of noise annoyance and specific visual settings (Watts, et al 1999, Viollon, et al, 2002, and Zhang & Kang, 2007), the importance of bi-modal interaction in the construction of tranquil space has not yet been reported.

The study reported here builds on the contribution made by Herzog et al into tranquillity and preference (1992 & 1999), and develops further the relationships first proposed in a prior article (Pheasant, et al, 2008), where they were presented as a 'Tranquillity Rating Prediction

Tool' for use by engineers, planners and others charged with managing areas of public amenity. In this report, we seek to reconcile the results of two related studies to determine the extent to which auditory-visual interaction influences the tranquillity construct. Study 1 utilizes still images to test the hypothesis that the individual landscape components contained within the visual scene, directly influence the uni-modal perception of tranquillity. Study 2 seeks to expand on this, by testing the hypothesis that landscape quality evaluations (i.e. tranquillity assessments), made in response to a uni-modal stimulus, can become modified in the presence of bi-modal information.

2. Study 1

2.1. Participants

The 58 females and 44 males (16 – 80 years, average age 37.6 years ± 17.0 years), that took part in Study 1 were recruited from students and staff at the University of Bradford, and from members of the public visiting the Brockhole Visitors' Centre in the Lake District National Park. The recruited volunteers were representative in age, gender and ethnicity of British society and not subject to any set level of academic achievement. No remuneration or study credits were awarded to any of the subjects taking part in the project. In addition, because it was suspected that geographic and cultural variations could influence the perception of tranquillity, only British nationals were used in the study.

2.2 Materials and Settings

The images chosen for this exercise were drawn from a database of 360 photographs that were taken from across England during the summer of 2005. The images were captured using a Canon EOS 50E SLR camera that was loaded with 200 ASA colour film, and were presented as 15 cm x 10 cm photographs. In an attempt to ensure that all types of English landscapes were covered, 20 colour images were selected from each of the following five generic landscape categories: mountainous and wilderness, coastal, parks and gardens, urban and rural. It is acknowledged, due to the highly modified nature of English landscapes, that some of the locations could fall into more than one group, for example mountainous/rural, urban/coastal or urban/parks and gardens. Because of this, the generic classifications, whilst typifying groupings along a continuum of easily readable scenes, cannot be taken as definitive or mutually exclusive. There were however some distinct attributes within the scenes that could be quantified.

Whilst the quality of the photograph was considered during selection for inclusion in each category, the perceived level of tranquillity was not. Indeed, it was never intended to present only the quietest and 'greenest' areas of England, where the notion of tranquillity is least contested, but to include a broad spectrum of landscapes that were identifiable, if not familiar to, all of the subjects taking part in the study. The chosen angle of view was generally suitable for taking typical landscape pictures, i.e. telephoto shots were avoided, and the photographs were taken from a position of rest, which was generally seated with the camera at eye height (i.e. approximately 1.5m above ground level).

2.3 Measures

Each of the 100 photographs was scored according to the ranked position allocated to it by the subjects, with a value of 100 being attributed to the most tranquil scene and decreasing values awarded to the remaining 99 images. The least tranquil scene scored 1. These values were summed and statistically tested for agreement using Kendall's coefficient of concordance (Siegel & Castellan, 1988), and an approximation of x^2 obtained to test whether the resultant correlation was statistically significant. Table 1 lists the mean score and standard deviation of each of the 100 images against their ranked position.

Objective measures of the percentage of natural and anthropocentric features contained within each scene were also established. Natural features were deemed to include flora, fauna, geological features (including dry stone walls which, for many, are an intrinsic part of the English countryside) and water. Although it was recognised that the sky contains important information about the suitability of an environment for rest and relaxation, the percentage contained within each image was not included. This decision was taken as it was considered that very small deviations in the camera angle could bias the overall percentage of natural features by introducing larger tracts of sky than would not normally be within view. In addition, weather conditions were for the most part, uniformly sunny, therefore little differentiation in environmental quality could be gleaned from the sky. Anthropocentric features included people, the space that they occupied, and all manmade objects. Each of the individual components that comprised the natural and anthropocentric features categories were statistically tested against the summed value corresponding to each ranked position (dependent variable), using multiple linear regression analysis.

The percentage value of each component of the visual scene was calculated by overlaying a 10 x 10 grid onto each image and counting the amount of space occupied. Where more than one landscape component occupied the same 1% of space a smaller 4 x 4 grid was used, thus enabling the values to be determined to within <0.1% of overall space.

