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Citation: Watts G and Marafa L (2017) Validation of the Tranquillity Rating Prediction Tool (TRAPT): comparative studies in UK and Hong Kong. Noise Mapping. 4(1): 67-74.

Research Article

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Validation of the Tranquillity Rating Prediction Tool (TRAPT): comparative studies in UK and Hong Kong

https://doi.org/10.1515/noise-2017-0005
Received Jun 08, 2017; accepted Jul 17, 2017

Abstract: The Tranquillity Rating Prediction Tool (TRAPT) has been used to make predictions of the quality of tranquility in outdoor urban areas using two significant factors *i.e.* the average level of anthropogenic noise and the percentage of natural features in view. The method has a number of applications including producing tranquillity contours that can inform decisions regarding the impact of new anthropogenic noise sources or developments causing visual intrusion. The method was intended for use in mainly outdoor areas and yet was developed using responses from UK volunteers to video clips indoors. Because the volunteers for this study were all UK residents it was important to calibrate responses for other ethnic groups who may respond differently depending on cultural background. To address these issues further studies were performed in Hong Kong using the same video recording played back under the same conditions as the study in the UK. The HK study involved recruiting three groups *i.e.* residents from Hong Kong, Mainland China and a diverse group from 16 different nations. There was good agreement between all these groups with average tranquillity ratings for the different locations differing by less than one scale point in most cases.

Keywords: TRAPT, tranquillity, validation, soundscape

1 Introduction

Tranquil spaces are important as they provide respite from the attentional demands of modern city life and can be considered restorative environments assisting health and wellbeing [1–7]. The Tranquillity Rating assessment tool has been developed to assist planners and designers to take into account the level of tranquillity that can be attained with the aim of maximising this level to promote benefits for visitors to these valuable spaces. In both urban and rural environments 'tranquil space' is predominantly constructed via the sensory information received primarily by the auditory and visual modalities. To capture this information for experimental study it has been necessary to carry out binaural recordings using a binaural head with attached video camera. Recordings of a wide range of spaces from open moorland to crowded city centres were later replayed to subjects in the laboratory in both the United Kingdom (UK) and Hong Kong (HK). Ratings of perceived tranquillity were obtained. From a wide range of factors it was found that the A-weighted sound pressure level of anthropogenic noise combined with the percentage of natural features in the scene could account for much of the variance in these ratings [8, 9]. It was found that further improvements in accounting for this variance could be obtained by adding in contextual features. These include a range of man-made features that directly contributed visually to, or were in context with, the overall natural environment. Examples of such features are: listed buildings, as these have already undergone a value assessment, religious and historic buildings, landmarks, monuments and man-made elements of the landscape that are geographically and aesthetically in keeping with the natural environment of woods, fields, lakes, hills or parkland. In addition, it was found that the presence of litter and water sounds can decrease or increase ratings, respectively [10, 11].

Equation (1) gives the final model [12], where TR = Tranquillity Rating, L_{Aeq} the equivalent continuous sound pressure level of anthropogenic noise and NCF, the percentage of natural and contextual features in the scene (excluding the sky). The moderating factors MF are included to take into account the presence of litter and water sounds.

$$TR = 10.55 - 0.146L_{Aeq} + 0.041NCF + MF \qquad (1)$$

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Figure 1: Experimental subject rating a video clip taken using "Marina"

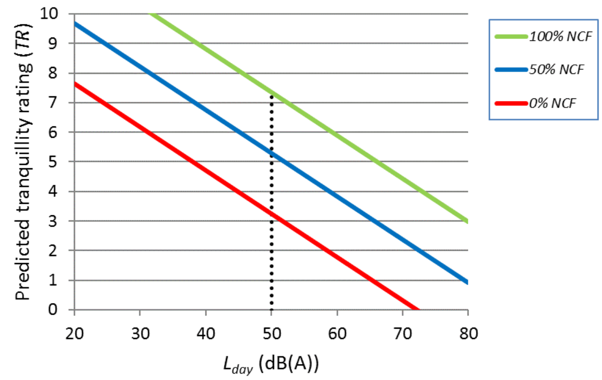

Figure 2: Linear variation of Tranquillity Rating (TR) with L_{day} at levels of Natural and Contextual Features (NCF) of 0, 50 and 100%

