Verification of emotional taxonomies on soundscape perception responses

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Introduction

Emotions are part of human life and can influence our decision making. Theories of emotion describe it as a complex construct of various classes of evidence [1] or components [2] which includes verbal reports of feelings. Emotions can also be a result of a cognitive response to human interactions to its environment. Here, we address the emotional responses to urban soundscapes also considered as the perceived sonic environment in context. By better understanding how people feel about these sounds, we seek to aid healthier design decisions.

In previous works Cain and colleagues [3] achieved emotional dimensions through a factor reduction obtained from three preliminary experiments using open questions of how and why participants felt about different sounds and locations. Then, the authors summarized results into five dimensions (Calmness and Relaxation; Comfort and Reassurance; Vibrancy and Arousal; Informative; and Intrusiveness and Sense of Self) including their semantic descriptors. Their conclusions were that urban soundscapes have two principal emotional dimensions (Calmness and Vibrancy) which must come together with their semantic descriptors to be adequately expressed [3].

Axelsson and colleagues [4] proposed a model for soundscape perception which has resemblances with Russell's circumplex model of affect [5] and can be considered as a rotation of Cain's dimensions [3]. Authors initially used a predetermined set of 189 adjectives developed from interviews for assessing aesthetic features of photographs that was reduced to 116 words for better representation of soundscape characteristics. The group of words was used in the evaluation of 50 different soundscapes by 100 participants. Variance in the results were explained by three principal components: pleasantness, eventfulness, and familiarity. The small variance of the last component led to its elimination given possible perceived similarities among used soundscapes resulting in a limited application in soundscape assessments. Finally, the authors suggest that outdoor soundscapes can be represented within a two-dimensional space constructed by the two components, pleasantness and eventfulness. These soundscape attributes were later adopted in the soundscape standard ISO 12913-2:2019 in method "A" as the soundscape perceived affective qualities [6].

In this paper, we apply two different emotional approaches from Plutchik [1] and Scherer et al. [2]. Plutchik [1] defined emotion as a complex chain of reactions in the following sequence: stimulus event, inferred cognition, feeling, behaviour, and effect. Their work [1] arranged eight basic feelings into an emotion circumplex colour wheel according to pairs of opposites and similarities of emotional terms such as 'fear / terror', 'anger / rage', 'joy / ecstasy', 'sadness / grief', 'acceptance / trust', 'disgust / loathing', and 'anticipation / surprise'.

In a similar form, Scherer et al. [2] also stablished a circular distribution of emotion terms. However, these authors arranged the words according to a discrete (emotion words) and a two-dimensional (valence and control/power axis) approach. After many enhancements in ten different languages, their work is summarized in the Geneva Emotion Wheel (GEW) that includes 20 emotion terms distributed along four quadrants of the circle varying from positive to negative valence and high to low control. The emotion words are labelled clockwise as follows: 'involvement / interest', 'amusement / laughter', 'pride / elation', 'happiness / joy', 'enjoyment / pleasure', 'tenderness / feeling love', 'wonderment / feeling awe', 'feeling disburdened / relief', 'astonishment / surprise', 'longing / nostalgia', 'pity / compassion', 'sadness / despair', 'worry / fear', 'embarrassment / shame', 'guilt / remorse', 'disappointment / regret', 'envy / jealousy', 'disgust / repulsion', 'contempt / scorn', and 'irritation / anger'. Opposite from Plutchik [1], the more intense the feeling is, the closer to the rim the rating is placed in the wheel [2].

The aim of this work is to see if other emotional models besides the one used in ISO 12913 can be used to evaluate emotional responses to soundscapes. The Emotion Wheels of Plutchick [1] and GEW [2] are used to classify emotions reported during soundwalks in Aachen, Germany, and surveys in Goiânia, Brazil. A principal component analysis helps to extract components that summarize the emotional content which describes the sonic environment.

