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EFFECTS OF NATURAL SOUNDS ON STUDENTS' LEARNING AND CLASSROOM SOUNDSCAPE

Matteo Pellegatti[1,2*] **Chiara Visentin**[1,2] **Simone Torresin**[3]
Francesco Babich[2] **Nicola Prodi**[1]
[1] Department of Engineering, University of Ferrara, Italy
[2] Institute for Renewable Energy, Eurac Research, Italy
[3] Department of Civil, Environmental and Mechanical Engineering, University of Trento, Italy

ABSTRACT

Previous studies on the effect of acoustic exposure on cognitive abilities mainly explored the effect of anthropogenic sounds (e.g., traffic and chatting noise), intended as environmental stressors. However, recent soundscape research highlighted the potential of positive and desired sounds to increase student performance. In this paper, the effect of natural sounds (including birdsong in a garden) on students' cognition and soundscape assessment was analysed by comparing students' performance in a math task and affective responses when exposed to birdsong with those obtained in the classroom ambient noise. 229 pupils aged between 11 and 13 (grades VII and VIII) participated in the experiment, carried out with a class-wise paradigm. The data from the cognitive tests were analysed using Generalised Linear Mixed-Effect Models, while the soundscape data were compared using the Wilcoxon test. The results show an increase in calculation accuracy and perceived pleasantness and eventfulness when birdsong is played.

Keywords: *classroom acoustics, math, soundscape, natural sounds*

**Corresponding author*: matteo.pellegatti@unife.it

1. INTRODUCTION

Previous studies on the effect of acoustic stimuli on students' cognitive abilities and well-being mainly focused on the effect of disruptive and unpleasant sounds [1], such as traffic and chatting noise, treating the sound stimuli as something intrinsically undesirable that needs to be removed. However, according to soundscape research, the sound environment should be valorised and shaped using pleasant and desired stimuli [2], when possible, to increase acoustic comfort while supporting task performance [3]. Indeed, there might be a possibility that exposure to pleasant and desired sounds positively influences students' cognitive abilities. For example, exposure to water sounds restores memory and attention [4], while the sound of rain improves calculation ability [5]. In this paper, the Authors studied the effect of acute exposure to birdsong on a numeracy task and on soundscape assessment in middle school students, comparing it with a quiet condition (classroom ambient noise).
The data were extracted from a broader research project in which the effect on students of sounds related to classroom ventilation (mechanical – fan noise - or natural – e.g., traffic noise, children playing in the courtyard) was studied.

2. METHODS

2.1 Participant

A total of 229 students aged from 11 to 13 (average age 12.8 years, 53% male) from five middle schools in the province of Bolzano (Italy) participated in an experiment in which calculation accuracy and soundscape assessment under different listening conditions were analysed.

2.2 Listening condition

Two listening conditions are included in the present analysis. The first is a listening condition related to natural ventilation, i.e., birdsong, while the second is the sound environment of the classroom when students are silent (quiet condition). The birdsong was recorded with binaural headphones and played through calibrated headphones at a level of 47 dBA.

2.3 Description of the experiment

The experiment was divided into two days. In the first day, the students performed the calculation task, a soundscape assessment, and a noise sensitivity questionnaire according to Weinstein's noise sensitivity scale [6], while in the second day they performed a test of their arithmetic calculation skills [7]. The tasks of the first day were implemented on the online platform Gorilla.sc (http://www.gorilla.sc/). The study was approved via Eurac Research's ethical office.

2.3.1 Calculation task

For each listening condition, the calculation task consisted of 24 trials. In each trial participants were asked to judge whether a math equation that was displayed on a table through a touchscreen was correct or false (e.g., 84 + 12 = 95), by pressing a true-false button. Background sounds (birdsong) were played back continuously during the task. The equations were two-digits additions and subtractions (half of each type) whose difficulty was manipulated to obtain two difficulty levels (easy - without borrowing and carrying, and difficult - with borrowing and carrying). A fully description of the equations could be found in Caviola et al. 2021 [8]. Accuracy (correct/wrong answer) and response time (RT) were recorded for each trial.

2.3.2 Soundscape evaluation

In absence of a model for the assessment of the affective response to sounds in indoor school environments, affective responses were obtained via the questionnaire and perceptual attributes described in ISO 12913-2 – Method A [9]. Students completed the questionnaire while the listening condition was played back through headphones. The assessment was repeated for each of the conditions included in the experiment.

2.4 Data analysis

All data from students with cognitive or hearing impairments were removed from the analysis. As concern the calculation task, data were hence cleaned by removing all trials with too fast responses (RT<1.5s) and all listening conditions with an accuracy lower than chance level (50%) and with less than half of the trials remaining. At the end of data cleaning, the sample size was reduced to 150 participants. Accuracy in the calculation task was analysed by using generalized linear mixed-effects models (GLMM). The fixed factors included in the model were: the listening condition, noise sensitivity, order of execution of the listening condition, difficulty, the calculation skill level, the interaction between listening condition and difficulty, and between listening condition and noise sensitivity. Participant was included in the model as a random intercept. The post-hoc analysis was performed with pairwise comparison. The response time was not analysed.

