Perceived Tranquility in Groningen

predicting tranquility scores with an online questionnaire

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Summary:

In this study, the formula proposed by Cassina et al. (2018) to predict tranquility scores in public spaces was subjected to validation by using an online questionnaire, that included three parks and one inner city alley in the city of Groningen. Other soundscape research indicated that more variables than originally included could be of influence on the tranquility scores given by participants, such as certain visual elements, age, and the meaning participants give to the word 'tranquility'. By including a location in the study that was not commonly seen as a place where people go to experience tranquility, the influence of visual elements marked as 'positive' could be established; for the other two mentioned variables, no significant evidence could be identified. The performance of administering the questionnaires online, instead of on site, was evaluated with the Cassina formula - the results showed that participants experienced the environmental sounds played in the questionnaire as loud as they should have heard them, validating the research method.

1. Introduction

In the field of soundscape, research is currently a very time consuming activity. Soundscape is defined by Southworth (1967) as the acoustic environment as perceived by humans, in context. Since human perception is part of its definition, research on this topic is almost always affected by human limits. It takes a lot of time to conduct surveys with humans, and therefore research possibilities are limited. Because of this, researchers are looking for a way to predict how humans will think about certain areas, especially places which are designed to relax, such as parks and squares.

In 'Audio-Visual Preferences and Tranquillity Ratings in Urban Areas', Cassina et al. (2018) proposed a method to help identify and quantify the effects of certain parameters on the level of tranquility of quiet areas within the urban space. Via a questionnaire, data was obtained on how people perceived certain areas that were expected to have a relatively high tranquility rate (parks, city squares, etc.) while simultaneously recording audio and 360 degree video in a fixed point in the area. By using the data gathered from the questionnaires, they aimed to create a model, using linear regression, that can predict to calculate the (subjective) value of 'perceived tranquility' of an area with measurable variables, listed below.

$$TS = 6.4 - 0.047\ LA_{10} + 0.189\ SSP - 0189\ SSN - 0.514\ EVN$$

TS= tranquility score
LA_{10} = adjusted sound level (dB(a)) that is exceeded 10% of the time
SSP = presence of positive sound sources (can be either 0 or 1)
SSN = presence of negative sound sources (can be either 0 or 1)
EVN = presence of negative visual elements (can be either 0 or 1)

The tranquility model is in need of validation in more different contexts, such as other types of areas, and is in need of more objectification. Presence of water, trees or parked cars, as well as the sound of animals, bicycles or aircrafts is an objective measure, but determining the 3 most prominent sound sources, or visual elements is still something that differs from person to person. This research aims to validate and/or improve the proposed formula by Cassina et al. (2018), by using an online questionnaire that features several areas in the city of Groningen. The central question of this research can therefore be phrased as:

Is the formula, proposed by Cassina et al., to calculate the perceived tranquility of an area, also accurate for parks and quiet areas in (the inner city of) Groningen?

With sub-questions:

- *Does age play a role in predicting the perceived tranquility?*
- *What is the influence of positive visual elements on the perceived tranquility?*
- *Can Cassina's formula be used to validate the sound-related data gathered by online questionnaires?*

2. Theoretical framework

Input for Cassina's formula was gathered via questionnaires. To determine the value of SSP, SSN and EVN, participants were asked about the 3 most dominant sound sources and visual elements of the area they were in. Mentioning of one sound source classified as positive by a participant would lead to a SSP-value of 1, and so on. In another part of the survey, people were asked about the presence of certain sound courses and visual elements, and whether they thought those would be pleasant, unpleasant, of neutral; the complete classification is illustrated in Table 1.

Sound sources		**Visual elements**
Water		*Wind*
Grass/trees		*Water*
Playground	**pleasant**	*Animals*
Monumental buildings		*Voices/steps*
People		*Music*
Sports equipment		*Cafés/stores*
Animals	**neutral**	*Bicycles*
		Bells
Passing cars		*Cars*
Parked cars		*Mopeds*
Litter	**unpleasant**	*Aircrafts*
Construction site		*Machineries*

Table 1: classifications of visual elements and sound sources as described by Cassina et. al. (2018)

Brambilla et al. (2013) took a similar approach in gathering data: they also used questionnaires and fixed points to record their objective data; the only difference being that they used multiple spots in each park to conduct these measurements. Their aim was very similar to that of Cassina et al.: to gain insight in the correlation between the perception of the environment and soundscape on one hand and on the other acoustic parameters. Even though the they did not find any significant relations between these two, they did find that, even though all 3 researched parks have average sound levels above the lawful limit of 50 dB, the parks were still perceived very tranquil by participants.

This might be due to L_{eq} (average sound levels) not being a very good predictor of 'quietness' due to being relatively susceptible to peaks. They also propose a method to determine the 'type' of park, by using the unweighted spectrum centre of gravity and N_5 (a value used because of its correlation to the perception of loudness of sudden sounds).

The proposed model of Cassina et al. (2018) states that only negative visual elements have an impact on the perceived tranquility. However, one of the main conclusions of the article of Brambilla et al. (2013), is that in some cases visual elements have more influence on the (positive) experience of the park and its soundscape, suggesting that the perceived tranquility might also be influenced by this.

Both articles do not account for differences in perspective of people from different ages. Cassina et al. (2018) discard age as a non significant factor in predicting the perceived tranquility, and Brambilla et al. (2013) merely note the age distribution of their data group. However, a big difference in the datasets is noticeable: Cassina et al's data is mainly gathered from people below 35, whereas Brambilla et al's sample consists of a lot of people over 35 and even over 65. This might explain some of the differences in conclusions in these two articles, but further research is needed on this.

Filipan et al. provide extra insight in their research on the perception of the word 'tranquility' itself (2017). They carried out questionnaires in order to determine the differences in emotional value that people have with the word 'tranquility' in relation to a park. They determined 3 different groups: a group that perceives a tranquil area as a place to meet people, a group that perceives it as a place to appreciate nature, and one that sees it almost parallel to silence. The last group, they note, is significantly older than the first two mentioned. This suggests that age might play a significant role in the perception of the word tranquility, and therefore also in the perception of the area.

Combining the conclusions from these researchers creates several interesting elements that needed further investigation, which this research aims to accomplish. Specific elements of the proposed formula of Cassina et al. (2018) were looked at, following the aforementioned conflicts of conclusions following from Filipan et al. (2017) and Brambilla et al. (2013).

Since the data gathering possibilities were limited at the time of this research during the coronavirus, on-site research was neither permitted nor possible. Therefore, another approach was taken to gather data; participants filled out online questionnaires. The research of Cassina et al. (2018) also included a segment where they test if an experimental setup in a laboratory can give results on the questionnaire that are similar with statistical significance to the questionnaires that were done in the field. With their setup, results proved to be insufficient for reliable results, as the data obtained via this method differed too much from the original dataset. The goal of the questionnaire build was therefore to approach a real visit to the area as best as possible; this is further explained in sections 3.2 and 3.4.

