A cross-national comparison in assessment of urban park soundscapes in France, Korea, and Sweden through laboratory experiments

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Abstract

This study aims at examining the effect of socio-cultural context, including language, on soundscape assessments in urban parks. In total, 95 persons took part in three laboratory experiments, conducted in France (30 participants), Korea (30 participants) and Sweden (35 participants). Twenty-eight audio-visual excerpts from recordings conducted in five urban parks were used as stimuli. The participants evaluated soundscape quality using attribute scales provided in their own native languages. Principal Components Analysis produced two principal components of perceived affective quality, *Pleasantness* and *Eventfulness*. There were high levels of similarity in attributes associated with the *Pleasantness* among the three countries, whereas some differences were observed in the attributes related to *Eventfulness*. Two hierarchical cluster analyses were conducted based on perceived dominance of sound sources, and component scores of perceived affective quality. There were no significant differences in clustering results based on perceived dominance of sound sources among the different nationalities. In contrast, discrepancies were found in the clustering results based on perceived affective quality. In particular, perceptual responses to human sounds, birdsong, and water sounds, which are closely related to *Eventfulness,* were significantly different across the three cultural backgrounds. These findings provide empirical evidence of socio-cultural differences in soundscape assessment.

Keywords: Soundscape, urban parks, cross-national, Clustering, perceptual assessment

1. Introduction

The International Standard ISO 12913-1 provides a definition and a conceptual framework of 'soundscape' [1]. It defines the term as an "acoustic environment as perceived or experienced and/or understood by a person or people, in context." Thus, the standard emphasizes the importance of the contexts inferring that when people are presented to a given acoustic environment, individuals may respond differently based on their personal, socio-cultural backgrounds and previous experiences. For instance, sounds that are acceptable in some communities or societies may be perceived as objectionable in others.

Previously, studies on community noise have considered non-acoustic factors, such as personal and social variables, that influence noise annoyance [2–6]. Accordingly, the Community Response to Noise Team (Team 6) of the International Commission on the Biological Effects of Noise (ICBEN) developed general noise reaction questions for the standardization of community noise surveys in order to enable international comparison of survey results across languages [7,8].

Hitherto, it has been impossible to compare the results of soundscape assessments from different countries, because there is yet no internationally agreed standard for the collection of soundscape data. Researchers have investigated how people perceive acoustic environments using adjective attributes in their native language, and various perceptual factors, representing for example hedonic value, temporal variability, and spatial impressions, have been identified [9–14]. Axelsson et al. [11] developed a Pleasantness–Eventfulness model, whereas Cain et al. [15,16] established a Calmness–Vibrancy model, which represents a 45° rotation of the Pleasantness–Eventfulness model. The two underlying components have been commonly identified in several studies across different countries [9,12,14,15,17–19], demonstrating that these components are robust across languages, cultures and environments.

Based on their findings, Axelsson et al. [20,21] developed the Swedish Soundscape-Quality Protocol, which includes eight adjective attribute scales (Annoying, Calm, Chaotic, Eventful, Exciting, Monotonous, Pleasant, and Uneventful) for the assessment of perceived affective quality. On request, the protocol has been translated into some 10–15 languages and used for local research purposes. According to the authors' records, it has so far been used in Argentina, Austria, Belgium, Canada, Croatia, England, France, Greece, Italy, Netherlands, Portugal, Singapore, South Korea, and Spain. However, these linguistic versions are not validated. Thus, there is no guarantee that their results are comparable across languages, in absolute terms. Moreover, the studies have seldom been published in scientific papers. However, some papers are planned to be published in a forthcoming special issue on soundscape assessment.

Even though there are similarities in how people in different parts of the world perceive the acoustic environment, the connotative meaning of words, and linguistic nuances differ from one language or culture to another [3,7,22,23]. For example, there are two different Spanish versions of the Swedish Soundscape-Quality Protocol; one for Spain and one for Argentina. Thus, in order to compare the results of verbal assessments obtained in different languages and to achieve an international standard on data collection methods, it is necessary to consider socio-cultural variations. This shows that cross-national research is essential for the standardization of soundscape assessment.

The main aim was to examine the influence of socio-cultural context, including language, on soundscape assessments in urban parks. Urban parks are among the most important public spaces for sustainable urban environments, providing urban dwellers with places to improve their physical and mental health [24]. They consist of diverse spaces and facilities (e.g., green open spaces, walking paths, children' playgrounds, water fountains, or outdoor theaters etc.) for various social-recreational activities [25]. In addition, the acoustic environments of urban parks consist of various sound sources, including sounds from human activities, traffic, and nature, such as water and bird song, contributing to various soundscape qualities [26–29].

Binaural recordings of the acoustic environments in five urban parks in Paris and Stockholm were assessed in three laboratory experiments, conducted in Paris, Seoul and Stockholm. In the three laboratory experiments, French, Korean and Swedish participants used semantic descriptors in their own native language. Data on perceived dominance of sound sources and perceived affective quality were analyzed and compared between the three countries.

2. Methods

2.1 Audio-visual stimuli

Binaural recordings were conducted and photographs taken in five urban parks, including three parks in Paris, France [André Citroën (AN), Montsouris (MO), and La Villete (LV)], and two parks in Stockholm, Sweden [Observatorielunden (OB) and Kronobergsparken (KR)]. They are popular among the local citizens, and visited frequently.

In order to decide on the locations for the audio-visual recordings, preliminary individual soundwalks were carried out in the five urban parks, based on a methodology that Jeon et al. developed [30]. Two or three co-workers walked along predefined routes in the five parks and freely selected recording locations with distinctive visual and/or auditory qualities. The walks were conducted between 13:00 and 17:00 in June (Stockholm) and October (Paris). In total, 28 recording locations were selected in order to include various soundscape and landscape qualities such as promenades, green spaces, playgrounds, water features, roadsides and squares. Fig. 1 presents aerial views of the five parks and the 28 recording locations. In Paris, eight recording locations were selected in AN, and four in MO and in LV. In Stockholm, five recording locations were selected in OB, and seven in KR.

At each location, the acoustic environment was recorded for a duration of at least 5 min, using binaural, in-ear microphones (B&K Type 4101) and a digital recorder (Zoom H4n). The operator's head orientation was fixed during the recordings, facing the same direction as the views depicted in the corresponding photographs (Fig. 2; see further below). The sampling rate and the bit depth of the audio recording were 48 kHz and 24 bits, respectively. Recording levels were calibrated by a sound calibrator (B&K Type 4231 with adaptor DP-0978). Binaural recordings were conducted to reflect the human binaural auditory system, making it possible to reproduce the 3D spatial characteristics of the recorded acoustic environments [31,32].

For the laboratory experiments, an audio excerpt (1 min) was selected from each of the 28 binaural recordings. Several acoustic indicators were calculated for both the left and right channels of the 28 audio excerpts, including the A-weighted equivalent continuous sound pressure level ($L_{\mathrm{Aeq,1min}}$), statistical levels (L_{A90}, L_{A50}, L_{A10}), temporal variability (L_{A10}–L_{A90}), and low frequency content (L_{Ceq}–L_{Aeq}). The arithmetic mean values of the left and right channels for the 28 audio excerpts are presented in Table 1, along with the urban inter-aural level difference (uILD_2) [33]. The overall sound pressure levels ($L_{\mathrm{Aeq,1min}}$) showed a large variation, ranging from 48.7 to 72.2 dB(A). The difference between the largest to the smallest L_{A10}–L_{A90} and L_{Ceq}–L_{Aeq} values was larger than 10 dB. This shows that a wide range of acoustic environments were recorded in the five parks.

While conducting the audio recordings, the 28 recording locations were also photographed with a digital camera (Canon IXUS 300 HS). For each location, the most representative photograph was selected to be used as visual stimuli in the laboratory experiment. Fig. 2 presents these 28 photographs.

Fig. 1

Fig. 2

Table 1

2.2 Participants

In total, 95 persons participated in the three experiments. Their demographic information is summarized in Table 2. They comprised 30 participants in France (19 males, 11 females), 30 participants in Korea (14 males, 16 females), and 35 participants in Sweden (15 males, 20 females). In order to achieve a homogenous group of participants, a qualified majority were university students. The age distribution of the participants ranged from 18 to 53 yrs. (M_{age} = 26.0, SD_{age} = 7.6 yrs.), with 90.4% of the participants in their 20–30s. The hearing threshold levels of all participants were tested using an audiometer before they took part in the laboratory experiments. All participants from the three countries had normal hearing. In agreement with ethical procedures, the participants were provided written information about the study, and written consent was obtained from all of the participants in all three countries.