The TRAPT equation was based on laboratory studies [8, 9] where subjective assessments of tranquillity were made using 30 sec video clips taken from 34 different real environments. Subjects were seated in a semi-anechoic chamber with auditory inputs provided via compensated headphones and visual input using a wide plasma screen. The tranquillity rating is dependent on many factors but it has been found that approximately 85% of the variance is accounted for by the two independent factors in equation (1). Note that for practical application in urban areas during daytime the A-weighted level could be replaced by the level L_{day} (0700-1900) predicted from the major anthropogenic noise source(s) [12].

Figure 1 shows an experimental subject rating a video clip. The video recorder was mounted on top of a dummy head ("Marina") as can be seen in the figure. Microphones placed in the artificial ear canals allowed binaural recordings to be made which contributed to the realistic environment on playback as it created a 3-D stereo sound sensation for participants.

To illustrate the nature of equation (1) Figure 2 shows the relation between L_{day} and *TR* for 3 levels of *NCF* (0, 50 and 100%). Where there are no natural or contextual features visible (*NCF* = 0%) it can be observed that at the mid-range urban noise level of 50 dB(A) *TR* reaches only 3.3 ("unacceptable") while with *NCF* = 50% the value is predicted to rise to 5.3 ("just acceptable"). However, with *NCF* = 100% the *TR* value is 7.4 *i.e.* "good". This graphically demonstrates the importance for rated tranquillity of the natural components of the visual scene. In addition, the equation allows trade-offs to be made to improve tranquillity. For example, a 50% increase in *NCF* is predicted to raise *TR* by approximately 2 scale points while decreasing noise level L_{day} by 14 dB(A) changes *TR* by approximately the same amount.

Predicted *TR* values in eight urban open spaces were found to be highly correlated to the level of relaxation (*i.e.* "less relaxed", "no change", "more relaxed") of people after visiting such spaces where there was found to be highly correlated $r = 0.98$ ($p < 0.001$) [12]. For example, for a *TR* value of 5.0 nearly 50% of visitors report that they are "more relaxed" after visiting the park while at a value of 8 approximately 80% report being "more relaxed". These results can be used to calibrate the following category limits for *TR* defined previously based on the judgements of the research team :

<5	unacceptable
5.0 – 5.9	just acceptable
6.0 – 6.9	fairly good
7.0 – 7.9	good
≥ 8.0	excellent

These category labels have proved useful in describing the benefits of changes in the *TR* value using mapping. To protect tranquil areas it would be useful to provide plots of tranquillity contours which can be monitored in order to indicate changes that might pose a threat. Figure 3 illustrates cases where the noise from traffic on a park perimeter road varies and indicates the corresponding changes in

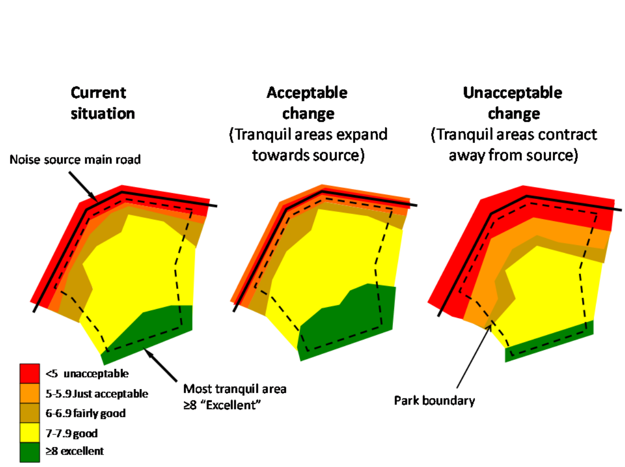

Figure 3: Tranquillity contours showing effects of traffic noise variations

the areas of tranquil spaces of various qualities based on the above classification.