2.1 Hypothesis

The researcher's expectations, prior to conducting the research, was that more significant influences on the Tranquility would be found than just the factors described in the formula. It was however anticipated that the TS that followed from the formula would prove to be relatively accurate in parks. As explained before, Brambilla et al. (2013) suggest that positive visual elements could also have a positive impact on the TS, instead of only the negative ones. The expectation of the researcher was that the conclusion drawn by Cassina et al. (2018) could have been influenced by the fact that only parks and squares were included in the survey. An alleged influence of age on the TS derives from the findings of FIlipan et al (2013); the researcher expects that if a significant difference in 'meaning' of the word tranquility can be found between age groups, a difference in TS might be found as well. Expectations on the usefulness of the formula to validate the online questionnaire are more or less tied to the expectations of the overall performance of the formula.

2.2 Conceptual model

The conceptual model that will be used in this research can be seen in Figure 1. It shows that the tranquility score given by participants is influenced by what they think is a tranquil place; this is quantified by Cassina et al. through certain variables (the continuously lined arrows). Dotted lines are possible correlations, which were investigated in this research. These were added to the model on the basis of results found by Filipan et al. (2017). and Brambilla et al. (2013), which contradict the fact that only the 3 variables included in the formula would have an influence on the TS. EVP stands for positive visual elements, and is one of these variables to be investigated in this research.

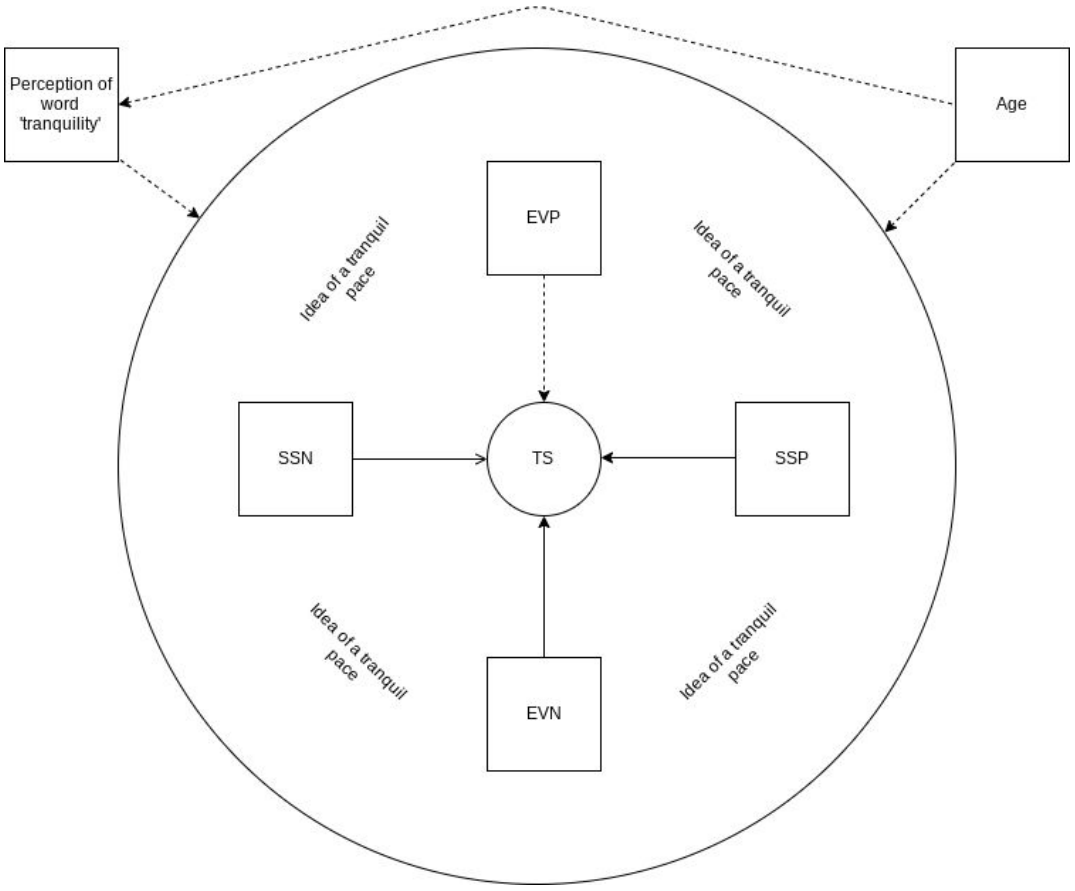

Figure 1: conceptual model, based on the models and theories of Cassina et al. (2018), Brambilla et al. (2013) and Filipan et al. (2017).

3. Method

3.1 Research locations

Sound pressure level data needed to calculate the predicted tranquility score, as well as audio and video material used in the questionnaire, was collected at 4 different research sites in the city of Groningen, visible in Figure 2 on the next page. For each location, a short description is provided below.

(1) Martinikerkhof - This area, like the name suggests, used to be a cemetery, until the municipality banned burial sites within the city walls. It has had several functions since, leading to being used as space for parking before the city centre of Groningen was declared car-free. After this it has been converted into a small area of green, surrounded by the church and several monumental buildings.

(2) Noorderplantsoen - one of the bigger parks in Groningen, which, due to the roads going through the whole park, is very often used by cyclists. The hills, ponds and trees that give the park its characteristic look make for good noise barriers and some grass patches and an arbour in the middle of the park make for an ideal place to relax. The specific location chosen for this research (given that the Noorderplantsoen is a fairly big area) features two fountains and is situated near a main road that crosses the park.

(3) Sterrebos - being one of the oldest parks in Groningen, the Sterrebos may not be as quiet as it once used to be. Its original function, being a ‘sterrenbos’ (a forest area with a star shaped avenue pattern, mainly used for hunting), is long lost; the park was remodeled in the late 19th century. The park is now surrounded by train tracks and two busy roads very closeby, not to mention the current remodeling of the ring road. An interesting site to investigate for this research.

(4) Lutkenieuwstraat (Control site) - to properly see if visual elements only have a negative impact on the perceived tranquility, it was deemed useful to use a ‘control’ like area in the inner city which is quiet, but lacks the positive elements of a park. This alley, that leads nowhere important and has no particularly important or notice worthy buildings in them, fitted this purpose. A lot of birds can be heard in the area, making for an even better comparison between the parks (where this is also the case) and the control site.