Table 2

2.3 Data collection instrument

In the three laboratory experiments, the participants assessed the perceived dominance of sound sources and perceived affective quality. To assess the former, the participants used a 5-point ordinal category scale with the response alternatives: "not heard at all" (–2), "heard a little" (–1), "heard moderately" (0), "heard a lot" (+1), and "dominates completely" (+2). Based on previous studies [26,34], the sound sources were classified as traffic noise, sounds from humans, water, birds, wind, and other sounds (e.g., construction noise, mechanical noise, music, barking dogs and other miscellaneous sounds).

In this study, the Swedish Soundscape-Quality Protocol was employed to assess perceived affective quality using the following eight adjectives: Pleasant, Unpleasant, Eventful, Uneventful, Monotonous, Exciting, Calm, and Noisy. The term ‘Chaotic,’ from the Swedish Soundscape-Quality Protocol, could not be translated into Korean and was replaced with ‘Noisy.’ To ensure that the adjective attributes were homonymous in all three linguistic versions of the data collection instrument, an English version was first agreed. The English terms were then translated into French, Korean and Swedish. For the translation process, the authors from each country compared several adjectives for each English term in their languages, and selected the attributes that seemed to be best corresponding to the concepts in Axelsson’s soundscape model based on the authors’ experience and knowledge of soundscape research [11,35,36]. Besides the English terms, Table 3 presents the French, Swedish, and Korean terms used in the three experiments. The participants assessed the degree to which an adjective applied to their perception of the acoustic environment, using a 5-point verbal scale with the response alternatives: “strongly disagree” (–2), “slightly disagree” (−1), “neither disagree nor agree” (0), “slightly agree” (+1), and “strongly agree” (+2). In addition, perceived visual and overall qualities of audio-visual stimuli were assessed on 5-point scales.

Table 3.

2.4 Procedure

In the three experiments, the acoustic stimuli were presented to the participants through the same type of circumaural, acoustically open headphones (Sennheiser HD 600), at the authentic sound level. The experiments were performed in a testing booth or in a sound-proof listening room, with a background sound level of less than 20 dB(A). While an acoustic stimulus was presented to a participant by headphones, the corresponding visual stimulus was presented on a screen in order to help the participant to imagine himself/herself at the location. This was either a white screen, using a beam projector, or a large computer monitor. The 28 recording locations were presented in an irregular order to every participant, who was free to repeat every sound as many times as he or she wanted. All participants were tested individually.

2.5 Statistical analyses

In order to compare the results from the three countries (France, Korea and Sweden), Principal Components Analyses (PCA) were performed on the rating scale data for perceived affective quality. This resulted in two different PCA solutions. The first solution was based on average data for each country, the second was based on the 95 participants' individual responses. Thereafter the results for the three countries were analyzed further. Relationships between perceived affective quality, perceived dominance of sound sources, and acoustic parameters were explored for the three countries separately based on Pearson's correlation analyses. Cluster analyses were conducted to classify the 28 recording locations based on how the 95 participants perceived them. Clustering solutions were then compared across the three countries. The statistical analyses were performed with the aid of SPSS 23 for Windows, and R (R Development Core Team, 2014).

3. Results

3.1 Principal components of perceived affective quality

For each of the eight attributes of perceived affective quality, arithmetic mean values were calculated for the 28 locations, across the participants. This procedure was repeated for each of the three countries. This resulted in a 28 locations × 24 adjectives data matrix, which was subjected to a PCA (SPSS 23 for Windows). This allowed comparison of how the adjective attributes were used in the three different countries using a common PCA solution (cf. [11]). To identify the optimized orthogonal components, VARIMAX rotation was applied. Two components with Eigenvalues larger than 1 were obtained. Components 1 and 2 explained 59.3% and 26.8% of the variance in the data set, respectively.

Fig. 3 presents the VARIMAX-rotated component loadings of the eight attribute scales divided on the three countries, France (Fig. 3a), Korea (Fig. 3b), and Sweden (Fig. 3c). Most importantly, all vectors in Fig. 3 are long, with their endpoints located close to the periphery of the graphs, represented by unit circles that correspond to the maximum length of the vectors. This shows that the VARIMAX-rotated PCA solution is mainly a two-dimensional plane, with limited variance in any other dimension. Second, for all three countries, all the vectors are organized in the same and expected order along the circumplex: Pleasant, Calm, Uneventful, Monotonous, Unpleasant, Noisy, Eventful, and Exciting. They are also largely organized as expected in the two VARIMAX-rotated components, easily interpreted to represent *Pleasantness* (Component 1) and *Eventfulness* (Component 2).

The pleasantness vectors point in approximately the same direction in all three panels of Fig. 3 revealing that the participants in the three countries used this term in approximately the same way, and that Plaisant, Trivsam, and 유쾌한 mean approximately the same thing. This observation is true for almost all the attributes, except for Monotonous and Exciting, for which there is a larger variation between the three countries showing that there were larger disagreements on these attributes among the participants from the three countries.

It is interesting to note that the graphs for France (Fig 3a) and Sweden (Fig 3c) are rather similar, except for the attribute of Monotonous. The French term Ennuyeux is located closer to the negative end of Component 1 than the Swedish term Enformig, indicating that Ennuyeux has a stronger negative connotation than Enformig, which is located halfway between Störande

(Unpleasant) and Händelselös (Uneventful). This can be explained by the choice of the French translation Ennuyeux which is literally closer to Boring than to Monotonous. On the contrary, the Korean participants used the term 단조로운 (Monotonous) as almost synonymous with 비활동적인 (Uneventful), meaning that this Korean term, 단조로운 (Monotonous), was used as neutral in terms of *Pleasantness*.

The French and Swedish terms for Exciting are both well located halfway between Eventful and Pleasant, and are opposed to the respective translations of Monotonous. This shows that Stimulant and Spännande are equivalent terms, having positive connotations. The Korean term 활기찬 is located closer to the positive end of Component 2 (*Eventfulness*), indicating that, like the term 단조로운 (Monotonous), it was used as rather neutral in terms of *Pleasantness*. These findings imply that semantic nuances in describing soundscape quality might be different across countries (i.e., nationalities). The different meanings of the chosen words which have been translated as carefully as possible, might be considered as a cultural factor.

Fig. 3

3.2 Cross-national comparison of recording locations

In order to conduct a cross-national comparison of perceived affective quality of the 28 recording locations, a second PCA was conducted. All 95 participants' responses (30 French, 30 Korean, and 35 Swedish) on perceived affective quality were accumulated. An 8 attributes × 2660 individual responses (95 participants × 28 locations) data matrix was created for the PCA. This allowed a cross-national comparison of perceived affective quality of the 28 locations using a single PCA solution. As in the previous PCA, two components, representing *Pleasantness* and *Eventfulness,* were extracted, explaining 39.3% and 26.8% of the total variance, respectively. The principal component loadings of the eight attributes based on VARIMAX-rotation are presented in Table 4, showing good agreement with a PCA solution in a previous study [11].

Individual component scores of *Pleasantness* and *Eventfulness* were calculated for the second PCA solution, using the regression method (SPSS 23 for Windows). Then arithmetic mean values were calculated for each of the 28 recording locations, separately for each of the three countries. Fig. 4 presents these mean component scores divided on the 5 different parks.

It is found that the mean *Pleasantness* scores for the 28 recording locations are similar across all three countries. On the other hand, for *Eventfulness* there is a large variation. Overall, Korean participants provided higher mean *Eventfulness* scores than the participants from France and Sweden (see Fig. 4).

Statistical analyses were conducted to examine the mean differences in *Pleasantness* and *Eventfulness* scores among the three different countries. Normality of residuals and homogeneity of variances, required assumptions for analysis of variance (ANOVA), were tested using and Shapiro-Wilk and Levene's tests, respectively. Shapiro-Wilk test showed that *Pleasantness* scores for the three countries failed to meet normality assumption ($p < 0.01$), while normality of residual for *Eventfulness* score was found to be met. Regarding the Levene's test, *Eventfulness* scores were not satisfying the assumption for the homogeneity of variances ($p < 0.01$). Accordingly, Kruskal-Wallis H test, a rank-based non-parametric test, was performed to determine statistically significant differences in *Pleasantness* scores among the three countries, while Welch's test for unequal variances was conducted for *Eventfulness* scores.