2.4. Procedure

For each of the participants the 100 photographs were laid out on a table in random order and the subjects asked to hand the image that they perceived to be most tranquil to the research assistant, who recorded its unique number against its ranked position. The subjects were left to decide upon the value judgments they made, however, in order to give them a benchmark from which to work they were told that for the purpose of the exercise they should consider a tranquil space to be “a quiet peaceful place, a good place to get away from the demands of everyday life’. The subjects were also told that the images they were assessing represented ‘steady state’, i.e. they would never change and that they were to make their assessments based solely on the visual information given. On average, it took the subjects 30 minutes to complete the task.

2.5. Results

The combined use of Kendall’s Coefficient of Concordance and x^2 showed that the degree of agreement between the subjects ranking the 100 photographs was highly significant (p-<.01). This enabled the null hypothesis, i.e. that the rankings were unrelated to each other, to be rejected, thereby allowing a wider analysis of the photographs’ ranked position and its visual composition to take place. This was achieved by using multiple linear regression analysis to test the relationship between the mean numerical value attributed to each image (i.e. the dependent variable) and the percentage of space occupied by water, flora, geological features and people, as independent variables. The percentage of space occupied by fauna was also considered. However, English landscapes are for the most part agricultural and the photographs utilized in this study were taken soon after a nationwide cull of livestock, following the spread of foot and mouth disease. This left the countryside relatively empty in terms of fauna; therefore, this variable was omitted from the analysis due to the very small sample size.

Results of the regression analysis are contained in Table 2. The perception of tranquillity as represented in the photographic scenes was significantly influenced in a positive way by the percentage of water, flora, and geological features contained therein, whereas it was negatively influenced by the percentage of space occupied by people. The significance of these results is supported by the relatively small confidence intervals, which enabled the null hypothesis to be rejected at the 95% level of significance. An identical pattern of results was obtained using a non-parametric measure of correlation between the dependent variable and these independent variables (Spearman rank correlation).

2.6. Discussion

The results of the photographic ranking exercise supported the hypothesis that the individual landscape components contained within the visual scene directly influence the uni-modal perception of tranquillity. These components include physical aspects of the landscape that can be objectively measured, such as the percentage of natural and manmade features contained within a scene, or the amount of space occupied by people. However, landscape characterization, and in particular the construction of ‘tranquil space’, is a complex process that draws upon a wide range of sensory inputs that cannot be adequately provided for by still photography alone. Although both smell and touch supply important environmental cues, auditory information provides vital contextual detail about an environment’s quality and suitability for purpose. Therefore, the extent to which auditory and visual information contribute to the perception of tranquillity, was explored in Study 2.

3. Study 2

3.1. Participants

Forty-four subjects (20 male and 24 female, average age 35 ±14.1 years), took part in Study 2. Approximately half of these had taken part in Study 1 ten months earlier and the rest were drawn from staff and students of the University of Bradford’s School of Engineering, Design and Technology. Familiarity with the stimuli being presented to the subjects that had participated in the photographic ranking exercise was not considered problematic, given that each of the sweeping video clips to be used in Study 2 contained 800 frames of dynamic information, in contrast to the 1 frame of still data presented in each of the photographs used in Study 1. The two sets of stimuli were therefore considered sufficiently different. Each subject received a £10 gift voucher for his or her contribution to the research, which lasted approximately two hours. The sample of participants was once again demographically representative in gender, age and ethnicity and only British nationals took part.

3.2. Materials and Settings

As an unbiased method of identifying locations for use in Study 2, those ranked at ten percentile intervals during the photographic ranking exercise of Study 1 were chosen. These 10 locations, along with the location assessed as being ‘most tranquil’, gave 11 contrasting environments that were revisited and audio-visual data (video footage), recorded using the equipment and calibration procedure described in Pheasant et al (2008). A central view and generic description of each location is provided in Figure 1.

Where possible the footage was taken from exactly the same place as its corresponding still image. Each video clip lasted for 32 seconds, and comprised an 8 second sweep from the left hand limit of the view to the centre, where the camera remained stationary for 16 seconds, before completing the recording arc by sweeping right for a further 8 seconds. During video capture every attempt was made to include as much acoustic context as possible within the footage, and in order to preserve integrity of the audio data it remained unchanged throughout the editing process. The 32-second exposure time was determined during a pilot study, in which 12 subjects made ‘tranquillity assessments’ of a location based on repeated exposure to a video clip over escalating time scales (2, 4, 8, 16, 32 and 64 seconds). The mean point at which the assessments of perceived tranquillity remained constant was identified as 32 seconds and this was incorporated into the study.

The captured video data was edited using Adobe Premier 6.5 software in order to provide 32-second audio only, video only and combined audio-video data cuts. Each data stream was placed in a randomised order unique to the pair of subjects it was being presented to, and stored on a DVD for use in the psycho-acoustic suite.