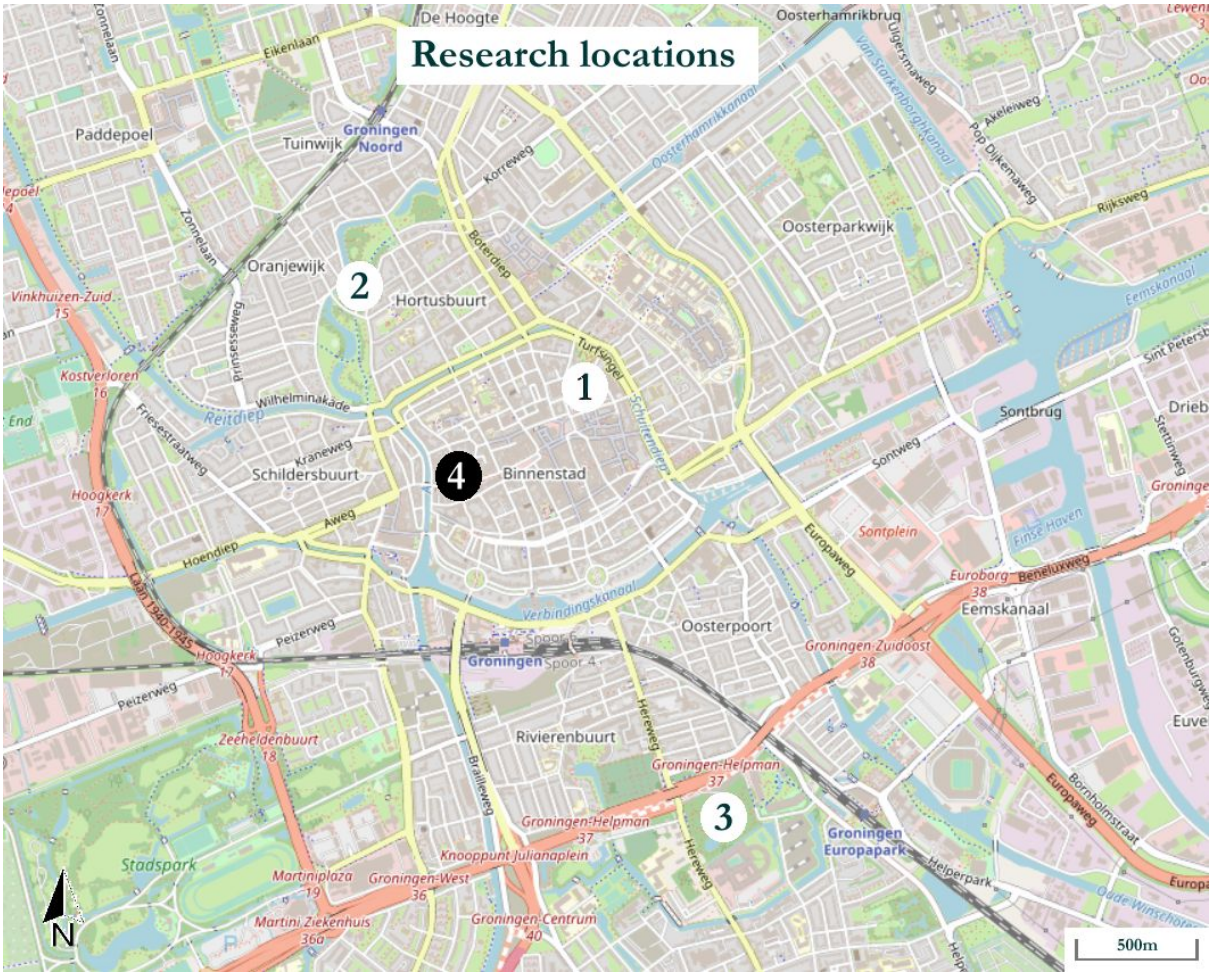

Figure 2: a map of the inner city of Groningen, with all 4 research locations marked. The 'control' location is marked with a black dot.

3.2 Questionnaire

The questionnaire started by strongly recommending (but not requiring) that participants use headphones, and not the inbuilt speakers of their device, and asked the participants what they would be using to listen to the environmental sounds. A quick calibration followed, to make sure that participants will be able to hear the environmental sounds properly and which clarifies that they should not adjust the sound level of their device during the questionnaire. This calibration was based on the perception of the participant, as research of Sudarsono and Sarwono (2018) suggests that such a method is feasible for getting representative results. Choosing to not exclude participants that do not use headphones was mostly done in order to ensure that a greater number of people would complete the questionnaire (see also section 5.4).

In the main part of the survey, participants were asked to answer the location specific questions that are derived from the original enquête that Cassina et. al administered for two of the four locations. Participants were not asked to fill in the questions for all four locations, because this would almost double the length of the questionnaire, to an estimated completion time of 18 minutes. Average completion time for the final version (excluding 8 participants who needed between 25 minutes and two days for completion) was just under 11 minutes; data from Qualtrics, as well as research has shown that a survey length of under 12 minutes lowers the risk of participant break-off in online surveys (Qualtrics, 2020; Galesic & Bosnjak, 2009). After this section of the questionnaire is complete, the not-location specific questions of the original questionnaire, plus the added question about the perception of the word ‘tranquility’.

For each location, the video of the area was shown at the top of the page, with the questions regarding that area listed below. Photos of that area were used as a background, and the sound recording (of approximately two minutes) were played on a loop. As soon as they answered all questions about the site and continued the survey, a new video would start and the corresponding sound file would be played as well. The questions was largely modelled after the one used by Cassina et al., to ensure their model could be tested properly. Since the questionnaire was be administered online, location-specific questions were taken out.

The participants were given a notice before the questionnaire that their answers will be anonymously processed and that they could stop participating at any time. Since the questionnaire did not require the participants to fill in their first or last name, (email) address, or any personal details that could be traced back to them, the survey did not ask for specific consent to store their data,

3.3 Equipment and distribution channels

LA_{10}, as well as LAeq and other sound related descriptives used in the analysis of the questionnaire data, were gathered via use of the ‘Noise Capture’ mobile application installed on a Nokia 6, calibrated with an official sound level meter. This was not only done for the test location, but around the whole park area, so that a Tranquility-score map could be composed. Sound files for the questionnaire were recorded at the same time via the ‘Voice Recorder’ mobile application, installed on a Samsung Galaxy A50; an attempt was made to use both apps simultaneously on the same device, but this proved to be impossible because

of limitations within the Noise Capture app, demanding full access to the microphone of the used device. For each location, 120 seconds of continuous sound was recorded. For each of the test locations, 30 seconds of video was recorded using the Samsung Galaxy A50, photos were made using both the Samsung and Nokia.

The questionnaire itself was built in the 'Qualtrics' environment, using in-built functions as well as HTML, CSS and Javascript programming; use of HTML was needed to play, hide and loop the sound file that was recorded for each location, and to make sure that the video for each location would be correctly embedded, muted and looped. A combination of Javascript and CSS was needed to set a different background, where photos of that specific site were displayed, for each location.

The survey was distributed via various social media channels (Facebook, Whatsapp and LinkedIn). An attempt with on-site QR-code distribution was also made, but this resulted in only 1 response.

3.4 Processing data & validation

To test the validity of the predictions given by the formula, statistical analyses was used: since the TS scores were not found to be normally distributed for any location (using the Shapiro-Wilk test), a Wilcoxon signed rank test was used to compare the individually calculated TS for each participant with the actual given TS. For certain variables, a Kruskall Wallis test was performed to check for a possible influence on TS.