Methodology

Studied areas

The areas studied are two urban parks from Aachen, Germany denominated Westpark (WP) and Stadtgarten-Farwickpark (CA). This first is a park near to a campus from RWTH Aachen University, and the users are mainly persons who work and study in the university. There are playgrounds, sport courts, a pond, barbecue area, train tracks and major roads nearby. The second is a park near to the city center, surrounded by typical residential areas from Aachen, the users are composed of residents and tourists (Figure 1).

Another area investigated was in Goiânia, central Brazil. Mutirama park is in central Goiânia, surrounded by two secondary schools, a high school, the main interstate bus station of the town, as well as major roads of the city. Inside the park there is also an amusement park (Figure 2).

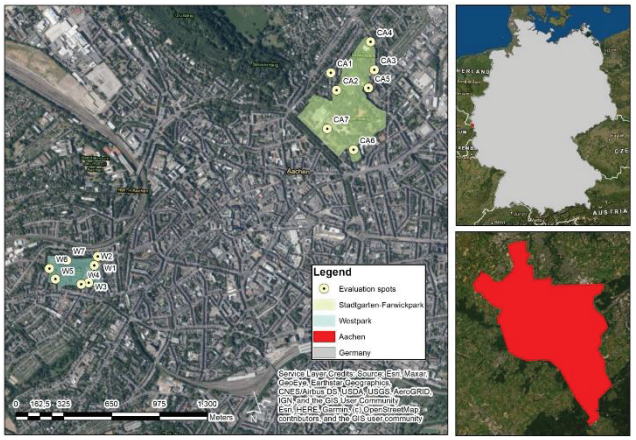

Figure 1: Aachen, Germany: Westpark (WP) and Stadtgarten-Farwickpark (CA).

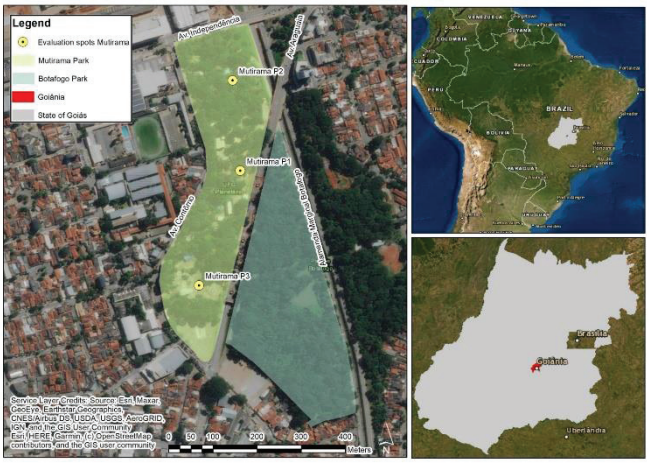

Figure 2: Goiânia, Brazil: Mutirama Park.

Data collection

Subjective data was collected through 30 soundwalks in each park in Aachen and 50 questionnaires in Goiânia. The soundwalks from Aachen generated 360 perceptual responses in each park, of which 87 had emotional evaluation in Westpark and 69 in Stadtgarten-Farwickpark. The questionnaire responses from Goiânia included 85 perceptual responses, of which 79 had emotional content.

In Aachen, open-ended questions asked about which sound source the participant was perceiving [7]. It was possible to report up to four sound sources in each spot investigated. Another question was: 'Does the sound source generate any emotion? If yes, describe in:' [8].

In Goiânia, an open-ended question asked which sounds were the most pleasant and annoying in the sonic environment [9]. Additionally, multiple choice questions were used to classify the identified sound sources in natural sounds, human sounds, mechanical sounds, and other [4] and to identify groups of sensation/emotions through the following options: (a) agitation, stress, not relaxing; (b) calm, tranquility, peacefulness; (c) intimidation, anxiety, nervousness; (d) comfort, safety, reassuring; (e) annoyance, tiredness, boredom; (f) excited, energy, animation; and (g) other: _____ [3].