The results show that there is no statistically significant differences in *Pleasantness* across the different countries ($p = 0.69$) from Kruskal-Wallis H test, while statistically significant differences are found in *Eventfulness* among the three countries ($F_{2,49.5} = 4.73$, $p = 0.01$, $\eta_p^2 =$

0.11) from Welch's test. A Games-Howell post hoc test indicates that mean *Eventfulness* score for Sweden ($M_{Eventfulness}$ = –0.22, $SD_{Eventfulness}$ = 0.48) is statistically significantly lower than Korea ($M_{Eventfulness}$ = 0.19, $SD_{Eventfulness}$ = 0.65) and France ($M_{Eventfulness}$ = 0.06, $SD_{Eventfulness}$ = 0.31) with a significance level of 0.05.

Table 4.

Fig. 4.

3.3 Correlations among soundscape variables

To investigate the relationships between perceived affective quality, perceived dominance of the sound sources and acoustic indicators, Pearson's correlation coefficients between these variables were calculated, as presented in Table 5. Perceived dominance of traffic noise has strong and negative correlation coefficients with the *Pleasantness* scores for all countries. In Korea and Sweden, weak correlation coefficients are found between perceived dominance of traffic noise and *Eventfulness* scores. The perceived dominance of sound of human activities shows a positive relationship with *Eventfulness* scores in Korea and Sweden, while the same relationship is not statistically significant in France. Perceived dominance of birdsong is mainly associated with the *Pleasantness* scores. Interestingly, perceived dominance of water sounds has a negative correlation coefficient with *Pleasantness* scores for all countries. It has been reported that water sounds do not always enhance soundscape quality [37–39]. This finding verifies that water sounds with high sound intensity and low temporal variability may deteriorate acoustic comfort in urban parks [37–41]. Perceived dominance of wind sounds has a moderate correlation coefficient with *Pleasantness* scores in Korea and Sweden, but not in France.

There are statistically significant relationships between *Pleasantness* scores and visual quality, which demonstrates strong consistency with findings from previous studies [13,42,43]. The correlation coefficients between *Eventfulness* scores and perception of visual quality in urban parks are relatively smaller than those for *Pleasantness* scores. In particular, a relatively weak correlation coefficient is obtained for *Eventfulness* scores and visual quality in Korea, in comparison to the correlation between these variables in France and Sweden. This result corresponds to findings in a previous study [13] where weak association was found between *Eventfulness* of sound and visual quality in recreational spaces from survey data from Korean respondents. Perceived overall quality has a strong and positive correlation with *Pleasantness* scores, whereas only moderate associations with *Eventfulness* scores are found in France and Sweden. A statistically significant relationship between *Eventfulness* scores and the perceived overall quality of the environment in urban parks is not observed in Korea.

The Pearson's correlation coefficients for the component scores among the three countries were also calculated to examine the similarity of perceived affective quality at the 28 locations. As presented in Table 6, the correlation coefficients of the *Pleasantness* scores among the three countries are higher than 0.9, whereas the *Eventfulness* scores show relatively smaller coefficient values ranging approximately from 0.7 to 0.8. These findings support the results reported above that *Eventfulness* exhibits greater variation across the three countries than *Pleasantness*.

Table 7 presents the Pearson's correlation coefficients between acoustic indicators and soundscape variables, including perceived dominance of sound sources and perceived affective quality, for each country. Overall, correlations between acoustic indicators and perceived sound sources are similar among the three countries. Perceived dominance of traffic noise show positive correlations with L_{Aeq}, L_{A10}–L_{A90} and L_{Ceq}–L_{Aeq} for all the three countries. This indicates that traffic noise containing larger low frequency energy increased background noise level in the urban parks. There are negative relationship between L_{Aeq} and perceived dominance of sounds from human activities, while human sounds show moderate and positive correlations with L_{A10}–L_{A90} and L_{Ceq}–L_{Aeq}. Perceived dominance of bird sounds has positive correlations with L_{A10}–L_{A90} and negative correlations with L_{Aeq} and L_{Ceq}–L_{Aeq} because bird songs have high temporal variability and are heard in places with low levels of traffic noise in urban parks. Perceived dominance of water sounds shows positive relations with L_{Aeq}, whereas negative correlations are found between perceived dominance of water sounds and L_{A10}–L_{A90} and L_{Ceq}–L_{Aeq}. These findings indicate that the water sounds generated from the water features in the studied urban parks, had low temporal variability and higher energies at high frequencies. This explains the negative correlation between water sound dominance and *Pleasantness*.

Similar correlation tendencies between *Pleasantness* score and acoustic indicators are found for the three countries; *Pleasantness* is closely associated with L_{Aeq} for all the three counties. This finding implies that overall sound levels in urban parks has an impact on judged pleasantness of soundscape. Unlike *Pleasantness* score, correlation tendencies between *Eventfulness* and acoustic indicators are different across the countries. Interestingly, L_{A10}–L_{A90}, indicating temporal variability of sound, is positively related to *Eventfulness* score across the three countries. However, there are positive relationships found between *Eventfulness* score and L_{Aeq} only for the Korean participants. These findings also support that *Eventfulness* can be significantly different across the three cultural backgrounds.

Table 5.

Table 6.

Table 7.

3.4 Clustering of urban park soundscapes

3.4.1 Validation of cluster analysis

The previous section describes how the perceived affective quality of the 28 recording locations tended to vary across the three different countries, even though the same audio-visual stimuli were assessed using equivalent questionnaires in the native language of each of the countries. This implies that classification of the 28 recording locations might be different in France, Korea, and Sweden. Consequently, the 28 recording locations were classified based on how the 95 participants perceived them. Two cluster analyses for 84 cases (28 locations × 3 countries) were conducted. They were based 1) on arithmetic mean values of perceived dominance of the five sound sources: traffic noise, human sounds, water sounds, birdsong, and wind sounds, and 2) on mean principal components scores of perceived affective quality (*Pleasantness* and *Eventfulness*) obtained from the second PCA for the 28 recording locations.

In order to determine the most optimal clustering method and number of clusters, internal validation measures including connectivity, the Dunn index, and silhouette width were calculated using clValid, the R package for cluster validity [44]. Four clustering methods including hierarchical cluster analysis (HCA), K-means, partitioning around medoids (PAM), and model-based clustering were employed to classify the 28 recording locations [27]. Connectivity is a measure that indicates the degree of connectedness of the observations in the same clusters. Connectivity values are between zero and ∞, and should be minimized. The Dunn index and silhouette width are indicators that are widely used for measuring both compactness and separation. The Dunn index possesses a value between zero and ∞. Silhouette width has a value between −1 and 1. Higher values of the Dunn index and silhouette width indicate better clustering in terms of internal validation.

The internal validity measures for the four clustering algorithms are summarized in Fig. 5 and 6. As presented in Fig. 5, for clustering based on perceived dominance of the five sound sources, HCA with three clusters produced lower connectivity values and a greater silhouette width value than the other clustering algorithms. In addition, for clustering based on perceived affective quality, as presented in Fig. 6, HCA with three clusters showed the best scores of connectivity and the best Dunn index out of all the clustering algorithms. Thus, HCA was identified as the most appropriate clustering algorithm, and three was determined to be the optimum number of clusters. Accordingly, HCA was performed with application of the Ward algorithm for agglomerative clustering. Squared Euclidean distance was selected as the metric of distance among the variables.

Fig. 5.

Fig. 6.

3.4.2 Clustering based on perceived dominance of sound sources

Based on the perceived dominance of sound sources at the 28 recording locations, three clusters are obtained by HCA. Clusters A1–3 contain 70.2%, 14.3% and 15.5% of the cases, respectively. Each location evaluated by French, Korean, and Swedish participants is classified into the same clusters. In other words, the clustering results based on perceived dominance of sound sources are assumed to be the same in France, Korea, and Sweden. This finding indicates that there were no significant differences in the identification of sound sources according to the three nationalities.

Mean values of the participants' responses for Cluster A1–3 are presented in Table 8. Cluster A1 include the relatively tranquil locations with lower levels of traffic noise, which obtained high *Pleasantness* and low *Eventfulness* scores. The locations where water sounds were predominant are classified into cluster A2. Due to the water sounds, which reduce tranquility, the *Pleasantness* score of cluster A2 is lower than the *Pleasantness* score of cluster A1. In cluster A3, traffic noise is one of the most predominant sound sources, followed by sounds from human activities. Accordingly, cluster A3 obtains the lowest *Pleasantness* and highest *Eventfulness* scores among the three clusters.