Also, to replicate the original study, a regression model was used to test the correlation between perceived tranquility and the independent variables used in the model, as well as age positive visual elements and all other variables. All significant variables were composed into one linear regression model, from which newly insignificant variables were removed until only variables with $p<0,05$ remained.

To try and validate the means of using an online questionnaire, a separate test was used. Despite of the calibration method that was added to the questionnaire (following Sarwono (2018), variations in volume might still have occurred between participants. To account for this difference, an estimate of the LA_{10} experienced by participants was calculated from the gathered data, using a rewritten version of Cassina's formula. Since 3dB is assumed to be the smallest noticeable difference for inexperienced listeners (Stevens & Poulton, 1956), a variation of 3dB was considered to be acceptable between predicted and measured LA_{10}. The re-written formula for this purpose is shown below:

$$LA_{10} = \frac{6.4 + 0.189\,SSP - 0189\,SSN - 0.514\,EVN - TS}{0.047}$$

4. Results

The survey was completed 111 times, collecting a total of 222 valid responses. In the last stages of data collection, a feature was added in the questionnaire to grant people who completed the survey once, the opportunity to fill in the questionnaire for the two locations they were not shown the first time; 7 people used this feature. General descriptives of the participants are listed in Tables 2 and 3 below. A clear sampling bias is visible when looking at Table 2. This can be seen as a direct effect of the (successful) distribution methods of the survey, which limited the sample mostly to the social network of the researcher.

	< 18 years		*18-26 years*		*27-35 years*		*36-50 years*		*51-65 years*		*> 65 years*		*Total*
Male	4,00%	2	30,00%	15	18,00%	9	20,00%	10	18,00%	9	10,00%	5	50
Female	4,92%	3	44,26%	27	4,92%	3	16,39%	10	22,95%	14	6,56%	4	61

Table 2: sample distribution by age and gender.

	high school		*associate*		*graduate*		*postgraduate*		*Total*
Male	6,00%	3	12,00%	6	34,00%	17	48,00%	24	50
Female	3,28%	2	4,92%	3	49,18%	30	42,62%	26	61

Table 3: sample distribution by education level and gender.

Following answers given by participants at various sites, some sources were classified differently than in the original research (visible in Table 1). These sources are marked with asterisks in Table 4, which gives an overview of the most identified sources for each location. Why these sources were treated differently is explained below:

- In the Noorderplantsoen 64% of people who marked music as one of the three dominant sound sources also noted it as a factor reducing the tranquility of the area. This led to the reclassification of ‘music’ for this location from positive to negative sound source.
- At the Lutkenieuwstraat (the control site), a lot of people a lot of people marked ‘monuments / historic buildings’ as one of the three most influential visual elements, although no actual monuments or historic buildings are visible during the video and photos (apart from a glimpse of the top of the martini tower on one of the 4 background pictures). The positive classification of this visual element can therefore be questioned for this location; one respondent described the “concrete jungle” reducing the tranquility of the area, and 4 people used the ‘other’ option in the visual elements section to specifically refer to ugly buildings. It has to be noted that a lot of people did not specifically comment on the buildings however; therefore, the presence of (historic) buildings will be seen as a ‘neutral’ element for this location, rather than a positive one.
- A similar correction for the presence of bicycles in the Lutkenieuwstraat was done: instead of attributing is with ‘neutral’ status, it was given a ‘negative’ status, to better

reflect the amount of people who specifically indicated that they thought the bicycles reduced the tranquility in the area.

- For the Noorderplantsoen and the Sterrebos areas, the visual element ‘people’ was given a ‘negative’ attribute (marked with a double asterisk), while leaving it as a positive (or neutral) attribute for the Martinikerkhof. Because this is a clear deviation of a universal method, which is what Cassina et al. aim for and can be debated, this is further explained in the discussion (section 5.2).

1. Martinikerkhof	**2. Noorderplantsoen**
dominant sounds:	*dominant sounds:*
1 animals	1 natural sounds (water)
2 natural sounds	2 voices
3 road traffic	3 music*
dominant visuals:	*dominant visuals:*
1 plants / flowers / trees	1 plants / flowers / trees
2 monuments / historic buildings	2 water (fountain)
3 people	3 people**
3. Sterrebos	**4. Lutkenieuwstraat**
dominant sounds:	*dominant sounds:*
1 animals	1 animals
2 road traffic	2 road traffic
3 voices	3 voices
dominant visuals:	*dominant visuals:*
1 plants / flowers / trees	1 parked Bicycles*
2 water (pond)	2 parked Cars
3 people**	3 buildings*

Table 4: most dominant sound sources and visual elements for each test location.

4.1 Effect of age and visual elements on tranquility perception

First, a simple linear regression was done to predict TS based on LA_{10}, the most objective measure in the formula. A significant regression equation was found when including only the parks ($F(1,167) = 14,208$, $p<0,001$), with an R^2 of 0,078. Since all linear regressions in the research of Cassina et al. (2018) are performed with at least one noise descriptive, all subsequent linear regressions were performed together with LA_{10}. Results from these regressions can be found in Table 5.

Variable	*only parks included*	*all data (with control)*
SSP	XXX*	0,07
SSN	0,04	0,02
EVN	0,07	<0,01
EVP	0,59	0,05
Age	0,96	0,85
Importance of peace and quiet at location	<0,01	<0,001
Dominance of traffic noise	<0,001	<0,01
#attributes decreasing tranquility	0,03	0,04
Pleasantness score	<0,001	<0,001

Table 5: p-values for variables following from linear regression with LA_{10}, Included variables were either significant or focus of one of the research (sub)questions. marked in red are p-values for insignificant regressions

Only 1 of the 222 responses did not include identification of a positive sound source. Proper analysis for this variable can therefore not be done, especially since the model assumes that if there would be a significant relationship between SSP and TS, it would be a negative one (that particular participant scored the location fairly high on TS). This variable will therefore not be included in further regressions.

Also, as expected, the Pleasantness score is very highly correlated with the tranquility score (Cassina et al. also found this). EVP was found to not have a significant correlation with TS when only including the parks, but by adding the control site to the sample, the variable does become of significant influence. Age, however, does not play any role in predicting TS.

To check for differences in TS-scores for the three different groups identified by Filipan et al. (2017), A Kruskall Wallis test was performed. No difference between the three different groups was found for the dataset as a whole, but a significant difference ($p=0,04$) was found for the Noorderplantsoen, where the ‘meeting people’ group gave an average TS of 4,33 (against the 2,79 average). No age differences were visible within the 3 identified groups.