Data post-processing

Before conducting the statistical analysis, the data were subjected to a dummy coding to allow statistical calculations. In Aachen the sound sources were classified into human, natural and technological sounds [4]. This classification was already done in the data from Goiânia. The described emotions from Aachen were classified according to the taxonomies from Plutchik [1] and Geneva Emotion Wheel (GEW) [2]. Afterwards, a dummy coding was realized on both classifications. The described emotions from Goiânia were originally classified according to Cain et al. [3] and had to be re-classified into Plutchtik [1], as well as GEW [2]. The same procedure of dummy coding was adopted to enable the statistical calculations.

Statistical analysis

A Principal Component Analysis (PCA) was realized with the help of a statistical package IBM SPSS Statistics 26 ®. The data analyzed were the dummy coded questions about emotions description separated in Plutchick [1] and GEW [2]. The assumptions attendance was observed, as follows: variables with continuous level [10]; linear relationship between variables; sample adequacy through Kaiser-Meyer-Olkin (KMO) test; suitability for data reduction and no significant outliers. Then, a confirmation of data reduction was realized by a simulation of components and eigenvalues through a Parallel Analysis [11]. Additionally, the interpretation of the statistical analysis observed a loading cut-off of 0.5 for communalities and component loadings.

Results

Demographic information

In Aachen, the participants were mainly males (53.8%) with an age range from 26 to 35 years old (59%), in which 46.2% were German, 15.4% Brazilians, 7.7% Iranian, and other nationalities like Austrian, Belgian, Dutch, Chinese, Indian, South Korean, Chilean, and North American. In Goiânia, the participants were mainly females (48%) under the age range of 36 to 45 years old, and 100% of the participants were Brazilians (Table 1).

Table 1: Demographic information.

Gender	Aachen [%]	Goiânia [%]
Male	53.8	38
Female	46.2	48
Not specified	-	14
Age range		
18 – 25 y	33.3	26
26 – 35 y	59	22
36 – 45 y	5.1	34
Over 46 y	2.6	18
Nationality		
Brazilian	15.4	100
German	46.2	-
Iranian	7.7	-
Austrian	5.1	-
South Korean	5.1	-
Chinese	5.1	-
Indian	5.1	-
Chilean	2.6	-
Dutch	2.6	-
North American	2.6	-
Belgian	2.6	-

Sound sources classification

The reported sound sources were classified into human, natural and technological sounds [4]. In Westpark and Stadtgarten-Farwickpark most of the reported sound sources were natural sounds. In the Mutirama Park the majority of the reported sound sources were human sounds (Table 2).

Table 2: Classified sound sources.

Classified sound sources	Westpark (N=30, n=87)	Stadtgarten-Farwickpark (N=30, n= 69)	Mutirama Park (N=50, n=79)
Human	21	10	40
Natural	48	37	8
Technological	18	22	31

Principal component analysis

Table 3 shows the results of the PCA of 'human sounds' according to Plutchik from Aachen and Goiânia. The parks from Aachen were analyzed together. Significant results were observed in Aachen and Goiânia. The data from Aachen show a KMO=0.081, χ^2 (10) = 63.621, and $p < 0.001$ through four components which explain 99.1% of the variability of the data. In Goiânia, results show a KMO=0.280, χ^2 (3) = 65.510, and $p < 0.001$ through two components explaining 97.2% of the data variance. The quantity of components was confirmed through a parallel analysis [11]. Components indicated in dark grey are not relevant according to the parallel analysis. Component loadings are shown in Table 3, in which loadings with cut-off over 0.5 are relevant and indicated in light grey.

Table 3: PCA of human sounds for the Plutchik taxonomy.