Such an approach is currently being used in Westlands and Mount Cook national parks in New Zealand to assess the impact of helicopter tourist flights on walkers using scenic trails in the valleys below.

However, there are concerns that studies based on laboratory experiments using UK residents cannot be easily generalized. In particular, the extent to which:

(a) tranquillity assessments made in the laboratory environment match those made in the real outdoor environment and
(b) different ethnic groups concur on rating tranquillity under identical conditions.

This paper sets out to provide evidence to address these issues and consequently to inform decisions on the applicability of TRAPT in diverse situations.

2 Method

In order to validate the findings assessment were made at a number of tranquil and non-tranquil locations on the campus at the University of Bradford in Yorkshire, UK. Participants made ratings on site and at the same time video records were taken. These video clips were then replayed at least 3 months later in the laboratory using the same replay methods as used previously to develop the prediction tool. The video was then replayed under identical situation in the Landscape Laboratory at the Chinese University of Hong Kong in Hong Kong. Three groups were recruited in Hong Kong for this purpose: Residents of HK, visitors from Mainland China and international visitors

2.1 Recordings and assessments in the UK

Binaural head recordings were made under 8 different conditions at 6 locations on the University of Bradford campus. A video camera was mounted on top of the artificial head and operated simultaneously with the binaural recordings. Figure 1 shows views of the assessment conditions that were videoed and evaluated. The locations are described below and shown in Figure 4:

- Peace Garden: adjacent to a busy road on the edge of the campus. Assessments were made under 3 conditions: "as is" and with replayed water sounds and with litter added
- Great Horton Road: On the pavement next to this busy radial route into Bradford city centre
- Quadrangle: A green in the centre of the campus overlooking a grassed area with mature trees
- Theatre in the Mill: At the edge of the quadrangle on a bridge over a stream with water sounds
- Library: Fairly narrow space between two university buildings with hedge in foreground
- Construction site: This was close to the busy road and reconstruction work was in progress

Eight subjects (Ss) were recruited to take part, their average age was 28.6 years. They were asked to complete biographic and contact details before commencing the assessments. They were given a £10 voucher for their time.

Each condition was presented in a quasi-random order. At each location they were asked to stand to the side of the binaural head and video recorder (Canon XM2 camcorder) and look in the same direction as the camera. On a start and stop signal they were asked to assess the tranquillity of the environment during a 30 second timed period and at the end to assess the perceived tranquillity during that period. For this purpose a 0 to 10 point interval scale was used where 0 = not at all tranquil and 10 = most tranquil. Video footage was taken during these assessment periods. Prior to the experiment, the subjects were told that a tranquil environment was one that they considered a quiet, peaceful place to be, *i.e.* a place to get away from everyday life. They were also informed, that for the purpose of the exercise the environments that they saw should be considered 'steady state'.

They were also asked to note any factors that they felt improved the tranquillity and those that reduced the level of tranquillity. A score sheet was provided. They were