4.2 Model validity & online accuracy

Since the aim of the perceived tranquility predicting formula of Cassina et al. (2018) is to limit the amount of subjectivity that is usually involved in soundscape research, the formula was tested with these indicators for every participant, shown in Table 4 (leading to TS(u)), as well as with the 3 most important factors identified by each individual participant (leading to TS(i)). Both are used for different validation processes of the model:

As mentioned before, the Shapiro-Wilk test showed that for none of the test locations, TS-scores were normally distributed. Therefore, a Wilcoxon signed rank test was performed, comparing TS(i) with TS. With just data from the parks, an asymptotic significance of 0,734 was found, indicating that no significant difference can be found between the prediction and the actually given scores. However, performing this same test for the Lutkenieuwstraat shows an asymptotic significance of 0,018. This indicates that the formula does not accurately predict TS for the control site.

This same pattern is visible when calculating the predicted TS and LA_{10} with Cassina's formula (visible in Table 6). For the park areas, differences in LA_{10} are within the acceptable range of 3dB(a), validating the use of online questionnaires for this research. The control site shows too much deviation from the actual measurements co be considered accurate; this can be attributed to the formula itself, and not to the research method.

Location	*predicted TS(u)*	*average TS*	*predicted LA_{10}*	*measured LA_{10}*	*difference LA_{10}*
1. Martinikerkhof	3,60	3,57	60,2 dB(a)	59,6 dB(a)	0,6 dB(a)
2. Noorderplantsoen	2,86	2,79	65,8 dB(a)	64,3 dB(a)	1,5 dB(a)
3. Sterrebos	3,07	3,13	58,7 dB(a)	59,9 dB(a)	1,2 dB(a)
4. Lutkenieuwstraat	3,25	3,00	61,4 dB(a)	56,1 dB(a)	5,3 dB(a)

Table 6: predicted and actual values for perceived tranquility and LA_{10} at tested sites.

Using the Cassina formula, a soundscape map for the 'tranquility' attribute was created for each of the park areas. Since these parks are fairly small (except for the Noorderplantsoen, where only a part of the total park is modelled), it was assumed that dominant sound sources and visual elements do not change within the park. The results of this model-based mapping can be seen in Figure 3.

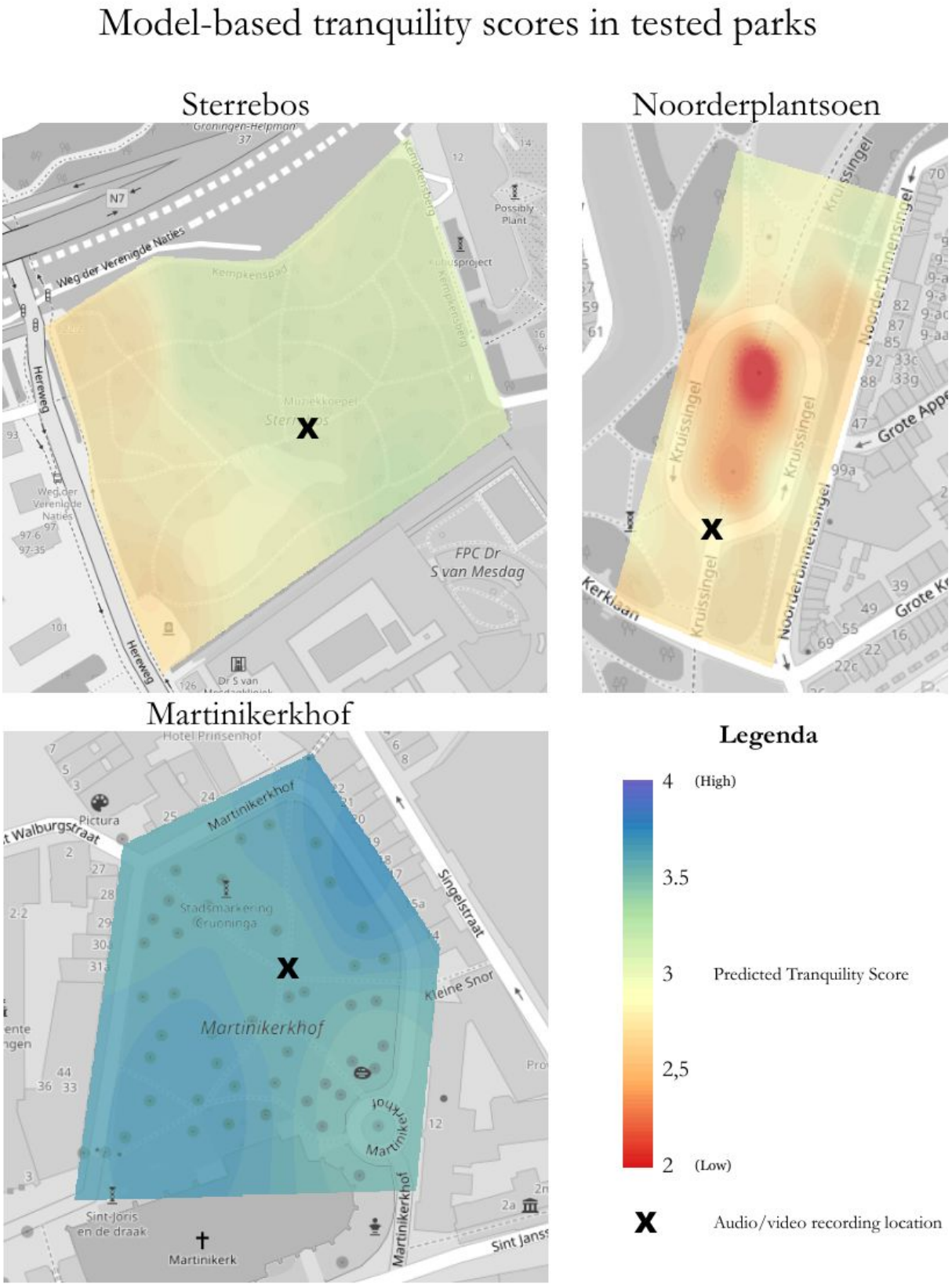

Figure 3: Model-based tranquility scores for all 3 parks included in the research, based on the formula from Cassina et al. (2018) and measured values of LA_{10}..

4.2.1 Proposed formula

Variable EVP loses its significance when combined with the other variables; therefore, EVP is not a usable variable to add to the model, to account for positive visual (park-like) elements. The question “How important are peace and quiet in this place?” also offers a clear distinction between the park areas and the control group, and adding this question to the regression model instead of EVP leads to stronger correlations for the model as a whole.

As discussed before and shown in Table 5, other predicting values were also found to have a significant influence on TS-scores - one of which showing stronger correlations than similar predictors already present in the model. A multivariable linear regression with LA10, SSN and the importance of road traffic will render SSN as not significant. Other variables mentioned in 4.2 proved to not be significant when added to the model. Result of the linear regression can be found in Table 7.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	6,610	1,308		5,055	,000
	How important are peace and quiet in this place?	,365	,100	,232	3,634	,000
	EVN (i)	-,407	,142	-,183	-2,877	,004
	The importance of road traffic as an element of the soundscape	-,208	,0059	-,228	-3,502	,001
	LA10	-,062	,022	-,188	-2,848	,005

a. Dependent Variable: On a scale from 1 (for nothing) to 5 (extremely) how quiet is this place? - Tranquility

Table 7: multivariable linear regression with LA_{10} and other significant variables that led to the highest value of R.