	Aachen					Goiânia		
Component	1	2	3	4	5	1	2	3
Eigenvalue mean	1.45	1.21	1.16	1.16	0.43	1.77	1.13	0.085
Simulated Eigenvalue mean	1.53	1.21	0.96	0.75	0.53	1.26	0.99	0.74
Joy	-0.987	-0.074	-0.063	-0.049		-0.950	-0.244	
Trust	0.203	0.115	0.209	0.947		-	-	
Fear	0.489	-0.823	-0.241	-0.128		0.052	0.993	
Surprise	0.270	0.217	0.840	-0.409		-	-	
Anger	0.359	0.689	-0.594	-0.188		0.934	-0.303	

The dimension reduction through the GEW for human sounds is presented in Table 4. Like in the taxonomy of Plutchik, the GEW also shows significant results for both cities. In Aachen, the KMO = 0.144, χ^2 (6) = 61.924, and p <0.001 with three components explaining 98.8% of the data variance. In Goiânia, the KMO = 0.077, χ^2 (10) = 93.545, and p <0.001 with four components explaining 99.4% of the data variance.

Table 4: PCA of human sounds for the GEW taxonomy.

	Aachen				Goiânia				
Components	1	2	3	4	1	2	3	4	5
Eigenvalues Mean	1.64	1.22	1.09	0.5	1.45	1.23	1.119	1.09	0.033
Simulated Eigenvalues Mean	1.42	1.09	0.86	0.62	1.44	1.18	0.99	0.79	0.58
Amusement/ Laughter	0.228	0.877	-0.412		0.370	0.698	-0.577	-0.190	
Enjoyment / Pleasure	-0.962	-0.255	-0.074		0.293	0.227	0.891	-0.250	
Irritation / Anger	0.805	-0.565	-0.130		-0.989	-0.063	-0.053	-0.074	
Longing / Nostalgia	0.134	0.287	0.946		-	-	-	-	
Happiness / Joy	-	-	-		0.478	-0.828	-0.233	-0.156	
Worry / Fear	-	-	-		0.148	0.057	0.074	0.983	

Regarding the dimension reduction of natural sounds, just the PCA of Aachen, using the Plutchink taxonomy was significant (Table 5) with KMO = 0.500, χ^2 (10) = 16.209, p < 0.001, and one component explaining 71.5% of the data variance. The GEW taxonomy in Aachen concentrated all emotional answers in two variables. In Goiânia, due to few natural sound responses, the PCA's were not significant.

Table 5: PCA of natural sounds for the Plutchik taxonomy.

	Aachen	
Components	1	2
Eigenvalues Mean	1.43	0.57
Simulated Eigenvalues Mean	1.08	0.91
Joy	-0.845	
Fear	0.845	

Concerning technological sounds, it is possible to see significant results with the use of Plutchik taxonomy. In Aachen, the KMO = 0.084, χ^2 (10) = 93.389, and $p < 0.001$ with four components. In Goiânia, the KMO = 0.314, χ^2 (3) = 58.098, and $p < 0.001$ with two components (Table 6).

Table 6: PCA of technological sounds for the Plutchik taxonomy.

	Aachen					Goiânia		
Components	1	2	3	4	5	1	2	3
Eigenvalues Mean	1.42	1.36	1.11	1.06	0.34	1.87	1.06	0.06
Simulated Eigenvalues Mean	1.44	1.18	0.99	0.79	0.58	1.27	0.99	0.73
Joy	0.000	0.954	-0.278	-0.068		0.052	-0.253	
Trust	0.000	0.049	0.889	-0.451		0.119	0.991	
Fear	-0.845	-0.474	-0.219	-0.058		-	-	
Sadness	0.000	0.036	0.388	0.920		-	-	
Anger	0.845	-0.474	-0.219	-0.058		-0.977	-0.126	

The dimension reduction with the use of the GEW was only significant for Goiânia with KMO = 0.239, χ^2 (3) = 58.978, and $p < 0.001$ resulting in two components. In Aachen due to a concentration of answers in one variable, the results are not significant (Table 7).

Table 7: PCA of technological sounds for the GEW taxonomy.