3.3. Measures

Subjects used a scale of 0 – 10 (0 = not at all tranquil and 10 = very tranquil) to rate the perceived tranquillity of each of the 11 locations, under three experimental conditions (audio-only, video only and combined audio-visual). The data were presented to each subject four times per experimental condition (i.e. 44 exposures per condition) in a balanced design intended to reduce order effects. To enable the subjects to become accustomed to both the environments being presented and the assessment process, tranquillity estimations for the first 11 tracks in each experimental condition were ignored, the mean tranquillity ratings being determined from the middle two sets of repeat data, i.e. tracks 12 – 33.

For the last set of repeat data in each condition (i.e. tracks 34-44), the subjects were asked to assess how loud they perceived each of the five generic soundscape components listed in Table 3 to be. Loudness was assessed using the following scale: 0 = sound source not present, 1 = quiet, 2 = moderately quiet, 3 = moderately loud and 4 = loud. An important aspect of the loudness estimation was obtaining valid baseline data. This was achieved by playing the subjects a 1 kHz calibration tone and asking them to assess how loud they perceived it to be. The tone was played via calibrated headphones at volumes equating to the highest and lowest sound sources that the subjects would be exposed to throughout the experiment. This procedure took place prior to commencing the experiment and again at the end, since it is known that the perceived magnitude of an auditory stimulus may decrease as the subject adapts to the sound source, and that conversely the absolute threshold measured after exposure to sounds may increase due to fatigue (Neuhoff, 2004). A comparison of both sets of results obtained from the loudness assessments of the calibration tone showed no evidence that the subjects had experienced either adaptation or fatigue. The results were therefore used to determine the subjective loudness limits of the objective dynamic range covered by the recorded sounds and scale accurately the bounds of the loudness assessment.

The mean percentage of natural features for each clip was determined by taking the average of three measurements, using the same measuring technique as Study 1. The first was taken at the start of the video (frame 1), the second at the central position (frame 400) and the third at the right hand limit of the view (frame 800). This allowed for the whole composition of the environment to be taken into account. Values for the noise indices L_{Aeq} and $L_{Amax,}$ were determined using Matlab 6.5 subroutines and calibrated WAV files.

The raw values allocated by the 44 subjects to each of the 11 locations in each of the 3 experimental conditions, were used to determine the dependent variable ‘mean tranquillity rating’. This was used in the regression analysis (Microsoft Excel 2007 and SPSS 16), along with the independent variables: weighted mean loudness, percentage of natural features present at each location (excluding sky), equivalent A-weighted continuous sound pressure level (L_{Aeq}) and maximum sound pressure level (L_{Amax}). However, when conducting regression analysis of the uni-modal results only those independent variables that could reasonably have influenced the perception of tranquillity were tested against the dependent variable (mean tranquillity rating). In the visual only condition relationships between the visual components of the scene and the mean tranquillity ratings were established, and in the audio-only condition, the subjective assessments of loudness, along with the noise indices L_{Amax} or L_{Aeq} were used as independent variables. In the bi-modal audio-visual condition, all visual and acoustic variables were tested against the mean tranquillity rating. This process was employed to identify the extent to which both the individual and collective auditory and visual components of each location influenced the tranquillity construct.

In an attempt to establish whether the uni-modal perception of tranquillity became moderated once bi-modal stimuli were presented, a repeated measures ANOVA was also conducted. This utilized the mean tranquillity rating awarded by each subject to each location (total 484 responses), for all three experimental conditions, the results of which were further validated by a post-hoc Scheffe test. In addition, a repeated measures analysis of variance was carried out using the bi-modal mean tranquillity ratings and the mean of the uni-modal estimates, in order to determine the extent to which the bi-modal percept of tranquillity was biased towards either of the uni-modal components.

3.4. Procedure

The study was conducted inside a psychoacoustic suite where subjects wearing Technics RP-295 headphones were seated in pairs 2m from the centre of a Pioneer PDP-506XDE plasma screen. A briefing was given that explained the experiment and described how the response sheets for both the tranquillity and loudness assessments should be completed. This information was also provided in printed form. The subjects were advised that for the purpose of the research a tranquil environment was one that they considered to be a quiet, peaceful and attractive place to be, i.e. a place to get away from ‘everyday life’ (Herzog and Barnes, 1999). Exposure to each location lasted 32 seconds per experimental condition, followed by a 6-second break in order that the subjective assessments could be recorded.

For the first 22 subjects the data was presented in the order: audio only, video only and combined audio-visual, and for the remaining 22 subjects the uni-modal sequence was switched and the data presented in the order video only, audio only and combined audio-visual. Analysis of the results showed that the order in which the uni-modal data was presented had no significant effect on the mean tranquillity ratings.