Table 8.

3.4.3 Clustering based on perceived affective quality

HCA for the 28 recording locations was conducted based on mean principal component scores of *Pleasantness* and *Eventfulness*. Three clusters, B1–3, are clearly distinguished, as illustrated in Fig. 5. Mean values of the participants' responses for Cluster B1–3 are presented in Table 9. Cluster B1 include 41.7% of the cases, which can be characterized as tranquil environments with the highest *Pleasantness* and lowest *Eventfulness* scores among the three clusters. Traffic noise is rarely identified in cluster B1. Cluster B2, containing 35.7% of the cases, comprises noisy environments with the lowest *Pleasantness* scores, while the degree of *Eventfulness* in cluster B2 is neutral. Traffic noise is one of the most frequently perceived sounds in cluster B2. Cluster B3, including 22.6% of the cases, obtains higher *Eventfulness* and moderate *Pleasantness* scores, and can be characterized as lively environments where sounds from human activities are predominant.

Cross-national comparisons of clusters B1–3 for each of the 28 recording locations were conducted. Unlike the results of clustering based on perceived dominance of sound sources (Clusters A1–3), there are discrepancies in clustering results based on perceived affective quality (Clusters B1–3) for 12 of the 28 recording locations (see Table 9). This finding demonstrates that lexico-semantic and socio-cultural differences among the three countries might influence perceived affective quality of the acoustic environment in urban parks.

As presented in Table 10, the twelve locations can be characterized by predominant sound sources. Interestingly, the perception of sound sources, including the sounds of human activities, birdsong, and water sounds, are differently associated with clusters B1–3 in France, Korea, and Sweden. Korean participants evaluated the locations in which human sounds were the predominant sound source (such as MO1, MO4, OB1, and OB4, with the exception of AN5) as lively acoustic environments. Locations MO4 and OB1, which consist mainly of traffic and human sounds, were characterized by Korean participants as lively environments due to the presence of human sounds, and yet these locations were described by French and Swedish participants as being noisy. In addition, Swedish participants tended to judge all soundscapes with predominant human sounds as noisy environments (AN5, MO4, OB4, and OB5). Korean participants generally rated the human sounds with higher values than other participants did. This finding indicates that the sounds of human activities play a more important role for Koreans in creating vibrant soundscapes in urban parks than for French and Swedish people.

Soundscape responses of participants to natural sounds, including birdsong and water sounds, were also different across the three countries. For French and Swedish participants, sound environments dominated by birdsong, such as MO1 and OB3, were perceived as tranquil, while Korean participants characterized the presence of birdsong as making a sound environment more vibrant. Our findings show that sounds from water features in urban parks potentially cause different soundscape perceptions across countries. French and Korean participants assessed the sound of waterfall, including locations AN6 and LV4, as a negative sound, whereas Swedish participants classified soundscapes with the sound of waterfall as being tranquil. Only AN8, which included a fountain that produces dynamic water sounds, was classified as noisy among Swedish participants. In addition, OB2 (in which both water sounds and birdsong are predominantly heard) was evaluated as a calm and tranquil sound environment by Swedish participants, while French and Korean participants classified OB2 as a lively and vibrant sound atmosphere. These findings imply that natural sounds such as birdsong and water sounds might be more essential soundscape elements in the creation of tranquil soundscapes in urban parks for Swedish respondents than for French and Korean respondents. In this study, water sounds (unlike birdsong) exhibit positive or negative effects on soundscapes according to the specific acoustic characteristics of water sounds. These results are consistent with the findings of previous studies supporting that waterfall sounds with small temporal variance and high-frequency content were relatively less preferred than other water sounds [37–40,45,46].

Previous studies [10,11,13] indicate that sounds from human activities, birdsong, and water are closely associated with the eventfulness of soundscapes. This corresponds to the results of the PCA, wherein significant differences were found across nationalities in adjectives describing the eventfulness of soundscapes, but not in the pleasantness.

Table 9.

Table 10.

4. Discussion and conclusions

Laboratory experiments were conducted in France, Korea, and Sweden to explore socio-cultural associations with urban parks soundscapes. The 95 participants, from the three countries, assessed 28 audio-visual stimuli with the aid of rating scales related to perceived dominance of sound sources and perceived affective quality. Classification of the 28 stimuli did not reveal any significant differences among the three nationalities for perceived dominance of sound sources (Clusters A1–3). In contrast, there were differences for perceived affective quality (Clusters B1–3), chiefly associated with *Eventfulness*.

The observed differences for *Eventfulness* may be explained by how the participants applied the corresponding attribute scales to their experience of the 28 experimental sounds. First, the different connotative meanings and semantic nuances describing the eventfulness of the sounds in the native languages of the three nationalities might cause different results. For instance, the French word Animé is not the exact translation of Eventful. The English translation of Animé would rather be Lively, whereas the chosen translation might be closer to the attribute Eventful in Korean and Swedish. This illustrates that it is necessary to conduct cross-national comparisons of semantic descriptors to standardize methods for data collection in soundscape assessment. To improve the attribute scales used in this study to be closer to the original terms used in the Swedish Soundscape-Quality Protocol, it would be necessary to find new French and Korean terms for Monotonous, and possibly a new Korean term for Exciting, as well as for Chaotic. This illustrates some of the limitations and challenges of direct translation. Secondly, as illustrated by the second cluster analysis (Clusters B1–3), even though the participants agreed on what sound sources they perceived as dominant in the 28 recording locations, different sound sources had different meanings for the participants, causing them to apply the attribute scales differently. For example, for this park corpus, in French Eventful (Animé) tended to be more linked to vehicles than to human presence, compared to Korea and Sweden.

Potential limitation of this study are related to the participants, stimuli, and data collection method. First, there were at least 30 participants in each country, mainly in the ages of 20–30 years. This ensures the cross-national comparison, but the results cannot be generalized to the population of France, Korea or Sweden. Consequently, it is not possible to comment on any general cross-national differences based on these results. Second, all 28 recording locations were located in European urban parks. No recordings from Korea were included. A wider range of stimuli, including recordings from city centers and rural areas, could potentially have shed more light on some of the cross-national differences observed, or potentially even reduced them. For example, inclusion of environments dominated by the sound of ventilation fans, which is a monotonous sound, could have increased the agreement among the participants on *Eventfulness*. Third, it was not possible to conduct the three experiments in a standardized fashion, under identical conditions, using the identical equipment in all three countries. Moreover, there were no resources to validate the three linguistic versions of the data collection instrument before the experiments were conducted. These potential limitations should be taken into account in future cross-national comparisons in soundscape studies.

It may be argued that using 8 unipolar attribute scales represents a potential limitation from a psychometric point of view in terms of the uncertainty of the assessments. It is common practice in psychology to use 2–3 scales as indicators when assessing the value of a latent factor, like *Pleasantness* and *Eventfulness* [47]. The present study is based on the Swedish Soundscape-Quality Protocol that assesses perceived affective quality based on a circumflex model [11]. That is, the 8 unipolar attribute scales are presumably evenly distributed in a circular order, spaced approximately 45° apart, on a 2-dimentional plane. Thus, they correlate with each other, and are all used as indicators of the different underlying latent factors. For example, the indicators of *Pleasantness* are all 8 attribute scales except Eventful and Uneventful that presumably are orthogonal to *Pleasantness*. Similarly, the indicators of *Eventfulness* are all 8 attribute scales except Pleasant and Annoying that presumably are orthogonal to *Eventfulness*. Per definition, a scale that is orthogonal to a latent factor does not contribute to the assessment of its value. Thus, not only 2–3 scales are used as indicators of each underlying latent factor, but at least 6 scales, which minimizes the uncertainty in the assessments of *Pleasantness* and *Eventfulness*. The assumption of Axelsson et al.'s circumplex model [11] that the 8 attribute scales are spaced approximately 45° apart is of no practical value when PCA is used, because this analysis uses the actual angles between the scales in the form of the Pearson product-moment correlation coefficients (*r*), (for further information on this issue see [48]).

The main conclusion from this study is that in the standardization of a data collection instrument for assessing perceived environmental quality, it is necessary to validate the linguistic versions before they are published. This must be done by cross-national comparison with a standardized data collection procedure, using the same set of stimuli, conditions and equipment. Without this rigorous procedure, there is a risk that the results obtained by the different linguistic versions are not comparable, which is the aim of a standard.

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Table 1. Acoustic parameters of 28 acoustic stimuli used in laboratory experiments [dB].