As mentioned before, positively rated sounds were not included in analyses because all but one participant identified them. It could be added to the LA_{10}-variant of the model (using the coefficient-value found by cassina and subtracting that value from the constant), resulting in the following formula:

$$TS = 6.421 - 0.062\ LA_{10} + 0.189\ SSP - 0.407\ EVN + 0.365\ IPQ - 0.208\ IRT$$

In this formula, **IPQ** is the importance of peace and quiet in this area that was indicated by the participant (ranging from 1 for irrelevant, to 3 for very important). **IRT** is the importance of road traffic (ranging from 0, when not marked in top 3 sound sources, to 3, when marked as most important sound source in the area)

Since LA_{10} is a descriptive mostly used to indicate traffic noise, a model with LA_{90} was also tested (in an attempt to cover more aspects of the soundscape as a whole): the predictor-value for this model (R=0,402) is slightly higher than for the LA_{10}-variant (R=0,401). The significance of other predictors changes slightly, but remains within the range of significant correlations. Results of this regression model are listed in Table 8.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	4,050	,463		8,752	,000
	How important are peace and quiet in this place?	,328	,099	,209	3,316	,001
	EVN (i)	-,366	,144	-,164	-2,536	,012
	The importance of road traffic as an element of the soundscape	-,225	,061	-,246	-3,667	,000
	LA90	-,024	,008	-,195	-2,868	,005

a. Dependent Variable: On a scale from 1 (for nothing) to 5 (extremely) how quiet is this place? - Tranquility

Table 8: multivariable linear regression with LA_{90} and other significant variables that led to the highest value of R.

Adding the SSP-variable to this formula cannot be done, since coefficients for the descriptives that are present in the formula change when substituting LA_{10} for LA_{90}. Therefore, using LA_{90} instead of LA_{10}, the following formula can be composed:

$$TS = 4.050 - 0.024\ LA_{90} + 0.328\ IPQ - 0.366\ EVN - 0.225\ IRT$$

5. Discussion

5.1 Useability of proposed formulas

A formula to predict the perceived tranquility is more valuable when most of the variables are objective measures. As discussed before in section 4.1 (and will be discussed in 5.2 and 5.3), the classifications given by Cassina et al. (2018) to certain elements of the soundscape did not match with data found in this research. It can therefore be argued that the two 'new' variables IPQ and IRT would be more usable, because there is only one level of subjectivity related to the variable; for variables like EVN, two levels of subjectivity are in play: the 3 most dominant sources, and if those sources are positive, neutral or negative influences.

However, these newly introduced variables seem to lose accuracy when they are not used as an average value, but treated as a round number (by taking the modus (IPQ) or the rank listed in Table 4 (IRT)); That this causes unwanted drift in predicted TS, particularly for the LA_{90}-variant of the proposed formula. visible from Table 9. It can therefore be debated how useful these variables are, since the binary variables proposed in the original formula are less subjected to sample size.

Location	*average TS*	*Prediction Cassina* *(TS(u))*	*Proposed LA_{10}* *(average / rounded)*	*Proposed LA_{90}* *(average / rounded)*
1. Martinikerkhof	3,57	3,60	**3,55** / 3,44	**3,49** / 3,39
2. Noorderplantsoen	2,79	2,86	**2,87** / 2,95	**2,81** / 2,90
3. Sterrebos	3,13	3,07	3,05 / **3,17**	**3,11** / 3,21
4. Lutkenieuwstraat	3,00	3,25	3,10 / **3,04**	**3,02** / 2,94

Table 9: comparison between the original formula and the two proposed formulas from section 4.4, with both average and rounded values (most accurate version of the proposed formula is printed bold) for IPQ and IRT.

It also has to be noted that road traffic was the only largely identified negative sound source in this sample; noise from airplanes, construction sites or trains would not be included in the proposed formulas. If IRT could be altered to represent the importance of all negative sound sources, is something that further research would have to determine.

5.2 Presence of people

As mentioned in the results, a significant irregularity is noticeable in the perception of 'people' at various sites; there seems to be a huge difference between the locations where Cassina's formula did or did not give a reliable prediction. For the Noorderplantsoen, 41% of the respondents noted that the presence of people in the area had a negative effect on the tranquility, and for the Sterrebos, 26% of the respondents did this; both of these areas showed a significant difference in predicted and actual TS. 16% Of respondents noted that 'people' reduced the tranquility of the Martinikerkhof, and 9,4% for the Lutkenieuwstraat (the only location in which 'people' was not one of the three dominant visual elements). Other possibly relevant descriptives for this phenomenon, together with the predicted and actual

TS can be seen in Table 10 below. Marking people as ‘negative’ corrects the results for the Noorderplantsoen and Sterrebos to be within acceptable error margins, but the the prediction for the Martinikerkhof loses its accuracy with this.

Location	*‘people’ as dominant visual element*	*‘People’ marked as reducing tranquility*	*‘People’ vs total indicated reducing tranquility elements*	*TS(u) (‘people’ negative)*	*Actual TS*
2. Noorderplantsoen	83%	50%	19%	3,38 (2,86)	2,79
3. Sterrebos	63%	41%	17%	3,58 (3,07)	3,13
1. Martinikerkhof	45%	36%	12%	3,60 (3,09)	3,57
4. Lutkenieuwstraat	30%	25%	7%	3,25	3,00

Table 10: indications on ‘people’ as a negative visual element. The most accurate version of TS(u) is underlined.

Since the questionnaire did not ask people about neutral or positive feelings towards the presence of people, we cannot determine with certainty to what extent people were seen as a negative impact on the visual environment; it is worth noting that very few people indicated they would like to hear people’s voices to increase the tranquility, with 3,6% for the Noorderplantsoen and Sterrebos, and 7,4% for the Martinikerkhof and Lutkenieuwstraat. These findings, together with the difference in accuracy of the TS(u) predictions, suggests that the presence of people in the researched locations can have a negative impact on the soundscape; but only when this presence is sufficiently dominant.

This claim is supported in literature: Research done by Pheasant et al. (2010) found a negative correlation between the tranquility score given by participants to a photo, and the percentage of that photo that was covered by people. This leads to concluding that presence of people is a positive element, up to a certain point, where it becomes a nuisance. This is why an adjustment was made to the ‘people’ attribute for the Sterrebos and the Noorderplantsoen, and not for the Martinikerkhof, as mentioned in the results.

Further research would have to be conducted on finding the most accurate descriptive to determine the ‘threshold’ for the presence of people to become of negative influence on the tranquility, and on how high this threshold would be. Some proposed indicators for this purpose were mentioned in Table 9.