3.5. Results

The mean tranquillity ratings and associated standard deviations in each experimental condition for the 11 locations used in Study 2 are shown in Table 4. In all but two locations, subjects rated the environments higher in terms of perceived tranquillity when responding to visual only stimuli, than they did when responding to audio only data. There is an overall tendency for audio-visual tranquillity assessments to fall in between the two uni-modal estimates, although this will be examined in more detail in Section 3.5.4.

3.5.1 Results of the video only experimental condition

When responding to visual only stimuli the subjects once again drew upon the individual components of the landscape to construct their perception of tranquillity. Interestingly the independent variables: percentage of water, flora and geological features contained within the scene, significantly predicted the mean tranquillity ratings (water $\beta = .51$, $t = 2.68$, $p<.05$, flora $\beta = .84$, $t = 4.40$, $p<.01$, geological features $\beta = .60$, $t = 3.70$, $p<.05$). $R^2 = .85$, $F(4, 6) = 9.14$, $p<.05$. However, this was not the case for the percentage of space occupied by people within the scene, variable ($\beta = .06$, $t = .40$, $p>.05$). This is in contrast to Study 1 and it may well be due to the differing sample sizes between the two studies. In Study 1, forty-three scenes contained people compared to only six in Study 2. While this approximates to half of the scenes in both cases, the range in number of people contained in the scenes of Study 1 (1 – 200+) compared to Study 2 (2 - 65), were sufficiently varied to establish a relationship. An alternative explanation could be that the length and dynamic nature of the video data allowed the subjects to apply a greater degree of configurational coherence to the scene, than they were able to do when responding to still images. However, testing this hypothesis fell outside the scope of this study.

3.5.2 Results of the audio only experimental condition

Within the audio-only experimental condition, two models were tested to establish which components of the soundscape the subjects utilized to make their tranquillity assessments. The first model included the objectively measured maximum A-weighted sound pressure level (L_{Amax}), and the subjectively derived loudness values, and the second model the equivalent continuous A-weighted sound pressure level (L_{Aeq}) plus the loudness values, as independent variables. In both models, the perceived loudness of mechanical sounds (PLM) and the perceived loudness of biological sounds (PLB) were shown to significantly predict the dependent variable ‘mean tranquillity rating’, to a similar extent. Using the multiple regression analysis results from model one as an example, it can be seen that biological sounds had a positive influence on tranquillity ($\beta = .56$, $t = 5.9$, $p<.01$), whereas mechanical sounds had a negative influence ($\beta = .32$, $t = -3.8$, $p<.01$), $R^2 = .97$, $F(3,7) = 77.37$, $p<.001$. None of the other five generic soundscape components listed in Table 3 was shown to have a significant effect in either model.

The mean tranquillity ratings (TR), for each model that includes PLM and PLB are defined by equations (1) and (2):

$$TR = 9.99 - 0.93L_{Amax} - 0.45\,(PLM) + 1.16(PLB) \qquad (1)$$

$$TR = 7.74 - 0.67L_{Aeq} - 0.53(PLM) + 1.19(PLB) \qquad (2)$$

Both models were statistically significant at the 95% confidence level and were supported by appropriate confidence intervals.

3.5.3 Results of the combined audio-visual experimental condition

Table 5 shows the results of the multiple linear regression analysis for the loudness assessments in the combined audio-visual experimental condition. It can be seen from the confidence intervals and their associated significance values, that the only elements of the soundscape that significantly influenced the tranquillity construct were biological sounds and sounds of the weather. For sounds produced by human, mechanical and water sources the confidence intervals show that the null hypothesis, i.e. that these sounds do not influence the tranquillity construct, could not be rejected. In the case of water, this result runs counter to the findings of previous studies (Watts et al, 2009) and further debate is given to this aspect in Section 3.6.

When tested using stepwise linear regression analysis the loudness of the individual soundscape components were not strong enough on their own to influence significantly the mean tranquillity rating. Instead, the equivalent continuous sound pressure level (L_{Aeq}), which incorporates all aspects of the soundscape, predominated. A similar result was given for the visual modality, where the overall mean percentage of natural features (NF), rather than any of the individual sub-components of the visual scene, correlated significantly with the mean tranquillity rating. Table 6 summaries the results of the regression analysis and shows the extent to which bi-modal stimuli contribute to the tranquillity construct. Here it can be seen that both L_{Aeq} and NF are significant predictors of mean tranquillity and that of the two variables the acoustic measure negatively influences the perception of tranquillity, whilst the visual measure has a positive influence. In both cases, the significance values are supported by appropriate confidence intervals. When L_{Amax} for all 11 locations was tested against the percentage of natural features, the result did not reach the required level of significance.