Regarding the soundscape assessments, the eight attribute responses were transformed into the ISOPlesantness and ISOEventifulness variables [10]. The new variables were analysed with the Wilcoxon test to assess the presence of significant differences between the two listening conditions.

3. RESULTS AND DISCUSSIONS

Figure 1 shows the mean accuracy, by listening condition and task difficulty for the calculation task. The statistical model indicates a main effect of listening condition ($\chi^2(1)$=6.78, p=0.009), of difficulty ($\chi^2(1)$=223.46, p<0.001) and of the calculation skill level ($\chi^2(1)$=48.25, p<0.001). Accuracy was higher for students with better arithmetic calculation skills and for easy compared to difficult equations (z=14.95, p<0.001). As concern the listening conditions the accuracy was higher while listening to birdsong rather than to quiet (z=2.66, p=0.008). The results are in line on what reported by Proverbio et al. [5], who found higher accuracy in the execution of a true/false arithmetic task by adults when listening to natural sounds (i.e., rain noise at 89dB) compared to a quiet condition. The present study thus highlights for the first time an improvement in complex cognitive abilities by children when hearing to a natural sounds inside real classroom setting.

Figure 2 shows the results in ISOPleaseantness and ISOEventfulness. The analysis indicated that birdsong was perceived by the students as more pleasant (W=9684, p<0.001) and more eventful (W=14112, p<0.001) than quiet.

Regarding pleasantness, the results are in agreement with studies reporting increased comfort by students in presence of natural sounds [10]. Interestingly, the level adopted in this study (47dBA) is close to that reported as corresponding to maximum pleasantness for natural sounds in the literature (45 dBA) [11]. As for eventfulness, results are consistent with the presence of salient events (such as bird tweets) in the recorded natural environments .

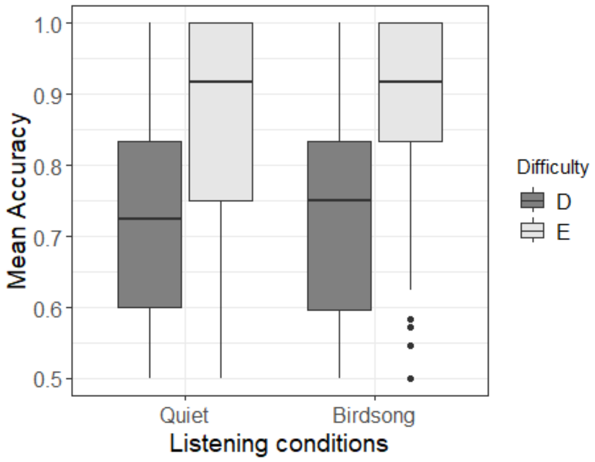

Figure 1. Boxplot of the mean accuracy in the math task by listening condition and difficulty (D=Difficult, E=Easy).

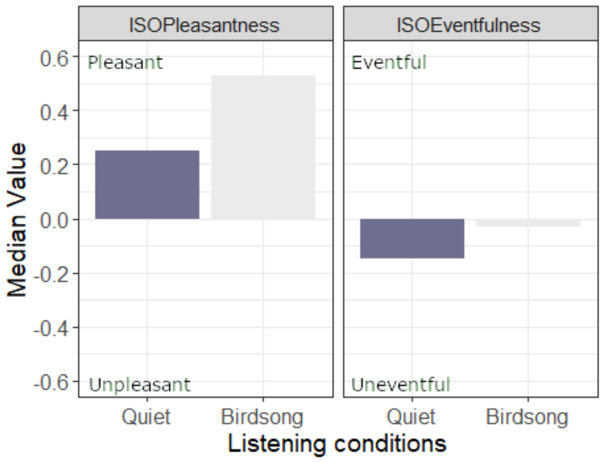

Figure 2. Median value of the ISOPleasantness and ISOEventufulness across all the participants.

4. CONCLUSIONS, LIMITATION AND FURTHER STUDIES

The results show that for neurotypical students both the difficulty of the task and the students' calculation proficiency are important in the accuracy of the calculation task; however, independently by the latter factor the exposure to natural sounds (birdsong in the present study) has a beneficial effect on students' performance and affective response to the classroom sound environment. The results thus highlight the importance of making natural sounds available to students through the exploitation of nature-based solutions in combination with ventilation strategies that allow contact with positive external soundscapes. Future research will be needed in order to further investigate the effect of different types of natural sounds, at different sound levels, and exposure durations. In the present study only neurotypical students were investigated. Since neuro-divergent people might have a different response to the sound environment, the experimental design employed in this study could be applied in future investigations to assess how the presence of hearing and communication needs affects soundscape perception.

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