	Goiânia		
Components	1	2	3
Eigenvalues Mean	1.79	1.21	0.06
Simulated Eigenvalues Mean	1.27	0.99	0.73
Amusement / Laughter	0.549	0.827	
Enjoyment / Pleasure	0.673	-0.727	
Irritation / Anger	-0.986	-0.036	

Discussion

As observed in the results, categories of emotions were highlighted in the PCA's using Plutchink [1], as well as with the GEW [2].

Human Sounds presented significant emotions results through Plutchik in Aachen, by the report of the following emotions: 'joy', 'trust', 'fear', 'surprise', and 'anger'. In Goiânia, the emotions were 'joy', 'fear', and 'anger'. The GEW helped to classify the following emotions in Aachen: 'amusement / laughter', 'enjoyment / pleasure', 'irritation / anger', and

'longing / nostalgia'. In Goiânia, the following categories were highlighted: 'amusement / laughter', 'happiness / joy', 'enjoyment / pleasure', 'irritation / anger', and 'worry / fear'. Regarding natural sounds, significant results were observed just in Aachen through the taxonomy of Plutchik [1] by the emotions of 'joy' and 'fear'.

Technological sounds presented significant results in Aachen for the taxonomy of Plutchik through 'joy', 'trust', 'fear', 'sadness', and 'anger'. For Goiânia, results were through 'joy', 'trust', and 'anger'. The GEW was just significant in Goiânia through 'amusement / laughter', 'enjoyment / pleasure', and 'irritation / anger'.

Conclusions

The aim of this work was to investigate if other emotional models besides the one used in ISO 12913 can be used to evaluate emotional responses to soundscapes.

It was observed that the GEW [2] could help in the classification of emotions according to geographic locations, as observed in Figure 3. In Aachen, there was a concentration of emotional responses for natural sounds and, in Goiânia, for human sounds. Human and technological sounds shared classified emotions in Goiânia.

The Plutchik [1] taxonomy was able to classify similar emotions, in any part of the world for any kind of sound source, as observed in the concatenations of Figure 4.

These results indicate that the choice of emotional model when classifying soundscape responses may depend on the aim of the soundscape study. It is recommended that regional studies should adopt the GEW and for interregional studies the Plutchik taxonomy is preferable.

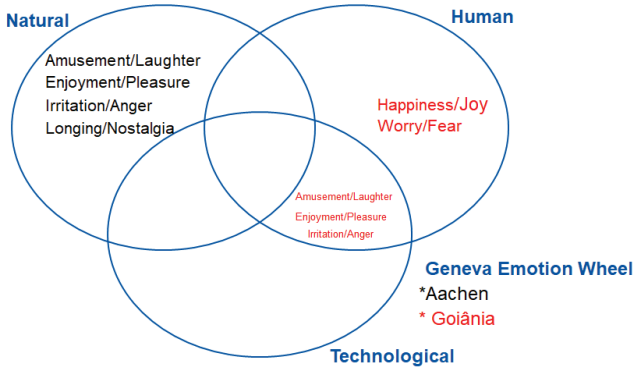

Figure 3: Classification of emotions according to the GEW.

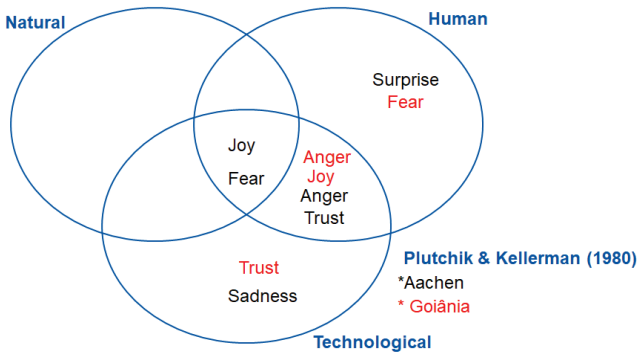

Figure 4: Classification of emotions according to Plutchik.

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