A pilot experiment on effects of motor and cognitive activities on memories of soundscapes

Edda Bild
INCAS[3], Assen, The Netherlands & Department of Geography, Planning and International Development Studies, University of Amsterdam, Amsterdam, The Netherlands.

Matt Coler
INCAS[3], Assen, The Netherlands.

Danièle Dubois
INCAS[3], Assen, The Netherlands & LCPE/LAM/University of Paris 6, Paris, France.

Karin Pfeffer
Department of Geography, Planning and International Development Studies, University of Amsterdam, Amsterdam, The Netherlands.

Summary
To evaluate the potential role of activities in evaluating memories of soundscapes, we performed a pilot experiment in which respondents, engaged in combinations of two motor (walking and sitting) and two cognitive activities (counting and talking), were asked to describe the memory of their sensory experience in their university campus, in writing. In this paper we show how a psycholinguistic analysis of the resulting written corpus can offer insight into the diversity of experiences of soundscapes and how activity can influence the description of these soundscapes. We propose a replicable framework for linguistic analysis to help structure and analyze a corpus of written text with the goal of developing a method to analyze qualitative descriptions from memory of soundscapes. Soundscapes are complex objects of scientific investigation, because they can be described both along physical parameters and human ones. Research on the human parameters has focused on the experience of soundscapes at an individual level, with the perceiver in the static position of a "receiver" of acoustic stimulations and whose actions and activities were not considered to influence the intepretation of these stimulations. Given the empirical evidence acquired by soundscape researchers and the work of historians, ethnographers, sociologists and anthropologists of sound on the two-way relationship between humans and their soundscapes in urban contexts, we adopt an approach that centers how *activity* can influence the memory of soundscapes and how soundscapes are described in language.

PACS no. 43.66.Lj, 43.90.+v

1. Introduction

A soundscape is a "hybrid" concept [1] insofar as it can be described with reference to physical/acoustic parameters as well as human ones. In this paper, we look exclusively at techniques dedicated to evaluating human processing at the individual (psychological) level that derive from perceptual experience. We intend to further integrate techniques researching the collective representations of auditory events and acoustic environments, as issues of concern for urban planning, geography and sociology, among others. Access to human parameters can be achieved through ethnographic descriptions of behavior, soundwalks [2], as well as free sorting tasks[3] and language data, elicited from focus groups [4] or individuals, in situ, in a laboratory setting based on recordings, or from memory [5], [6]. Those verbal responses, once transcribed, can form the basis of corpora that can be subjected to linguistic analysis.

To these ends, we show how linguistic analysis can provide insight into human subjectivity with the goal of developing a method to analyze qualitative descriptions from memory of soundscapes.

Research into the perception of the acoustic environment often studies sound recorded and reproduced from the environment in a laboratory setting (e.g. [7]). However, previous to designing such stimuli sets, we

wanted to take into account an ecological approach [8], that in addition to audio recording, considers how humans selectively focus on environmental stimuli according to their needs and adaption to it. That is, we wanted to account for aspects relating to the specificities of psychological and sociological processing to better identify similarities and differences of the users' Umwelten, i.e. the perceptual world of a human or animal perceiver and the sphere of its practical interaction [9].

This leads us to focus on the multi-sensorial experience of natural soundscapes to determine what is the part of it which actually relies on acoustic stimulations, with the understanding that the noise/sound acts as a *cue* pointing to something other than itself.

To learn more about the relationship between the world "as it is" and the world as experienced by subjects purposefully interacting in it, we performed a pilot experiment at Zernike Campus (Groningen, NL) and used a written, structured questionnaire, with open-ended questions to collect a corpus which was subjected to linguistic analysis.

The campus was of interest because it is jointly used by the Municipality of Groningen, the Province of Groningen, the University of Groningen, the Hanze Hogeschool Groningen (University of Applied Sciences), the University Medical Center Groningen and a business association. The students who were the subjects of this pilot experiment had some prior experiential and professional knowledge of the campus.

2. Procedure

To evaluate the role of activities in evaluating memories of soundscapes (as Umwelten), we asked a set of 36 students and one lecturer to describe their sensory experience of Zernike Campus. In the first steps of processing the written responses, we selected only those that referred directly to their acoustic experience of the campus.

The respondents were divided into four groups according to the motor and cognitive activity they were instructed to perform outdoors, in the campus. These two motor activities are listed below:

1. Walking: Respondents were instructed to follow a specified route in the campus, walking at a slow pace.
2. Sitting: Respondents were instructed to sit on benches in four locations along the route of the walkers.