3.5.4 The extent to which bi-modal *stimuli 'moderate' the tranquillity construct*

In order to determine whether the bi-modal perception of tranquillity across all observers and locations was significantly different to the uni-modal percept, a repeated measures analysis of variance (ANOVA) was carried out. This revealed a highly significant effect of observation type on tranquillity rating $F(2,996) = 181.69$, $p<.001$). Post-hoc analysis (Scheffé), revealed that all three observation types (audio, visual and bi-modal) were significantly different to one another ($p<.001$). Given this, we now ask whether the data conform to perhaps the simplest model of bi-modal tranquillity, that of an average of the uni-modal audio and visual estimates. The observation that audio-visual tranquillity estimates tend to lie between the two uni-modal estimates (Table 4) may be taken as support for this view. However, closer inspection reveals that the situation is not that straightforward. Whilst linear regression shows that the mean of the uni-modal estimate explains a significant proportion of the variance in the combined tranquillity estimate (R^2 = .98, p<.01), significant departures from a simple average exist. Figure 2 shows the difference between the combined tranquillity estimate and the mean of the uni-modal ratings, plotted against the combined estimate. The dashed line indicates perfect agreement, whilst data points lying above this line indicate that bi-modal tranquillity was rated higher than the average of the uni-modal estimates would suggest (and vice versa for data lying below the dashed line). A repeated measures analysis of variance (ANOVA), a summary of which is contained in Table 7, was carried using data from individual participants for each of the 11 locations in order to establish which scenes involved a bi-modal estimate significantly different to the average of uni-modal estimates. These data points are marked in Figure 2 with asterisks according to the level of significance attained (*, p<.05; **, p<.01; ***, p<.001). Interestingly, scenes which generated a low rating of bi-modal tranquillity (<5) tended to be rated as less tranquil than the average of their uni-modal components, and vice versa for the tranquil scenes. This suggests that the combined percept resulting from a tranquil scene is enhanced by the more tranquil of the two constituent sensory inputs. Conversely, for a non-tranquil scene, perception tends to be ‘captured’ by the less tranquil of the two components. In our scenes, this component tended to represent a low audio tranquillity rating resulting from high levels of mechanical noise, sometimes incongruous to the tranquil visual scene.

3.6. Discussion

The past decade has witnessed a growing shift of emphasis away from the study of the senses in isolation towards an understanding of how the human brain coordinates the array of information provided by the different sensory modalities. The results obtained during Study 2 have shown how important auditory and visual stimuli are in landscape characterization, and have supported the hypothesis that landscape quality evaluations (i.e. tranquillity assessments) made in response to a uni-modal stimulus can become modified in the presence of bi-modal information. In the same way that one sense has been shown to dominate or 'capture' another sense and thereby determine perception in laboratory experiments (McGurk & Macdonald, 1976; Shams et al., 2002; Heron et al., 2004), so the auditory soundscape or visual landscape have the potential to influence the perception of tranquillity in a real, multisensory environment.

When making their tranquillity assessments based on uni-modal sensory inputs, the subjects drew upon a number of key landscape and soundscape characteristics. For example, in the visual-only experimental condition the percentage of water, flora and geological features present within a scene, positively influenced how tranquil it was perceived to be. This corresponded with the findings of Study 1 and supports further the hypothesis that the individual landscape components contained within the visual scene, directly influence the uni-modal perception of tranquillity. In the audio-only experimental condition, the perceived loudness of biological sounds enhanced the perception of tranquillity and the perceived loudness of mechanical sounds detracted from it. However, although the results obtained from Study 2 show how important the presence of water within the visual scene is to the perception of tranquillity, the same positive influence was not identified when the loudness of water sounds was analysed. No definitive explanation can be given for this apparent contradiction, however, it is perhaps worth explaining that the A-weighted equivalent continuous sound pressure level (i.e. the ambient noise), for the one location where the soundscape was dominated by water noise (Chatsworth House), was 79 dB(A). This exceptionally high value, which is 7dB(A) greater than the level recorded at the construction site, can be attributed to the fact that the data was recorded 1m away from an ornamental water feature, rather than 12m away, which is where many of the tourists that visit each year tend to sit and enjoy the view. Subsequent measurements have shown the L_{Aeq} values at this distance to be 18 dB(A) lower than those used in the experiment.