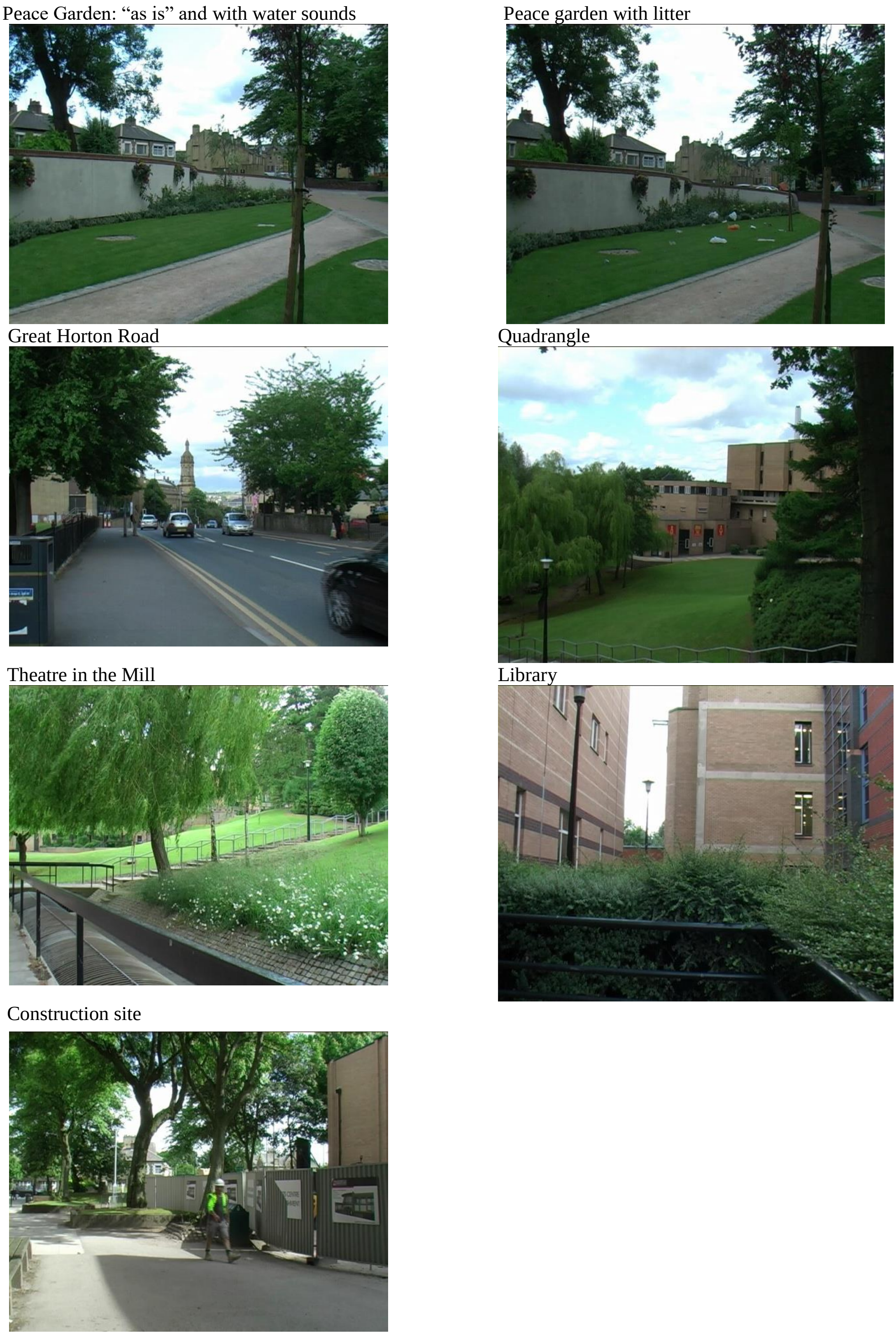

Figure 4: Views of assessment conditions

Table 1: Analysis of variance of outdoor ratings in UK

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Subjects	11.109	7	1.587	0.930	0.492	2.203
Environments	163.359	7	23.337	13.672	1.19E-09	2.203
Error	83.641	49	1.707			
Total	258.109	63				

asked not to confer over their assessments. There were 8 separate conditions so that the Peace Garden was visited 3 times during one random order sequence. While Ss were away from the Peace Garden litter was either scattered, collected up or a portable CD player was placed behind the position where Ss were instructed to make assessments. Recordings of water sounds were replayed simulating a water feature.

There were 3 random sequences so that each condition was presented 3 times. The assessments made during the first sequence were counted as a practice round and only the ratings made during the second and third sequences were used in the analysis.

2.2 Replay of recordings and assessments in the UK

Approximately 3 months after the outside assessments were completed the Ss were invited to return to take part in a similar study but using the reproduced environments provided by the recordings taken during the assessments outside. It was considered that during this period Ss would have forgotten the assessments they had previously made under real world conditions. The Ss were seated in a quiet room (semi-anechoic chamber) and positioned 2m from a Pioneer PDP-506XDE plasma screen and wearing calibrated headphones (either Technics RP-295 or Roland RH-300). They were instructed to subjectively assess how tranquil they found each environment to be using exactly the same 0-10 tranquillity rating procedure as used outside. Exactly the same instructions were given. The orders of presentations were exactly the same so that results were strictly comparable. As before assessments made during the first sequence were considered as practice results and only the results from the second and third sequences were used in the analysis.