We contrasted the two motor activities with two cognitive ones, counting and talking.

1. Counting: Respondents were instructed to sequentially count. If walking, they were instructed to count their steps; if sitting they were instructed to count passers-by.
2. Talking: Respondents were instructed to discuss in pairs specific topics. Those walking discussed the morphological properties of the space from an urban designer point of view. Those sitting discussed the features of users of the space (e.g. who they are, how they use the space).

The respondents were divided as follows, according to the combination of activity that they were engaged in: (i) walking and counting (9 respondents); (ii) walking and talking (10 respondents); (iii) sitting and counting (10 respondents); and (iv) sitting and talking (7 respondents).

After performing the activities listed above, respondents returned to the classroom and were asked to respond in writing to a structured questionnaire, of which only the answers provided to the following three questions are analyzed in this paper:

1. Please describe your time in the Zernike campus spent walking or sitting.

2. Please describe the Zernike campus, in as much detail, as you experienced it during your activity, using your senses (smell, touch, taste, vision, audition).

3. Please describe what attracted your attention during this time.

The questions referred to the respondents' overall experience, without a focus on the acoustic dimension exclusively, in order to evaluate the auditory events involved in the global sensory experience. Crucially, all respondents were native Dutch speakers who professed fluency in English.

The resulting written corpus was subjected to linguistic analysis; we contrasted the answers provided by users engaged in the four categories of activities described above. We further analyze these linguistic preferences to infer the properties of the mental representations of sounds, based on hypotheses on the link between language and cognition [10].

3. Analysis

To perform the linguistic analysis, we transcribed all responses and coded them into a multi-tiered grid. Each response was transcribed as a row, with each word mapped to one column corresponding to part-of-speech and phrase type. Each entry was coded for motor/cognitive activity pair.

Membership in one row or another was done on the basis of part of speech (determiner, pronoun, noun, verb, adjective, preposition, and adverb) and phrase type. Phrase-level categorization included noun phrases (NPs), verb phrases (VPs), prepositional phrases (PPs) and adjective phrases (APs). Two tiers of phrase levels were necessary because e.g. a VP can contain NPs and other VPs. For example, the sentence below is a single VP made up of NPs, PPs and other VPs.

Table I. Number of occurrences in the corpus: VPs and NPs

		Counting	Talking
VPs	Sitting	8	2
	Walking	8	2
	SUM	16	4
NPs	Sitting	15	10
	Walking	13	7
	SUM	28	17

$[[\text{I}]_{\text{NP}}$ [heard $[[\text{the cars}]_{\text{NP}}$ [on the highway$]_{\text{PP}}]_{\text{NP}}]_{\text{VP}}]_{\text{VP}}$

Membership in one phrase type or another was determined with reference to the part-of-speech of the phrase head. In the sentence above, the predicate *heard the cars on the highway* is a VP whose head is the verb *heard*.

Simple NPs and APs were typically analyzed as elliptic forms with a null subject and verb. Such constructions, common to natural language, arose by virtue of the design of the question and are treated in analyses of "answer ellipsis" [11].

While the amount of quantitative data in the corpus prevents statistical analysis, we can evaluate the productivity of this method and the linguistic criteria which are sensitive as "measurement instruments" to differentiate emic experiences[1].

The total occurrences of NPs, VPs, and ellipses (comparing between noun and adjectives, described below) proved the most promising differentiators in the corpus. Overall, the analysis of responses reveals a general tendency to use more NPs than VPs across different categories of activities. We counted a total of 20 VPs and 45 NPs.

The difference in the responses of respondents is apparent in their use of nouns and verbs. As shown by the distribution of verbs in the top half of Table I, there is a clear division between counters and talkers, but not sitters and walkers. That is, counters, but not talkers, preferred responses with verbs.

The division in the bottom half of Table I, which summarizes the distribution of the preference for nouns in responses, is not as black-and-white. Nonetheless, there are two observations to be made: (1) counters produced more NPs than talkers; and (2) sitters produced more NPs than walkers (a difference which did not hold for VPs). VPs included mostly either the copulative "to be" (e.g. "it was quiet") or verbs referring to sense modalities (e.g. "hear", "see"). Both sets of counters use considerably more VPs that include verbs related to sense modalities (e.g."hear", "see", "observe"). Talkers used significantly less VPs in their responses. Both sets of counters (left column in Table II) usually identify multiple sound sources in their detailed description of their soundscape. Those who walked and talked (right column in Table II) tend to offer global evaluations, and do not identify any specific sound sources in their descriptions. Examples of responses of each of the groups in Table I are provided in Table II and Table III .