It is known from the study into the auditory effects of increased stream flow on recreation reported by Brown and Taylor (1992), that the sounds of water are considered to be pleasant up to a certain level, beyond which their quality drops rapidly. However, it is not clear within the literature exactly what this level is. In fact experiments involving water sounds replayed at values below 60 dB(A), indicated both positive and negative impacts on perceived tranquillity, with the direction of change appearing to be dependent on whether the sounds were perceived as “natural” or not, (Watts^{a} et al, 2009).

Unlike in the uni-modal experimental condition (including Study 1), none of the component parts of the visual or acoustic scene on their own significantly influenced the tranquillity construct when bi-modal stimuli were presented and scene coherence, (context) was established. In the case of the visual data, the grouped variable ‘percentage of natural features’ correlated well with the perception of tranquil space, as did the equivalent continuous sound pressure level (L_{Aeq}) for the auditory inputs. It should be noted that these findings relate to the results of the stepwise linear regression analysis that looked for associations across all 11 locations in the bi-modal experimental condition, rather than breaking the dataset into smaller groups based on the dominance of natural or anthropocentric features. An extended study using a significantly larger dataset is currently being undertaken to test this relationship.

An unforeseen finding of Study 1 was the negative impact that the presence of people within the visual scene had on the construction of tranquil space. This suggests that solitude is as important for the tranquillity construct as it is for the restorative potential of the wilderness experience (Hollenhorst, et al, 1994). That this was not identified as significant in Study 2 may be due to the inadequacy of the dataset to allow that determination. It would therefore be an important factor in experimental design for follow on studies.

4. Conclusions

The present work addresses the contribution of vision and audition to the perceptive reality of the tranquillity construct and reveals lessons for identifying the attributes of tranquil space. The stimuli presented to subjects were taken from real locations rather than synthesized sounds and light sources.

Our results challenge again the notion of uni-modal perceptual processing, indicating that the perception of tranquillity represents a complex interplay between the visual and auditory activity evoked by everyday scenes. Indeed, it is important that those involved in soundscape research, with their concentration on one modality, i.e. audition, begin to develop as a minimum, a bi-modal approach to environmental characterization.

We contend that the work presented here on bi-modal stimuli is likely to be a first measure of the reality of soft fascination that restorative environments afford (Herzog, et al, 2003). Recent work carried out by SCANLab using fMRI neuro-imaging techniques supports our findings on bi-modal interaction by providing insights into the physiological basis for this interaction between modalities (Watts^b, et al 2009). It has been demonstrated for the first time that significant differences exist in effective connectivity between the auditory cortex and the medial prefrontal cortex under tranquil and non-tranquil conditions. Specifically the medial prefrontal cortex receives significantly enhanced contribution from the auditory cortex under tranquil visual conditions compared with non-tranquil visual conditions (Watts^b, et al., 2009). Such results indicate strongly that bi-modal stimuli are essential for a full characterization of tranquil space, and that even when a soundscape is being characterized the visual scene is likely to be an important modifying factor in auditory perception.

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Table 1.

Study 1 data showing mean score and standard deviation (SD) against ranked position for each of the 100 images.

Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD
1	82.91	18.78	26	65.52	22.52	51	49.74	22.00	76	39.33	26.21
2	82.58	17.22	27	65.24	24.25	52	48.55	24.60	77	37.64	22.86
3	81.68	19.34	28	63.94	27.50	53	48.47	20.33	78	37.12	19.58
4	79.08	19.14	29	63.72	21.50	54	48.02	20.74	79	36.82	21.43
5	78.75	18.94	30	63.36	22.35	55	47.84	20.64	80	35.69	21.67
6	77.90	16.23	31	61.06	21.98	56	47.80	18.43	81	33.55	18.61
7	77.01	20.50	32	60.68	20.41	57	47.37	23.41	82	33.20	18.10
8	76.36	20.17	33	60.28	23.81	58	47.33	24.44	83	32.91	20.42
9	75.23	23.23	34	59.65	24.10	59	47.30	22.63	84	32.35	19.92
10	74.89	20.69	35	59.60	21.30	60	47.21	20.93	85	31.35	21.69
11	74.81	20.94	36	59.12	21.68	61	46.78	20.58	86	27.79	18.80
12	74.19	19.49	37	59.02	22.17	62	46.58	25.65	87	27.75	25.29
13	73.05	22.58	38	55.48	24.15	63	45.70	20.38	88	23.49	19.37
14	73.05	22.89	39	54.50	24.68	64	45.42	24.00	89	19.68	15.15
15	72.63	21.19	40	54.11	23.57	65	45.27	24.11	90	17.06	17.68
16	71.95	19.73	41	53.84	20.39	66	45.21	24.54	91	16.40	14.43
17	71.75	20.98	42	53.79	24.53	67	45.04	21.15	92	15.81	16.87
18	69.99	21.85	43	53.32	19.89	68	44.66	20.72	93	14.28	13.91
19	69.87	20.03	44	53.29	20.69	69	44.61	26.65	94	14.03	19.73
20	69.84	20.32	45	53.25	24.08	70	43.84	26.41	95	12.44	18.40
21	69.82	21.99	46	52.22	22.43	71	43.46	21.74	96	11.03	16.23
22	69.66	19.61	47	52.14	23.62	72	43.38	24.00	97	10.78	17.59
23	66.80	21.60	48	52.08	21.25	73	40.36	18.23	98	9.99	15.11
24	65.94	21.99	49	50.50	23.45	74	40.17	22.69	99	8.51	14.39