Site	$L_{Aeq,1min}$	L_{A90}	L_{A50}	L_{A10}	L_{A10}–L_{A90}	L_{Ceq}–L_{Aeq}	$uILD_2$
AN1	50.6	48.6	50.0	51.8	3.3	8.0	0.8
AN 2	48.7	46.2	47.3	49.5	3.3	7.9	1.1
AN 3	48.9	47.0	48.6	50.1	3.2	11.7	0.1
AN 4	54.2	51.1	52.8	55.9	4.8	9.2	0.6
AN 5	60.0	58.1	59.6	61.1	3.1	5.8	0.3
AN 6	66.5	65.7	66.2	67.1	1.4	1.3	2.1
AN 7	53.3	50.9	52.8	54.4	3.5	10.9	0.3
AN 8	72.2	69.2	72.3	73.6	4.4	–0.1	0.4
MO1	55.2	48.6	52.7	58.4	9.8	12.6	1.1
MO2	51.9	48.8	51.1	53.7	5.0	10.1	3.2
MO3	51.6	47.5	49.7	54.5	7.0	12.2	0.4
MO4	61.3	51.4	60.0	64.0	12.6	10.2	1.7
LV1	61.2	59.4	60.5	62.7	3.3	8.2	0.8
LV2	54.7	51.9	53.4	56.4	4.5	10.9	0.1
LV3	55.4	52.4	54.1	56.9	4.5	8.4	0.8
LV4	66.1	65.3	66.1	66.8	1.6	0.7	0
KR1	71.2	67.5	70.6	73.2	5.7	9.8	2.5
KR2	61.1	57.6	59.7	63.8	6.2	11.4	0.1
KR3	52.2	49.9	51.3	54.3	4.5	13.9	0.3
KR4	56.2	48.7	52.7	56.8	8.2	8.2	0.6
KR5	57.9	53.4	55.5	61.0	7.6	9.9	1
OB1	60.5	55.9	58.7	63.5	7.6	8.3	3.4
OB2	65.7	62.8	64.2	68.1	5.4	6.8	0.7
OB3	61.5	56.5	61.0	63.6	7.2	7.4	0.6
OB4	54.3	50.8	52.9	57.0	6.2	10.8	2.1
OB5	57.3	52.1	55.3	60.0	8.0	5.6	1.1
OB6	65.3	58.8	65.4	67.0	8.2	8.6	0.7
OB7	68.5	63.4	67.7	71.3	7.9	7.7	4.7

Table 2. Demographic information for the participants

Nationality	Gender		Age (years)			Percentage (%)	
(Participants)	Male	Female	Mean	SD	Range	18–39	≥40
Korea (30)	14	16	23.0	2.16	20 – 29	100	0
France (30)	19	11	27.1	11.2	18 – 53	80	20
Sweden (35)	15	20	27.7	6.2	21 – 45	91.4	8.6
Total (95)	47	48	26.1	7.6	18 – 53	90.5	9.5

Table 3. Adjective attributes for perceived affective quality.

English	French	Swedish	Korean
Pleasant	Plaisant	Trivsam	유쾌한
Unpleasant	Déplaisant	Störande	불쾌한
Eventful	Animé	Händelserik	활동적인
Uneventful	Amorphe	Händelselös	비활동적인
Exciting	Stimulant	Spännande	활기찬
Monotonous	Ennuyeux	Enformig	단조로운
Calm	Calme	Lugn	조용한
Noisy	Bruyant	Bullrig	시끄러운

Table 4. VARIMAX-rotated component loadings of the second PCA solution with 95 individual responses to 8 adjective scales for 28 recording locations.

Attributes	Component 1	Component 2
Pleasantness		
Pleasant	0.84	0.17
Unpleasant	–0.84	–0.12
Calm	0.83	–0.24
Noisy	–0.80	0.11
Eventfulness		
Uneventful	0.29	–0.76
Eventful	–0.40	0.73
Monotonous	–0.19	–0.72
Exciting	0.25	0.68

Table 5. Pearson's correlation coefficients between perceived affective quality and perceived dominance of sound sources as well as perceived visual and overall quality, divided on the three countries.

		Traffic	Human	Water	Bird	Wind	Visual quality	Overall quality
Pleasantness	France	–0.46**	–0.08*	–0.19**	0.21**	0.02	0.42**	0.60**
	Korea	–0.46**	–0.04	–0.14**	0.23**	0.21**	0.42**	0.63**
	Sweden	–0.52**	–0.05	–0.09*	0.31**	0.34**	0.49**	0.72**
Eventfulness	France	–0.03	0.05	0.02	0.09*	0.11**	0.32**	0.26**
	Korea	0.14**	0.25**	0.11**	0.07	–0.06	0.15**	0.02
	Sweden	0.11**	0.28**	–0.13**	0.03	0.06	0.27**	0.21**

*p < 0.05 (two-tailed test of statistical significance)

**p < 0.01 (two-tailed test of statistical significance)

Table 6. Pearson's correlation coefficients for components scores between the three countries

	Pleasantness score		*Eventfulness* score	
	Korea	Sweden	Korea	Sweden
France	0.94^{**}	0.96^{**}	0.79^{**}	0.78^{**}
Sweden	0.92^{**}	-	0.72^{**}	-

$^{**}p < 0.01$ (two-tailed test of statistical significance)

Table 7. Pearson's correlation coefficients of soundscape variables with acoustic indicators

Variables	Nationality	L_{Aeq}	L_{A90}	L_{A50}	L_{A10}	$L_{A10}–L_{A90}$	$L_{Ceq}–L_{Aeq}$
Traffic noise	France	0.29**	0.18**	0.29**	0.32**	0.36**	0.24**
	Korea	0.33**	0.22**	0.32**	0.37**	0.40**	0.25**
	Sweden	0.27**	0.17**	0.26**	0.31**	0.35**	0.23**
Human sound	France	–0.20**	–0.20**	–0.21**	–0.19**	0.04	0.18**
	Korea	–0.11**	–0.14**	–0.13**	–0.09**	0.14**	0.14**
	Sweden	–0.21**	–0.24**	–0.24**	–0.20**	0.13**	0.20**
Bird sound	France	–0.14**	–0.23**	–0.18**	–0.11**	0.32**	0.18**
	Korea	–0.17**	–0.25**	–0.21**	–0.14**	0.31**	0.21**
	Sweden	–0.26**	–0.31**	–0.28**	–0.23**	0.21**	0.26**
Water sound	France	0.45**	0.55**	0.48**	0.40**	–0.42**	–0.66**
	Korea	0.45**	0.55**	0.47**	0.41**	–0.38**	–0.60**
	Sweden	0.48**	0.60**	0.51**	0.43**	–0.46**	–0.69**
Pleasantness	France	–0.57**	–0.54**	–0.57**	–0.57**	–0.08*	0.24**
	Korea	–0.60**	–0.55**	–0.60**	–0.62**	–0.16**	0.19**
	Sweden	–0.52**	–0.47**	–0.52**	–0.53**	–0.13**	0.21**
Eventfulness	France	0.06	0.02	0.04	0.08*	0.16**	0.05
	Korea	0.33**	0.27**	0.30**	0.35**	0.21**	–0.09*
	Sweden	0.02	–0.04	0.00	0.04	0.21**	0.16**

*$p < 0.05$ (two-tailed test of statistical significance)

**$p < 0.01$ (two-tailed test of statistical significance)

Table 8. Summary of cluster A1–3 in terms of perceived dominance of sound sources and component scores of perceived affective quality.

Cluster		Traffic	Human	Water	Bird	Wind	*Pleasantness*	*Eventfulness*
A1	Mean	–0.42	–0.07	–1.43	–0.25	–0.87	0.31	–0.04
	SD	0.67	0.72	0.66	0.91	0.41	0.45	0.51
	N	59	59	59	59	59	59	59
A2	Mean	–1.16	–0.24	1.65	–1.68	–1.41	–0.47	0.01
	SD	0.31	0.82	0.40	0.15	0.20	0.26	0.71
	N	12	12	12	12	12	12	12
A3	Mean	1.12	0.28	–1.87	–1.41	–1.37	–0.94	0.23
	SD	0.61	0.47	0.11	0.36	0.23	0.61	0.36
	N	13	13	13	13	13	13	13

Table 9. Summary of cluster B1–3 in terms of perceived dominance of sound sources and component scores of perceived affective quality.