Table II. Example responses for sitters

Counting	Talking
People were talking.	A car passing by.
The bus sounds were annoying.	Birds singing.
It was quiet.	Distant noise
I heard the people talking.	Quiet.

Table III. Example responses for walkers

Counting	Talking
It is surprisingly loud.	The quietness.
You can hear the traffic.	Noises.
I hear a lot of sounds.	Silent.
Bikes.	Noisy.
Not very quiet.	

At this juncture, it is also pertinent to remark on the variety of syntactic constructions. We observe a sharp contrast between the cognitive activities (counting and talking). People engaged in counting, regardless of the motor activity, usually produced more complex constructions when describing their previous experience of the campus. Those who were talking, likewise regardless of the motor activity, tended to produce either single words (typically nouns or adjectives, e.g. "noise", "silent") or modifier + head NPs (e.g. "distant noise"). Accordingly, we look at each group's use of ellipsis i.e. the omittance of elements from the constructions which were provided or insinuated by the question. Thus we can contrast responses like "I heard the noise from the traffic" with "cars passing by", where the latter are analyzed as instances of ellipsis: "(I hear/see) cars passing by". We categorized the instances of ellipsis into one of two types: those which resulted in a NP and those which resulted in an AP. There were no VPs resulting from ellipsis. In cases where such responses included more than one NP (e.g. "bus sounds, closing doors, cars passing by, heating systems."), we counted them as one instance of ellipsis.

When considering the distribution of the 36 elliptic forms attested, a clear contrast can be observed between different combinations of motor and cognitive activities. Those who walked and talked used ellipses most frequently, particularly by including APs in their responses. Similarly those who sat and counted used

[1] In cultural anthropology, *emic* descriptions are those made from a perspective internal to the people studied, as opposed to *etic* ones, which are descriptions of a phenomenon "as it is" from the observer's perspective.

Table IV. Number of occurrences in the corpus: ellipsis

		Counting	Talking
NPs	Sitting	8	5
	Walking	4	4
APs	Sitting	1	3
	Walking	3	8

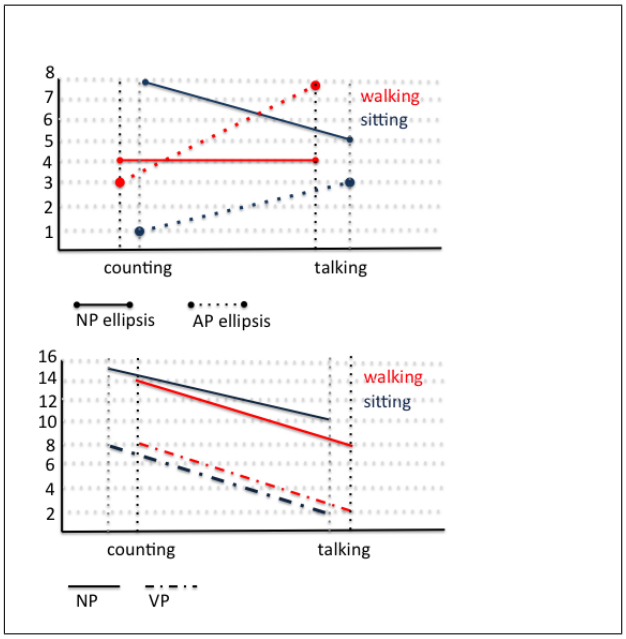

Figure 1. Occurrences of different phrases in the corpus: ellipsis (above) and non-ellipsis (below)

ellipses, in this case using mostly NPs in their responses. Those engaged in other combinations of activities used ellipses significantly less, particularly sitters and counters, as summarized in Table IV. No notable intra-category differences could be observed for cognitive activities (between walkers and talkers) or for motor activities (between walkers and sitters).

Figure 1 shows the total cases of ellipsis in the corpus and how they are distributed among the four activities (above graph) and the total cases of NPs and VPs between sitters and walkers and counters and talkers (below). From this figure it is clear that counters produce more NPs and VPs than talkers. In this sense, the frequency of NPs and VPs is sufficient to distinguish counters from the talkers. The difference between the walkers and sitters is not as notable.