5.2.1 Gender difference

It is also interesting to note that male respondents gave higher scores to the sites with less dominant human presence, and females gave higher scores to sites with more dominant human presence. Although Mann-Whitney test did not show a significant difference in TS for any of the test sites between men and women, the degree to which the presence of people is found important by the participant was found to have a significant negative correlation with TS for males (p=0,03), but not for females (p=0,16). Research of Gilow (2015) supports

these findings, stating that women, tend to avoid places with no social control out of fear, and that they feel less comfortable being alone in a public space when no other females are present in that area. This difference could also be focus for further research.

5.3 Cultural differences

The discrepancy between the findings discussed in 5.1 and the classification of 'people' by Cassina et al. (2018) could be due to cultural differences between Italy and the Netherlands; Agliati et al. (2005) argue that different cultures have different feelings towards a setting where people are not talking. They mention Italy among African and south-American countries as a 'word culture' where silence in conversations is handled as a threat and carries a lot of negative connotations with it. The sound of people in these cultures is therefore seen as pleasant, whereas people from so called 'silence cultures' find more comfort and trust in the sound of 'silence'.

It is not specified in which of these categories Dutch people would fall. The aforementioned research of Pheasant et al. (2010), finding a negative relationship between presence of people and tranquility, was conducted in Great Britain; a culture which is largely similar to the Netherlands. The researcher suspects that in 'word cultures', the percentage of people who would fall in the 'meeting people' group (specified by Filipan et al.) is much higher than was found in this study, affecting the TS of places where a lot of people are present. More research in countries with 'word cultures' would be needed to support this claim. Also, more research on cultural differences influencing the perception of soundscape in general is needed to accurately determine whether certain elements have positive or negative influence on the perceived tranquility, in order to properly use Cassina et al.'s formula.

A temporary solution for both the cultural differences and the aforementioned 'people' threshold problem could be to ask people to classify their feelings towards the 3 important visual and audio sources they identify. This would lengthen the survey that could accurately predict tranquility, but not to an extent where the survey would no longer be usable.

5.3.1 Meaning of 'tranquility'

One of the things that stand out from analysing the non-location specific data is that only 4 people indicated that a tranquil area would be a place to meet people, completely contradicting the findings from Filipan et al (2018). Also, no relation to age and meaning of the word tranquility was fount, despite their research suggesting that the group 'silence' group would contain significantly more older men. In fact, no people over 65 indicated that they would be in the 'silence' group. An explanation for this discrepancy could be found in the aforementioned work of Agliati et al. (2005) on different kinds of language cultures. Jeon et al. (2018) further supports this, suggesting that cultural differences might have an influence on the way that people experience certain sounds and objects.

However, there might also be a translation barrier: tranquility is translated into Dutch as 'kalmte' or 'rustgevenheid'; words that, like the English term, mostly means soothing, calming or relaxing. The word in French, however, translates to apaisant - from the verb apaiser. This verb has also a more social undertone: besides the previously mentioned meaning, the word apaiser can also mean anything from giving fulfillment to stuffing yourself

with food. Jeon et al. (2018) also experience some translation irregularities in their research, where they conclude that they needed a better translation for ‘eventful’ to French.

5.4 Quality of speakers

By looking at comments written by people in the ‘other, namely:’ section, it can be concluded that some people might have misheard subtle elements of the recording; this is probably due to low quality listening devices. Some people, probably with bad quality listening devices, were not able to recognise the music in the audio file of the Noorderplantsoen as such and mistook the beat of the music for footsteps, and one person identified the sound of passing cars in the background of the Sterrebos as being a fountain.

A Kruskall Wallis test was used to compare data from participants using headphones to those who did not; no significant difference was found for any of the locations, despite a visible trend that headphone users gave lower scores to the locations where constant background noise was present (Sterrebos and Noorderplantsoen), and higher scores to the other locations. When only including data from people who used headphones in analyses, significance of all variables drops slightly because of the smaller sample, but none show a remarkable change in significance. Because of this, data from non-headphone using participants was not excluded from analysis.

6. Conclusion

Contrary to what was hypothesised, age was not found have prediction value for TS, both directly and indirectly (no age differences were found in the 3 groups identified by Filipan et al.). Positive visual elements were found to be be of significant prediction value for TS: when including the control site into analysis, a positive correlation becomes significant. However, when combined with other variables than LA_{10} or LA_{90}, the p-value becomes higher than 0,05. This would reject the hypothesis, that the original study did not find a correlation between TS and EVP because all test locations were designed to be tranquil areas to begin with, therefore making sure that positive visual elements were dominant in all these areas. However, another variable (IPQ) was identified to account for the fact that no spaces designed for tranquility were included in the original study, confirming the hypothesis.

The formula to calculate TS-scores, proposed by Cassina et al., is an accurate predictor of actual tranquility scores for parks in Groningen. For a quiet area, which is not designed to be tranquil, the formula predicts less accurate TS-scores. This confirms the hypothesis about the accuracy of the formula. For the park locations, predicted LA_{10} scores lie within 3dB of the actually measured value, thus validating the research method.

Whereas the formula itself is accurate, the proposed universal classifications of visual and audible elements were found to sometimes not predict the feelings of participants towards this element well. Further research is needed to determine the influence of culture and gender on the perception of certain elements of the soundscape. Also, IRT was found to be a better predictor for TS than SSN; further research is needed on the accuracy at locations with other dominant negative sound sources than just road traffic.

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Appendix 1 - List of frequently used abbreviations

EVN = negative visual elements (1 if present at site, 0 if not)
EVP = positive visual elements (1 if present at site, 0 if not)
IPQ = Importance of peace and quiet (3 if 'very important', 2 if 'pretty important', 1 if 'irrelevant')
IRT = Importance of road traffic (3 if most influential sound source, 2 if second most, 1 if third most, 0 if not listed)
LA_{10} = sound pressure level (in dB(a)) that is exceeded 10 percent of the time
LA_{90}= sound pressure level (in dB(a)) that is exceeded 90 percent of the time
LA_{eq} = average sound pressure level (in dB(a))
SSN = negative sound sources (1 if present at site, 0 if not)
SSP = positive sound sources (1 if present at site, 0 if not)
TS = tranquility score
TS(i) = the tranquility score that was calculated for every individual response, using the sound and visual sources that each participant identified themselves.
TS(u) = the tranquility score that was calculated using the most dominant sound and visual sources identified by participants (listed in Table 4)

Appendix 2 - Questionnaire; alterations and translation

the questionnaire is still visible via the link below. To view all locations, indicate that you have taken the questionnaire before, than mark none of the locations in the next window. Forced answers have been turned off, allowing for better inspection of the questionnaire.
https://rug.eu.qualtrics.com/jfe/form/SV_9Zj5CZR7BQWmzWt

After a short introduction of the questionnaire and a quick calibration, 2 of the 4 research locations were randomly chosen by qualtrics to show to the participant. For every location, the following questions were asked. Crossed out are questions from the original questionnaire that were not usable or had to be phrased differently to make sense in an online questionnaire. Words in red are corrections and/or additions to the original.