Cluster		Traffic	Human	Water	Bird	Wind	*Pleasantness*	*Eventfulness*
B1	Mean	–0.67	–0.18	–1.30	–0.41	–0.90	0.54	–0.33
	SD	0.38	0.51	0.95	0.79	0.41	0.31	0.45
	N	35	35	35	35	35	35	35
B2	Mean	0.36	–0.07	–0.93	–1.11	–1.29	–0.67	0.02
	SD	1.11	.71	1.50	0.75	0.25	0.53	0.32
	N	30	30	30	30	30	30	30
B3	Mean	–0.60	0.27	–0.81	–0.31	–0.84	0.08	0.62
	SD	0.63	0.94	1.34	1.32	0.52	0.26	0.32
	N	19	19	19	19	19	19	19

Table 10. Average responses to recording locations with discrepancies in clustering based on perceived affective quality [tranquil (B1), noisy (B2) and lively environments (B3)].

Nationality	Site	Traffic (*T*)	Human (*H*)	Water (*W*)	Bird (*B*)	*Pleasantness*	*Eventfulness*	Clusters	Main sound sources
France		–0.93	–0.10	–1.43	0.33	0.58	0.21	B1	*(B)*
Korea	MO1	–0.90	0.90	–0.43	0.70	0.02	0.51	B3	*(B)*
Sweden		–0.74	–0.03	–1.60	0.26	0.45	0.17	B1	*(B)*
France		0.10	–1.17	–0.93	0.87	0.31	0.24	B3	*(B)*
Korea	OB3	0.20	–0.83	–1.17	1.43	0.29	0.22	B3	*(B)*
Sweden		0.23	–0.97	–1.31	0.89	0.24	–0.42	B1	*(B)*
France		0.03	0.60	–1.23	–1.83	0.04	–0.39	B2	*(H)*
Korea	AN5	–0.57	0.60	–1.23	–1.70	0.38	–0.41	B1	*(H)*
Sweden		0.03	0.31	–1.46	–1.49	–0.12	–0.35	B2	*(H)*
France		0.90	0.33	–1.77	–1.33	–0.55	0.23	B2	*(H, T)*
Korea	MO4	0.70	0.57	–1.83	–0.90	–0.57	0.78	B3	*(H, T)*
Sweden		0.83	0.71	–1.94	–1.37	–0.77	0.39	B2	*(H, T)*
France		0.13	0.07	–1.37	–0.03	0.01	0.16	B2	*(H, T)*
Korea	OB1	0.57	0.40	–1.13	0.67	–0.02	0.38	B3	*(H, T)*
Sweden		0.66	0.31	–1.63	–0.54	–0.38	0.03	B2	*(H, T)*
France		–1.17	–0.20	–1.70	0.40	0.66	0.14	B1	*(H, B)*
Korea	OB4	–1.37	0.83	–1.80	0.67	0.29	0.43	B3	*(H, B)*
Sweden		–.49	0.66	–1.91	–0.03	–0.01	–0.13	B2	*(H, B)*
France		–1.37	0.23	–1.80	0.37	0.30	0.27	B3	*(H, B)*
Korea	OB5	–1.37	1.10	–1.77	1.23	0.36	1.05	B3	*(H, B)*
Sweden		–0.57	0.74	–1.97	0.17	0.07	0.04	B2	*(H, B)*
France		–1.33	–0.97	1.87	–1.80	–0.66	–0.39	B2	*(W)*
Korea	AN6	–1.40	–0.50	1.80	–1.60	–0.48	0.04	B2	*(W)*
Sweden		–1.09	–0.80	1.91	–1.51	–0.59	–0.83	B1	*(W)*
France		–1.37	–0.10	1.70	–1.90	–0.92	0.43	B2	*(W)*
Korea	AN8	–1.17	0.37	1.80	–1.83	–0.43	1.15	B3	*(W)*
Sweden		–1.17	–0.20	1.83	–1.74	–0.90	–0.27	B2	*(W)*
France		–1.37	–1.43	1.87	–1.70	–0.51	–0.33	B2	*(W)*
Korea	LV4	–1.53	–0.90	1.90	–1.43	–0.33	–0.32	B2	*(W)*
Sweden		–1.37	–0.91	1.91	–1.66	–0.24	–1.18	B1	*(W)*
France		–0.53	–1.70	0.00	1.17	0.20	0.33	B3	*(W, B)*
Korea	OB2	–0.97	–1.90	1.80	1.77	0.01	0.68	B3	*(W, B)*
Sweden		–0.23	–1.66	0.66	1.00	0.32	–0.30	B1	*(W, B)*
France		–0.83	0.93	0.93	–1.87	–0.23	0.55	B3	*(W, H)*
Korea	LV1	–0.67	1.13	1.50	–1.63	–0.16	1.08	B3	*(W, H)*
Sweden		–0.60	0.49	0.74	–1.53	–0.18	0.20	B2	*(W, H)*

Figure captions:

Fig. 1. Aerial views of the five selected urban parks and the 28 recording locations. André Citroën (AN), Montsouris (MO), La Villete (LV), Observatorielunden (OB), and Kronobergsparken (KR).

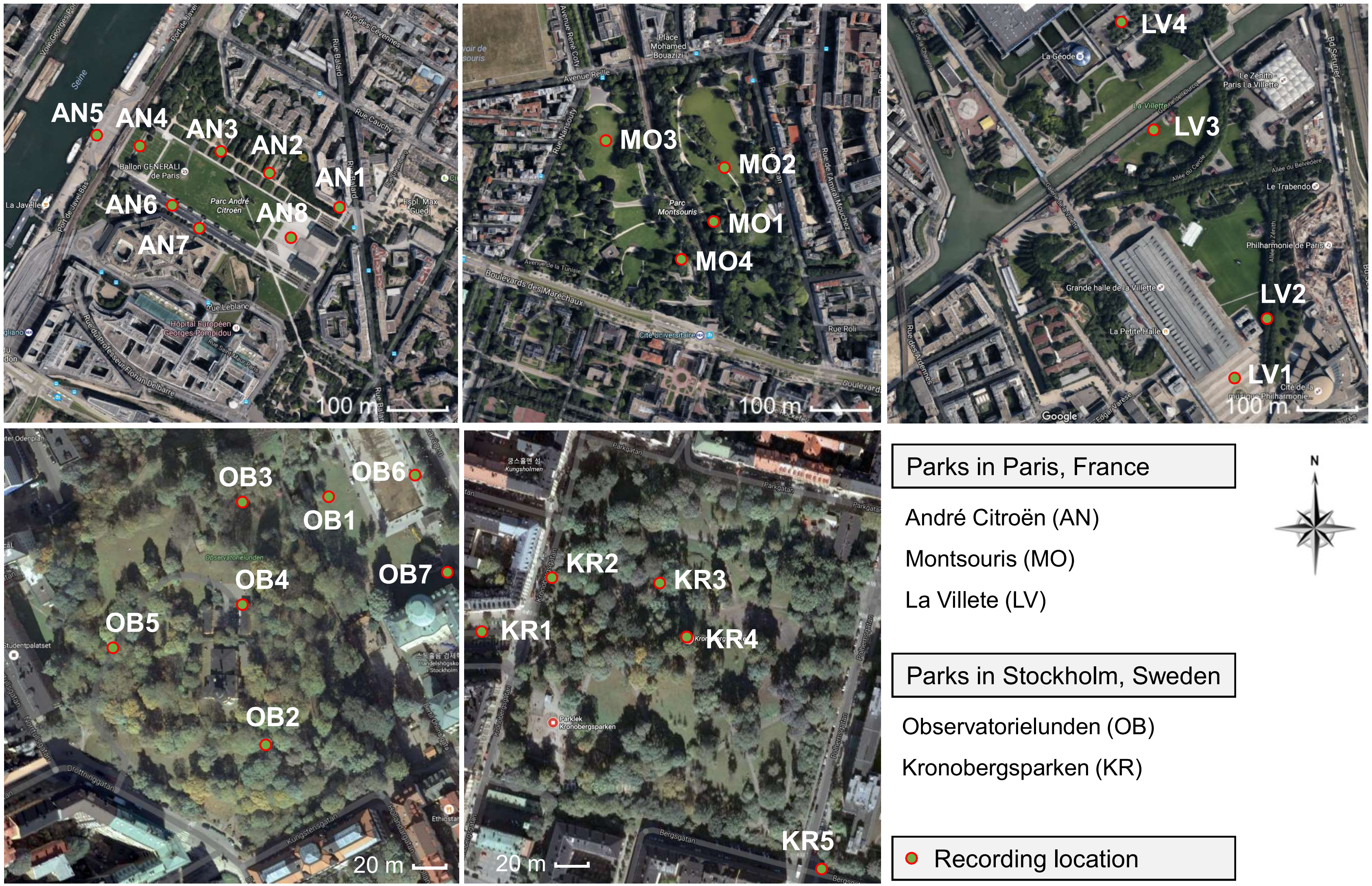
Fig. 2. Photographs used as visual stimuli in the laboratory experiments