2.3 Replay of recordings and assessments in the laboratory in HK

The Chinese University of Hong Kong (CUHK) has been active in soundscape studies for a number of years [13, 14] and because of their considerable experience and expertise were able to secure a grant to enable these comparative studies to be undertaken. The video prepared in the UK was replayed in the Landscape Laboratory at the Department of Geography and Resource Management at CUHK. A monitor screen was set up at a similar distance and sound levels were also arranged to be similar. Exactly the same assessment procedure was employed as for the original experiment in the UK. However, in this case three groups of Ss were recruited. They comprised residents from:

(a) Hong Kong (30 Ss, average age 27.7 years)
(b) Mainland China (30 Ss, average age 25.1 years)
(c) International (23 Ss, average age 22.7 years)

The international Ss included, in order of numbers, residents from: Finland (3), US (3), Czech Republic (2), Ecuador (2), South Korea (2) and then one from each of the following countries: Australia, Belgium, France, Germany, Malaysia, Mexico, Nigeria, Scotland, Spain, Taiwan and The Netherlands.

3 Analysis

3.1 Analysis of UK data

The ratings from the second and third sequences outside and in the simulated environment were averaged and compared. Three of the Ss who took part in the original experiment outside did not reply to the invitation to return so that for comparison purposes five Ss who had completed assessments both outside and indoors were utilised. Figure 5 shows a comparison of these average scores.

It can be seen that there is excellent agreement between the two sets of ratings ($R^2 = 0.946$, $r = 0.973$, $p<0.001$) with the regression line passing through the origin. This

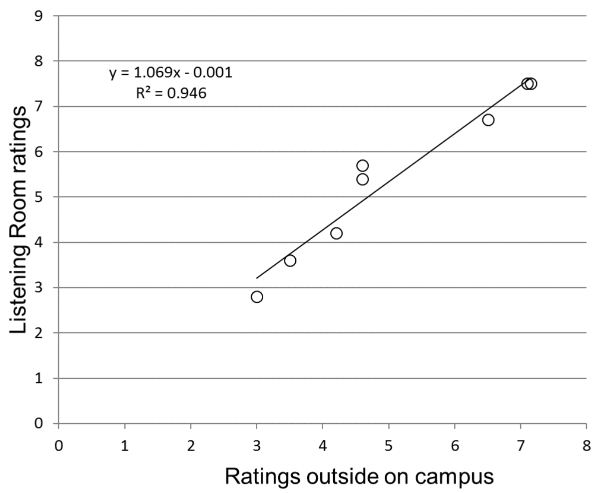

Figure 5: Comparison of ratings made outside and in the laboratory

implies that 95% of the variance could be explained by the direct relationship.

Analysis of variance of the outdoor experiment showed a significant difference between environmental conditions (p<0.001) but not between Ss as shown in Table 1.

The average ratings ranked in order of tranquillity are given below in Table 2:

Table 2: Average scores made outdoors for each environmental condition

Option	Average rating
Quadrangle (Quad)	7.65
Theatre in the Mill (TiM)	6.94
Library (Lib)	6.56
Peace Garden with water sound (PG(W))	4.94
Peace Garden "as is" (PG(N))	4.63
Construction site (CS)	4.31
Peace garden with rubbish (PG(L))	3.63
Great Horton Road (GHR)	2.75

It can be seen that the presence of the water sound lifted the average rating slightly (from 4.63 to 4.94). However, a more noticeable difference was the effect of litter on average ratings. This produced a whole scale reduction in average ratings (from 4.63 to 3.63). The presence of relatively low noise levels and natural features such as trees, grass and shrubs and running water would have lifted the levels of tranquillity in the centre of the campus (Quadrangle, Theatre in the Mill) compared with those near the periphery such as the construction site and the edge of Great Horton Road.