~~Name of the area~~ (will be used as a variable, but not necessary to include in questions)
~~Atmospheric condition during the interview~~
~~Estimated temperature~~
~~Comfort of the interviewer~~
~~Which is the reason for the visit?~~
How often do you visit this place in real life?

1. every day
2. one or more times a week
3. once a month
4. more rarely
5. ~~tourism~~ I have never visited this place

Can you state, in order of importance, the three sounds or noises that characterize this place?

A. road traffic
B. other transport (train, plane, ...)
C. voices
D. noise from construction sites, machinery
E. natural noises (water, wind, ...)
F. animals
G. facilities / services (air conditioners, boilers, ...)
H. music
I. business activities
J. other (…)

Can you mark, in order of importance, the three visual elements that characterize this place?

A. car in transit
B. cars parked
C. people
D. billboard
E. trash
F. water (fountains, river, ...)
G. facilities / services
H. monuments / historic buildings
I. animals
J. business
K. plants / flowers
L. other (…)

How important are peace and quiet in this place?

1. Irrelevant
2. Pretty important
3. Very important

Is there any element that reduces the tranquillity of this place? If so, which one?

A. car in transit
B. car parked
C. people
D. advertising board
E. trash
F. presence of shipyards / machinery
G. other transport (train, plane, ...)
H. music
I. water (fountains, river, ...)
J. facilities / services
K. monuments / historic buildings
L. animals
M. business
N. plants / flowers
O. other (…)

What elements could increase the tranquillity of this place?

A. people's voices
B. laughter / scream of babies
C. natural noises (water, wind)
D. animals
E. music
F. plants / flowers
G. monuments / historic buildings
H. equipment (games, benches, ...)
I. business
J. water (fountains, river, ...)
K. better cleaning
L. pedestrian area / traffic reduction
M. other (…)

~~After being in this place, how do you feel? 1. more relaxed 2. less relaxed 3. no change~~

How do you judge this place from a noise point of view?

1. very silent
2. quite silent
3. neither silent nor noisy
4. noisy enough
5. very noisy

On a scale from 1 (for nothing) to 5 (extremely) how quiet is this place?

On a scale from 1 (for nothing) to 5 (extremely) how pleasant is this place?

~~How long does it take to reach this place from where you resides / works? 1. less than 15 min 2. 15–30 min 3. 30–60 min 4. more than 1 h~~

~~How do you reach this place? 1. walk 2. bicycle 3. public transport 4. motorcycle / scooter 5. car~~

In relation to the perceived level of noise, how do you judge ~~the environment in which you reside~~ this environment?

1. very silent
2. quite silent
3. neither silent nor noisy
4. noisy enough
5. very noisy

~~Your address~~

The following questions were only administered only once, at the end of the questionnaire. An extra added question, based on the research of Filipan et al., was added here:

-- Which of the following descriptions comes closest to your idea of a tranquil area?

1. a place to meet people
2. a place to appreciate nature,
3. a place where you experience silence.

On a scale from 1 (not at all) to 5 (extremely) how much do you feel sensitive to noise?
~~In relation to weather conditions, how comfortable do you feel this day? 1. not comfortable 2. neutral 3. comfortable~~
~~Can you tell me your age range?~~ What is your age?

1. <18 years
2. 18–26 years
3. 27–35 years
4. 36–50 years
5. 51–65 years
6. >65 years

~~Can you tell me your level of education?~~ What is your level of education?

1. primary school
2. ~~secondary school 1st grade~~ high school
3. ~~secondary school 2nd grade~~ associate
4. graduate
5. postgraduate (master, doctorate)

What is your gender?

1. Male
2. Female
3. Other (...)

The survey was also provided in Dutch - a translation for relevant questions (those where a difference in language could have a nuance difference) are listed below.

Hoe vaak komt u op deze plek?

1. elke dag
2. een of meerdere keren per week
3. een keer per maand
4. bijna nooit
5. Ik ben nog nooit op deze plek geweest

Kunt u, in volgorde van belangrijkheid, de drie meest belangrijke geluiden aangeven die deze plek kenmerken?

A. wegverkeer
B. ander verkeer (trein, vliegtuig, ...)
C. stemmen
D. geluid van bouwplaatsen, machines
E. natuurlijke geluiden (water, wind)
F. dieren
G. faciliteiten / diensten (air conditioners, boilers, ...)
H. muziek
I. bedrijfsactiviteiten
J. anders, namelijk:

Kunt u, in volgorde van belangrijkheid, de drie visuele elementen aangeven die deze plek kenmerken?

A. rijdende auto's
B. geparkeerde auto's
C. mensen
D. reclame
E. afval
F. water (fontein, rivier, ...)
G. faciliteiten / diensten
H. monumenten / historische gebouwen
I. dieren
J. bedrijven
K. planten / bloemen / bomen
L. anders, namelijk:

Hoe belangrijk zijn rust en stilte op deze plek?

1. niet belangrijk
2. redelijk belangrijk
3. erg belangrijk

Is er iets wat de kalmte van deze plek vermindert? Zo ja, wat?

A. rijdende auto's
B. geparkeerde auto's
C. mensen
D. reclamebord
E. afval
F. de aanwezigheid van een haven / machines
G. ander verkeer (trein, vliegtuig, ...)
H. muziek
I. water (fontein, rivier, ...)
J. faciliteiten / diensten
K. monumenten / historische gebouwen
L. dieren
M. bedrijven
N. planten / bloemen / bomen
O. anders, namelijk:

P. er zijn geen dingen die de kalmte op deze plek verminderen

Wat zou de kalmte van deze plek kunnen verhogen?

A. stemmen van mensen
B. gelag / gekrijs van baby's
C. natuurlijke geluiden (water, wind)
D. dieren
E. muziek
F. planten / bloemen / bomen
G. monumenten / historische gebouwen
H. toestellen (speeltoestellen, bankjes, ...)
I. bedrijven
J. water (fontein, rivier, ...)
K. betere schoonmaak
L. voetgangersgebied / minder verkeer
M. anders, namelijk:
N. er is niets wat de kalmte van deze plek zou kunnen verhogen

In relatie tot het waargenomen geluidsniveau, hoe zou u deze plek omschrijven?

1. erg stil
2. redelijk stil
3. niet stil, maar ook niet lawaaierig
4. redelijk lawaaierig
5. erg lawaaierig

Op een schaal van 1 (helemaal niet) tot 5 (heel erg) hoe rustgevend is deze plek?

Op een schaal van 1 (helemaal niet) tot 5 (heel erg) hoe aangenaam is deze plek?

Hoe beoordeelt u deze plek vanuit een geluidsperspectief?

1. erg stil
2. redelijk stil
3. niet stil, maar ook niet lawaaierig
4. redelijk lawaaierig
5. erg lawaaierig

Welke van de onderstaande omschrijvingen past het beste bij uw idee van een rustgevende omgeving?

1. een omgeving om mensen te ontmoeten
2. een omgeving om van de natuur te genieten
3. een omgeving waar men stilte kan ervaren