4. Discussion and Conclusion

This analysis offers a useful alternative to those in the psycophysical tradition which are usually made through closed data collection instruments which include a priori categories from the natural sciences that are processed with quantitative analysis methods. For example, in the approach employed by Hall et al. [7] for assessments of soundscapes in focus groups, subjects rated 219 recorded "soundscape clips" according to six pre-defined semantic scales with adjectives listed at either end and provided a verbal account on what the soundscape represented. Ratings were then analyzed with a principal components analysis according to which each semantic variable was transformed to have a mean of zero and a standard deviation of one, and a correlation matrix of these variables was then constructed. Here, focusing on methodological issues, we would do well to consider Raimbault's remarks on inter-subject variations in responses to different scales and the polysemy of verbal labels [12].

The results following the linguistic analysis show the influence of activities on reports from memory of sensory experiences, here limited to the auditory domain. The analysis suggests that cognitive activities exerted a greater influence on the memory of auditory events than motor activities, indicating that perception is driven by high level processing. That is, perception is not just bottom-up information processing of any stimulation. It is a highly selective process driven by attentional processes, like those that are involved in counting and talking.

Comparing the linguistic responses between counters and talkers, talkers tend to *label* and counters tend to *describe*. The perceived and remembered auditory events differed depending on the type of activities performed within the same acoustic environment.

We started this paper with some remarks on the "hybrid" nature of soundscapes. Returning to that issue now, we can reconsider the relationship between acoustic and perceptual (linguistic) data with a fresh perspective. This pilot lends insight into how cognitive properties of soundscape could be accounted for in the physical description of the signal. This is to be achieved not with reference to strict cognitivist accounts according to which subjects would be seen as "extracting" information that is computationally processed in the brain, but instead by taking into account processes that involve selectivity in perception. The activities described and researched in this paper are defined at an individual level, categorized based on the motor and cognitive skills required for respondents to perform them successfully. Just as verbal communication implies the existence of a shared knowledge and language, people also give meaning to their performance of activities, which is embedded in a body of consensual knowledge shared by members of a community, materialized in everyday practice and that should be accounted for in further studies. The diversity of responses to the questionnaire indicates that researchers should pay attention to the diversity of practices through which members of different socio-cultural backgrounds become involved or relate to their acoustic environment. This opens soundscape research to a more sociological approach that goes be-

yond the analysis of psychological processes and the search for generality in the appraisal of acoustic environments and specific auditory events.

The variety of linguistic devices used by respondents, as visible in Tables II and III is a suitable illustration of how linguistic tools can be used to evaluate soundscape as a hybrid object. We see how responses indicate global and multimodal interpretations revealing the interplay between different "worlds of knowledge" (experiential knowledge, technical expertise, scientific knowledge, etc.) that show how auditory events are processed differently depending on respondents' categorical knowledge, familiarity and, specifically, activity in which they are engaged.

For example, both sets of counters identify sound sources in their description of their soundscape and those who walked and talked tend to offer global, qualitative evaluations. Both sets of counters use considerably more VPs than counters, which points towards a contrast in the way in which counters and talkers relate to their experience. The counters use personal pronouns in the description of their environment (e.g. "I heard the cars on the highway"). They refer to sound events as having an *effect* on them, rather than being simply "objects" in the world, with an existence separated from their own [5]. Similarly, research on acoustic comfort aboard trains [13] on the differential production of ellipsis and syntactically complex sentences indicates that the these linguistic forms correlate with different relations of the respondent with the world. Based on the findings of this research, we can infer that the respondents using most ellipses, namely walkers and talkers, and sitters and counters, interact and are aware of their environment in a different manner than respondents engaged in the other two combinations of activities. We hypothesize that a further study with a larger number of respondents would yield more insight on intra-category differences among motor and cognitive activities. As, for example, walking or sitting, or counting or talking involve different interaction with the environment and awareness of different environmental cues, we expect subtler contrasts among descriptions offered by those engaged in different categories of cognitive or motor activities to be apparent in a larger corpus.

The complexity of soundscape research must be addressed through the integration of additional variables in the study of the interaction between humans and their acoustic environment (i.e. activity) but also through the development of more precise instruments to address the relationships between mental representations and linguistic resources. For this, one step is to develop more detailed linguistic tools through which to access the mental representations of soundscapes in particular, and sensory experience more generally. Further research can also be conducted to determine what aspects of the description of a soundscape can account for the features or qualities that respondents specify as meaningful for their experience (e.g. quiet, noisy, pleasant, etc.).

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