The frequency of comments made during the outdoor assessments by the 8 Ss concerning both factors thought to improve or reduce perceived tranquillity are summarised in Table 3 below. The factors are listed in order of the frequency the factors were mentioned in the questionnaires. It can be seen that the presence of water sounds and natural features such as trees grass, shrubs and trees are frequently mentioned as are peaceful surroundings. Notice that old buildings appear to contribute as do open views. On the negative side high noise levels both from traffic and people depress ratings as do litter. Some Ss commented on the poor quality and loudness of the reproduced water sound and for some it was irritating.

Table 3: Positive and negative factors affecting tranquility

Factor	Number of Ss	*Auditory*	*Visual*
Positve			
Sound of water	8	X	
Trees, shrubs, flowers, grass	7		x
Quiet, peaceful, low noise	7	X	
Open space, views	3		x
Old buildings	3		x
Wind in trees	3	X	
Sunshine	2		x
Bird song	1	X	
Negative			
Traffic noise	8	X	
Noisy people (including music)	6	X	
Litter	5		x
Sound of water (recorded)	4	X	
Ugly buildings, paths and signs	4		x
Vehicle noise (reversing alarms, ice-cream chimes	4	X	
Building site view	3		x
Dirty conditions (exclude litter)	3		x
Excessive wind noise in trees	3	X	
Sound of water (natural)	2	X	
Construction noise	2	X	

Table 4: Analysis of variance of laboratory ratings in UK and Hong Kong

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Environments	73.567	7	10.510	97.448	1.434E-14	2.488
Groups	2.194	3	0.731	6.783	0.002	3.072
Error	2.265	21	0.108			
Total	78.026	31				

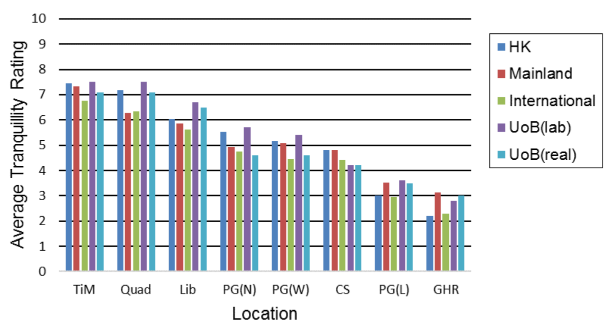

Figure 6: Comparison of average tranquillity ratings by subject groups and environments

3.2 Analysis of HK data and comparison with UK data

The tranquillity ratings of the video clips for all groups in the UK and Hong Kong were analysed and the mean ratings for each location compared. The results of the analysis of variance are given below:

It can be seen that differences in the environments are highly significant while the subject groups do show differences but much less than for environments. The size of these differences is demonstrated in Figure 6 above.

It can be seen that there is a good measure of agreement between the subject groups with differences on average being less than one scale point. Across all environments the average rating in the laboratory studies ranged from 4.7 (International) to 5.4 (UK). However, the average differences between environments rated in the laboratory studies ranged from 2.6 to 7.3.

4 Discussion and conclusions

The comparison of ratings made in UK both inside and outside lend support to the use of the laboratory method for developing TRAPT. There was very good agreement between these ratings (r=0.97, p<0.001).

The comparison of ratings made by four groups of Ss that included people from 19 different nations showed a good measure of agreement that indicates that TRAPT predictions are likely to be valid in UK, Hong Kong, Mainland China and probably in many other countries too. However, further work is required to confirm applicability in these other countries where there were few representatives. It was shown in the introduction how TRAPT can be used for mapping predicted tranquillity ratings. This can be used for assessing the impact of new noise sources and developments that have a visual impact [15].

The differences in ratings from different environments indicate that litter can depress tranquility ratings significantly. Averaged across all groups the effect of scattering litter in the Peace Garden was to depress ratings by 1.96 scale points. Another study in a country park where litter had been dumped showed an adverse effect of 1.20 scale points [10]. Clearly the amount and type of litter will influence the size of the effect. The effects of the water sounds was much less clear as it depressed average ratings by 0.21 scale points. A laboratory study has shown that the quality of the water sound is important and indicated that the water sounds generated from a natural source were more likely to improve tranquility with background traffic noise present [11].