Table

Table 2.

Multiple regression summary for dependent variable: ranked mean.

$r = 0.79$, $r^2 = 0.63$, adjusted $r^2 = 0.61$						
$F(4, 95)=40.02$, $p<0.001$, S.E. 12.31, $n = 100$						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	19.57	3.39	5.77	0.000	12.83	26.30
% Flora	0.49	0.05	9.85	0.000	0.39	0.59
% Water	0.70	0.10	7.08	0.000	0.51	0.90
% Geological Features	0.53	0.09	6.02	0.000	0.35	0.70
% Occupied by people	-1.59	0.48	-3.30	0.001	-2.55	-0.63

Table 3.

Definitions of the five generic soundscape components used in the loudness estimations.

Sound Source	Definition
Human	Sounds made by people including musical instruments and bells
Mechanical	Sounds emitting from anything manmade, excluding musical instruments, bells and water features
Biological	Sounds made by living organisms excluding human beings
Weather	Sounds made by the weather such as the wind in the trees / telegraph wires or thunder and lightening
Water	Sounds made by water e.g. rapids, breaking waves, rain, fountains, and ornamental water features

Table 4

Mean tranquillity ratings and associated standard deviations for each experimental condition.

Generic Location Descriptor	Audio Only	SD	Video Only	SD	Combined Audio-Visual	SD
Sea Cliffs	7.66	1.63	8.74	1.35	8.35	1.71
Community Garden	6.91	1.72	6.62	1.72	7.02	1.59
Lake Scene	5.74	2.12	7.68	1.54	7.18	1.81
Seascape	5.41	1.84	5.34	1.55	5.51	1.72
Disued Quarry	4.80	2.13	7.16	1.58	5.56	1.72
Coastal Scene	4.66	2.18	7.57	1.69	6.70	2.11
Stately Home	2.69	2.02	5.26	2.09	3.58	1.72
Rural Pond	2.44	2.01	6.68	1.44	3.64	2.11
Wind Farm	1.88	1.94	4.89	2.22	2.98	2.21
Urban Market	1.62	1.53	2.79	1.85	1.64	1.61
Construction Site	0.64	0.15	1.04	1.17	0.57	0.92

Table 5.

Multiple regression summary of the generic loudness components and the dependent variable mean tranquillity rating, in the combined audio-visual experimental condition.

r =0.97, r^2=0.95, adjusted r^2=0.91						
F (5, 5)=22.42, p <0.01, S.E. 0.72, n =11						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	1.64	0.94	1.75	0.141	-0.77	4.06
Human	0.27	0.20	1.30	0.249	-0.26	0.79
Mechanical	-0.16	0.22	-0.74	0.491	-0.72	0.40
Biological	1.78	0.24	7.42	0.001	1.16	2.39
Weather	1.04	0.36	2.86	0.035	0.11	1.97
Water	-0.13	0.31	-0.44	0.679	-0.92	0.65

Table 6.

Results of the stepwise multiple linear regression analysis for the combined audio-visual experimental condition.

$r = 0.88$, $r^2 = 0.78$, adjusted $r^2 = 0.73$						
F (2, 8)=14.71, $p < 0.01$, S.E.1.28, $n = 11$						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	8.57	2.95	2.91	0.020	1.77	15.37
NF	0.04	0.01	2.83	0.022	0.01	0.07
LAeq	-0.11	0.04	-2.74	0.025	-0.20	-0.02

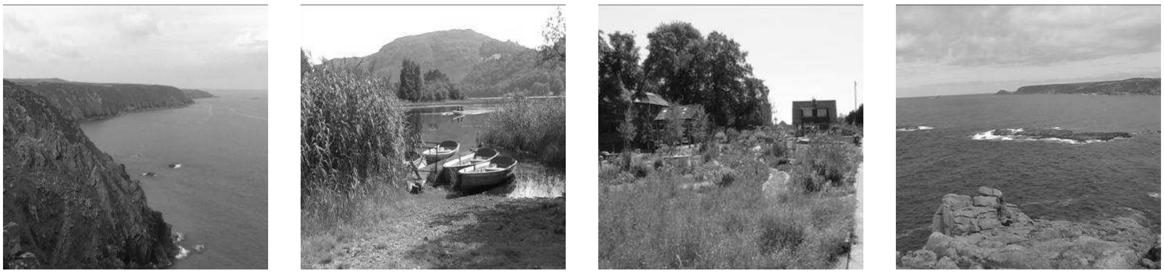
Table 7.