Fig. 3. Component loading plots of the eight adjective attributes: (a) France, (b) Korea, and (c) Sweden

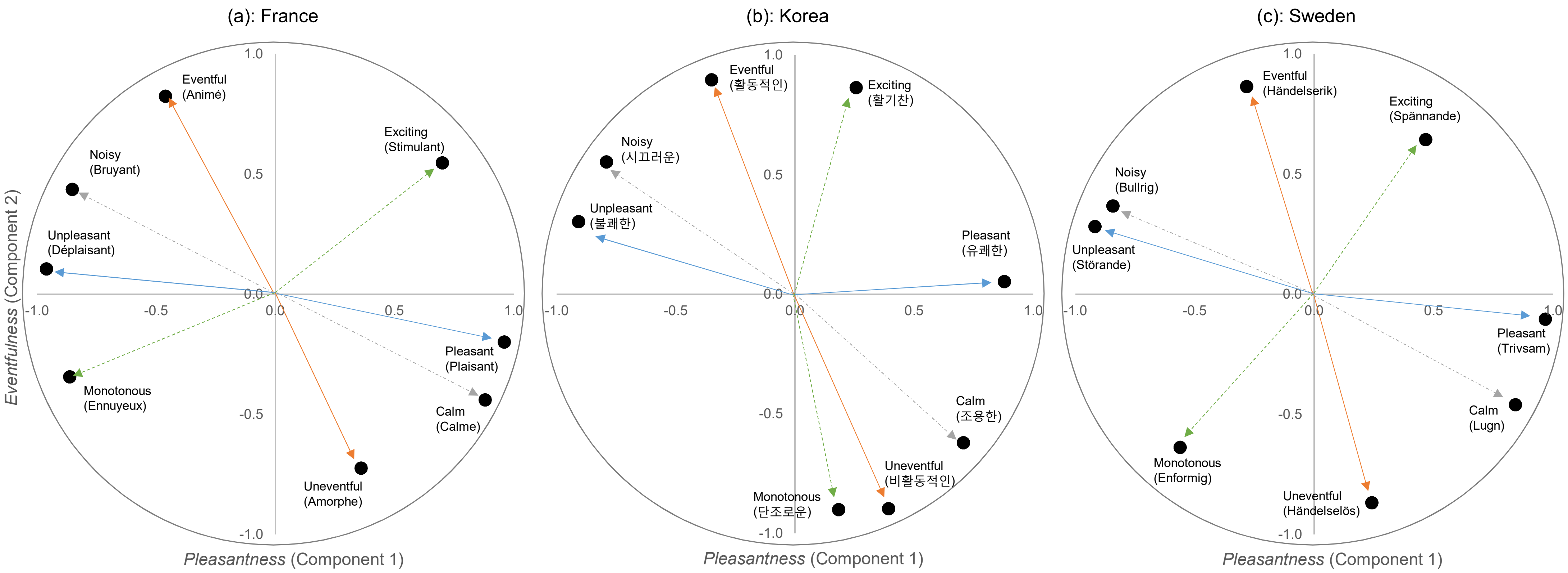
Fig. 4. Component scores of Pleasantness and Eventfulness for France, Korea and Sweden in the urban parks: André Citroën (AN), Montsouris (MO), La Villete (LV), Observatorielunden (OB), and Kronobergsparken (KR).

Fig. 5. Internal validation measures for clustering based on perceived sound sources: (a) connectivity, (b) Dunn index, and (c) silhouette width.

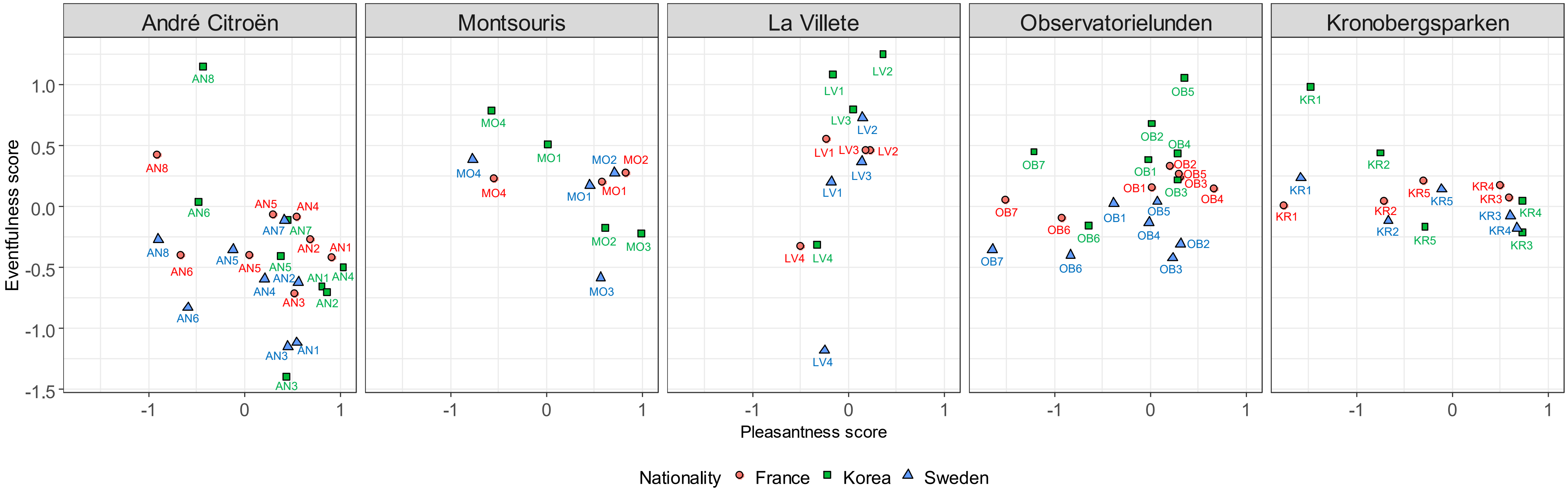
Fig. 6. Internal validation measures for clustering based on perceived affective qualities of soundscape: (a) connectivity, (b) Dunn index, and (c) silhouette width.