From the replies received from the UK group making assessments outside it was concluded that both visual and auditory stimuli affect rating of tranquility as fully reflected in the main factors in the TRAPT equation and shown graphically in Figure 2. Among the main factors reported as affecting tranquility positively were sound of water, presence of vegetation and low noise. Negative factors that were reported included traffic noise, noisy people and litter.

Acknowledgement: The study was supported by the Bradford Centre for Sustainable Environments at the University of Bradford and by the Research Grants Council of the Hong Kong Special Administrative Region, China (RGC/GRF. CUHK 449612). The authors wish to thank the numerous student helpers who assisted at various stages of the study and the contribution of Dr Rob Pheasant to the early phase of the work.

References

[1] Forest Research. Benefits of green infrastructure, Report by Forest Research. Forest Research, Farnham, UK, 2010.

[2] Ulrich RS, Simons RF, Losito BD, Fiorito E, Miles MA, Zelson M. Stress recovery during exposure to natural and urban environments. J Environ Psychol 1991; 11:201–30.

[3] Takano T, Nakamura K, Watanabe M. Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. J Epidemiol Commun Health 2002; 56:913–8.

[4] Grahn P, Stigsdotter UA. Landscape planning and stress. Urban Forest Urban Greening 2003; 2:001–18.

[5] Lechtzin N, Busse AM, Smith MT, Grossman S, Nesbit S, Diette GB. A randomized trial of nature scenery and sounds versus urban scenery and sounds to reduce pain in adults undergoing bone marrow aspirate and biopsy. J Altern Complem Med 2010; 16(9):965–72.

[6] Hunter MD, Eickhoff SB, Pheasant RJ, Douglas MJ, Watts GR, Farrow TFD, et al. The state of tranquility: subjective perception is shaped by contextual modulation of auditory connectivity. Neuroimage 2010; 53(2):611–8.

[7] Van den Berg M, Wendel-Vos W, van Poppela M, Kempera H, van Mechelena W, Maas J. Health benefits of green spaces in the living environment: A systematic review of epidemiological studies. Urban Forestry & Urban Greening, 14(4), 2015, 806–816.

[8] Pheasant RJ, Horoshenkov KV, Watts GR, Barrett B. The acoustic and visual factors affecting the construction of tranquil spaces in urban and rural environments. Journal of the Acoustical Society of America, 123 (3), 2008, 1446-1457.

[9] Pheasant RJ, Horoshenkov KV, Watts GR. Tranquillity rating prediction tool (TRAPT). Acoustics Bulletin November/December, 2010, 18-24.

[10] Watts G. R. and Pheasant R. (2013) Factors affecting tranquillity in the countryside. Applied Acoustics 74, 2013, 1094–1103.

[11] Watts GR, Pheasant RJ, Horoshenkov, KV and Ragonesi L, 2009. Measurement and subjective assessment of water generated sounds, Acta Acustica with Acustica 95, 2009,1032-1039.

[12] Watts GR, Miah A, Pheasant RJ. Tranquillity and soundscapes in urban green spaces - predicted and actual assessments from a questionnaire survey. Environment and Planning B: Planning and Design 40(1), 2013, 170–82.

[13] Lam, Kin-Che; Brown, A. L.; Marafa, Lawal; Chau, Kwai-Cheong. Human Preference for Countryside Soundscapes. Acta Acustica united with Acustica, 96(3), 2010, 463-471.

[14] Chau, Kwai-cheong; Lam, Kin-che; Marafa, Lawal M. Visitors' response to extraneous noise in countryside recreation areas. Noise Control Engineering Journal, 58(5), 2010, 484-492.

[15] Watts G. R.and Pheasant R. Identifying tranquil environments and quantifying impacts. Applied Acoustics 89 (2015) 122-127.