Summary of the repeated measures Analysis of Variance (ANOVA) conducted on each location.

Generic Location Descriptor	Mean of Uni-modal Estimates	Audio-Visual Mean	F	P-Value
Rural Pond	4.55	3.64	14.90	<0.001
Urban Market	2.20	1.64	14.43	<0.001
Construction Site	0.84	0.56	15.98	<0.001
Lake Scene	6.70	7.18	11.43	<0.01
Seascape	6.11	6.70	5.54	<0.05
Community Garden	6.76	7.02	4.16	<0.05
Coastal Scene	5.38	5.51	0.80	>0.05
Sea Cliffs	8.18	8.35	2.51	>0.05
Disused Quarry	5.97	5.56	3.66	>0.05
Chatsworth House Gardens	3.97	3.58	2.13	>0.05
Wind Turbines	3.38	3.00	3.26	>0.05

The following applies to the data contained in this table: df 1, Error 43, Fcrit 4.06

Figure



1. Sea Cliffs

2. Lake Scene

3. Community Garden

4. Seascape

5. Disused Quarry

6. Coastal Scene

7. Rural Pond

8. Chatsworth House Gardens

9. Wind Farm

10. Urban Market

11. Construction Site

Figure 1 – The central view of the locations used in Study 2.

Figure

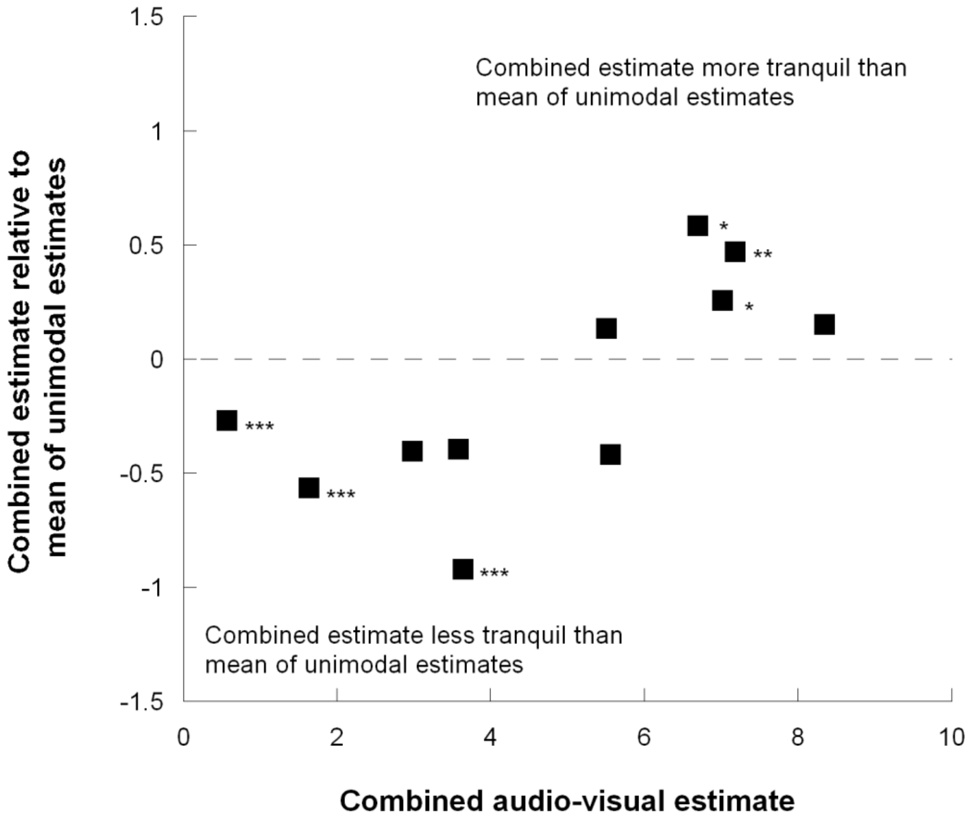


Figure 2 - Combined audio-visual estimate of tranquillity plotted against the combined estimate relative to the mean of the uni-modal tranquillity ratings