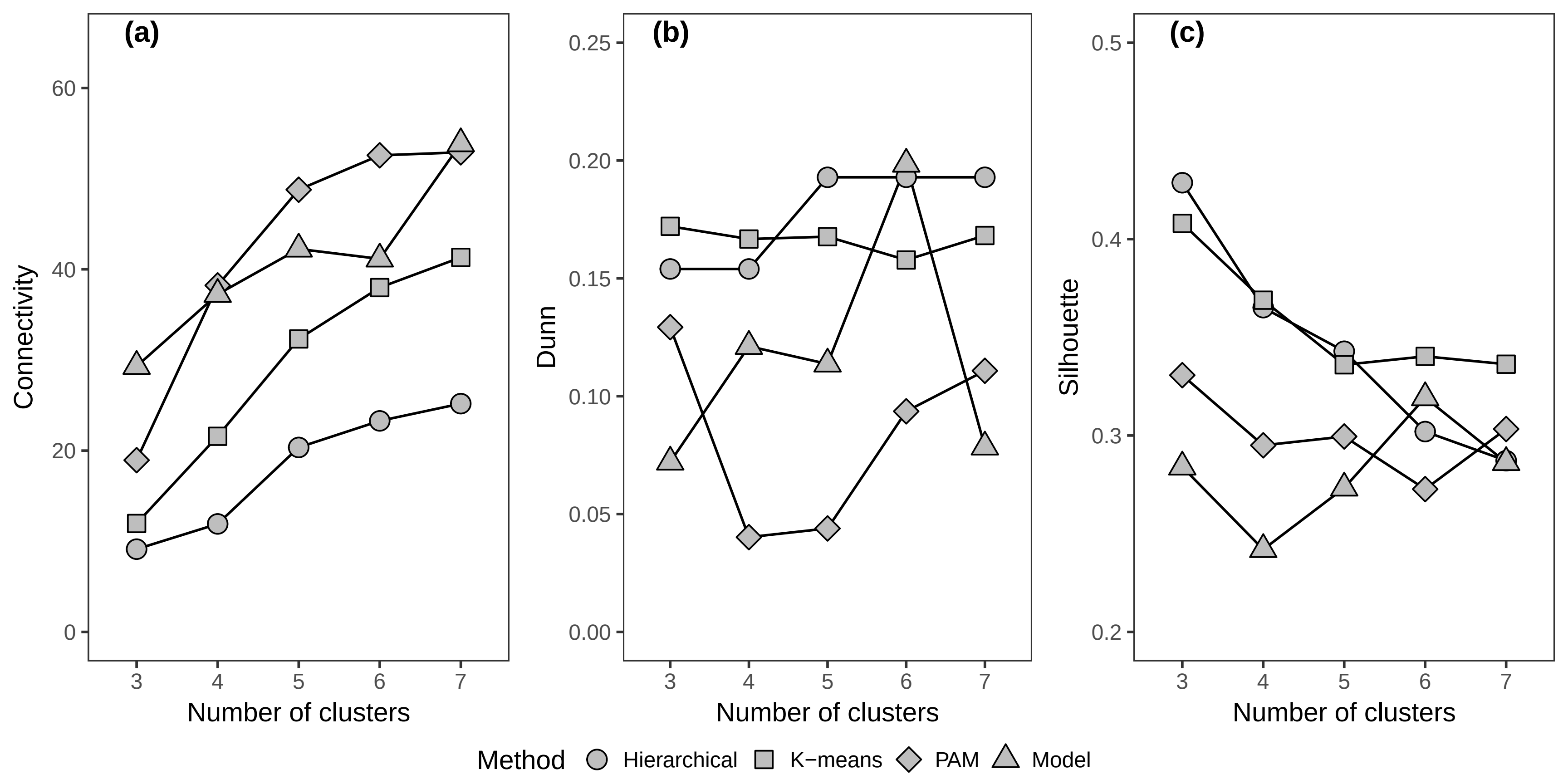

AN1
AN2
AN3
AN4
AN5
AN6
AN7
AN8
100 m
MO1
MO2
MO3
MO4
100 m
LV1
LV2
LV3
LV4
100 m
OB1
OB2
OB3
OB4
OB5
OB6
OB7
20 m
KR1
KR2
KR3
KR4
KR5
20 m
Parks in Paris, France
André Citroën (AN)
Montsouris (MO)
La Villete (LV)
Parks in Stockholm, Sweden
Observatorielunden (OB)
Kronobergsparken (KR)
Recording location
N


AN1
AN2
AN3
AN4
AN5
AN6
AN7
AN8
MO1
MO2
MO3
MO4
LV1
LV2
LV3
LV4
KR1
KR2
KR3
KR4
KR5
OB1
OB2
OB3
OB4
OB5
OB6
OB7

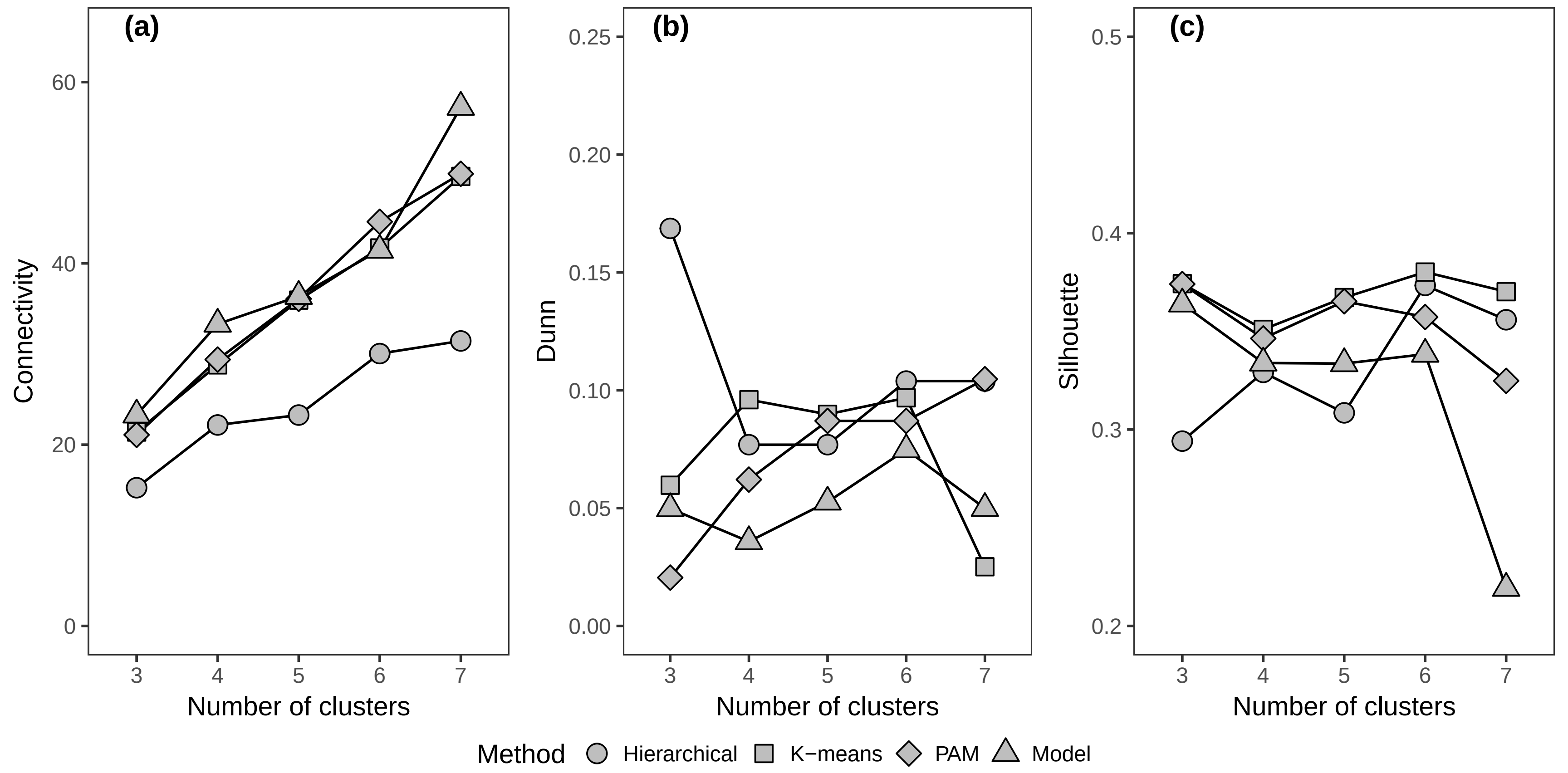


(a): France
(b): Korea
(c): Sweden
Eventfulness (Component 2)
Pleasantness (Component 1)
1.0
0.5
0.0
-0.5
-1.0
Eventful
(Animé)
Exciting
(Stimulant)
Noisy
(Bruyant)
Unpleasant
(Déplaisant)
Pleasant
(Plaisant)
Monotonous
(Ennuyeux)
Calm
(Calme)
Uneventful
(Amorphe)
Eventful
(활동적인)
Exciting
(활기찬)
Noisy
(시끄러운)
Unpleasant
(불쾌한)
Pleasant
(유쾌한)
Calm
(조용한)
Uneventful
(비활동적인)
Monotonous
(단조로운)
Eventful
(Händelserik)
Exciting
(Spännande)
Noisy
(Bullrig)
Unpleasant
(Störande)
Pleasant
(Trivsam)
Calm
(Lugn)
Monotonous
(Enformig)
Uneventful
(Händelselös)


André Citroën
Montsouris
La Villete
Observatorielunden
Kronobergsparken
Eventfulness score
Pleasantness score
Nationality
France
Korea
Sweden



(a)
Connectivity
0
20
40
60
3
4
5
6
7
Number of clusters
(b)
Dunn
0.00
0.05
0.10
0.15
0.20
0.25
3
4
5
6
7
Number of clusters
(c)
Silhouette
0.2
0.3
0.4
0.5
3
4
5
6
7
Number of clusters
Method
Hierarchical
K−means
PAM
Model



(a)
(b)
(c)
Connectivity
Dunn
Silhouette
Number of clusters
Number of clusters
Number of clusters
0
20
40
60
0.00
0.05
0.10
0.15
0.20
0.25
0.2
0.3
0.4
0.5
3
4
5
6
7
Method
Hierarchical
K−means
PAM
Model