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EFFECTS OF CHATTER NOISE ON LISTENING COMPREHENSION FOR PRIMARY SCHOOL STUDENTS

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ABSTRACT

This study investigated the effect of the number of competing speakers on a sentence comprehension task, and how this effect is modulated by individual factors. Seventy-one primary school children (age range: 10-13 years) completed the task in quiet and in two and four competing speakers (signal-to-noise ratio: +5dB). Outcome measures were accuracy and listening effort. Individual factors (cognitive abilities, noise sensitivity) were assessed in quiet. Results showed that students with low selective attention skills and high noise sensitivity are particularly at risk in the condition with two competing speakers, in which a decrease in performance (lower accuracy, slower response times, increased perceived effort) compared to quiet was observed.
Understanding the relationship between individual characteristics and sound environment has practical implications for the acoustic design of inclusive and supportive learning spaces.

Keywords: *classroom acoustics, listening comprehension, noise sensitivity.*

1. INTRODUCTION

Primary school students spend most of their time at school listening to the teacher in the presence of background noise. Whereas respect for acoustic standards and normative limits ensures that sounds coming from outside the classroom and/or generated by technical equipment or mechanical ventilation have a level too low to impair speech reception, a correct acoustic design only partially affects the chatter produced by the students themselves. Due to its spectro-temporal characteristics, this type of noise is particularly detrimental to verbal tasks [1], especially so when it is composed by only a few talkers and speech-on-speech masking realizes. Literature results show that children struggle to understand speech in this type of auditory masking [2] and the specific effect of the noise on every student is further modulated by his/her abilities and subjective perception.
This study aimed to explore the relationship between individual factors (noise sensitivity and cognitive abilities) and listening conditions (masking noise composed by two or four talkers) on a sentence comprehension task for primary school students [3].

2. MATERIALS AND METHODS

2.1 Measures of individual characteristics

Students were administered the following tests and tasks to assess the individual factors that might moderate their performance in the experimental task (see [4] for the choice of the tasks used to assess executive functions):

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(i) selective attention tasks (Simon task and Flanker task, presented in the visual domain).
(ii) working memory capacity task (2-back task, in the visual domain).
(iii) Weinstein Noise Sensitivity Test [5], to assess their self-reported noise sensitivity.

For each measure, the students were sorted into two groups based on the median score of the results (e.g., low/high sensitivity, low/high capacity). The sorting was not consistent across the groups, i.e., there could be the case of students with low sensitivity to noise and high selective attention.

2.2 Sentence comprehension task

The experimental task was designed to assess the listener's ability to comprehend a sentence in noise. Materials for the task were adapted from a standardized sentence-to-picture test in the Italian language [6].
In each trial of the task, a sentence was presented to the participant via headphones, in the presence of noise. At the audio offset, two images appeared on the tablet, and participants had to select the image that best matched the sentence content. Accuracy and response time (RT) were recorded for each sentence.
At the end of each listening condition (composed of 15 sentences), participants were asked to assess their perceived listening effort by answering the following question "*How hard did you have to work to understand the previous sentences?*" using a visual analog scale. Verbal anchors ("Not at all", "Extremely") were positioned at each endpoint of the slider bar.

2.3 Listening conditions

Participants completed the experimental task under three listening conditions: quiet, two-talkers (2T), and four-talkers (4T). The listening conditions were created by using auralization, simulating a virtual classroom with a reverberation time of 0.73 s, complying with the Italian acoustic standard on schools (UNI 11532-2). The speech level was set to 60 dB(A), based on the simulated level at the listening position for a talker speaking with a normal/raised vocal effort (63 dB(A) at 1 m [7]). The background noise was set to 55 dB(A), to obtain a positive SNR fitting within the range of values measured in actual classrooms.

2.4 Participants and procedures

A total of 71 students from three schools in Ferrara (Italy) participated in the experiment. They were in grades 5 and 7, aged between 10 and 13.
All the students performed the experimental task in three listening conditions (counterbalanced across the students of each class). Individual measures were completed in a separate session in quiet. A class-wise paradigm was adopted to increase the ecological validity of the experiment.

2.5 Data analysis

Data were analyzed by using generalized mixed-effects models (accuracy and RT data) or linear mixed-effects models (subjective listening effort). Fixed effects included in the models were listening conditions, selective attention, working memory capacity, noise sensitivity, and the two-way interactions between listening conditions and individual factors. Participants and items were included as random effects.

3. RESULTS

The statistical analysis of accuracy data indicated a significant main effect of the listening condition (p = 0.004) and a significant interaction between the listening condition and selective attention (p = 0.048). Pairwise tests revealed that students with high selective attention had lower accuracy in condition 2T compared to quiet and 4T (-6.3 and -4.4 percentage points, respectively). No difference between conditions was observed for children with low selective attention skills.
The statistical analysis of response time indicated a significant interaction between listening condition and selective attention (p = 0.001). Pairwise tests indicated that children with low selective attention had longer RT in 4T compared to quiet and 2T. Conversely, children with high selective attention had longer RTs in 2T compared to quiet.
Finally, the statistical analysis of subjective effort indicated a main effect of the listening condition (p = 0.02) and a significant interaction between the listening condition and self-rated noise sensitivity (p = 0.003). Pairwise comparisons indicated that children with low noise sensitivity perceived more effort in 4T compared with quiet, whereas students with high noise sensitivity perceived more effort in 2T than in quiet and 4T.

4. DISCUSSION AND CONCLUDING REMARKS

The direct assessment of the students' cognitive abilities and self-reported noise sensitivity made it possible to test whether these individual factors moderate the effect of multi-talker noise on the comprehension task. Selective attention, in particular, interacted with the listening condition on both accuracy and RT indicating that students with high selective attention had a lower performance (lower accuracy, longer RTs) in the listening condition with a two-talker masker. This listening condition appears to be challenging also for students with low selective attention (longer RTs but no changes in accuracy). The finding that selective attention, but not working memory, interacted with the effect of listening condition is in line with previous literature indicating that speech-in-speech recognition relies on the ability to selectively attend to the target speech while disregarding the other auditory objects [8].

The subjective measure of listening effort was instead moderated by the self-rated noise sensitivity of the students, with sensitive children perceiving increased effort with two interfering speakers compared to the other two conditions, and non-sensitive children perceiving more effort in noisy compared to quiet conditions. Therefore, it appears that noise-sensitive children are not more vulnerable to the effects of noise as a group per se, but they are more at risk depending on the specific characteristics of the background noise, namely the amount of informational masking.

Overall, the results show no direct influence of the number of competing speakers on the study results. However, the effect of listening conditions was moderated by the individual traits: selective attention for accuracy and reaction time, and noise sensitivity for perceived effort. When the effect of individual characteristics was included in the analysis, it was shown that the background condition with two competing speakers had predominantly negative effects on the more vulnerable students (e.g. with higher sensitivity to noise) presumably due to its larger informational masking.

This study has practical implications for the design of inclusive learning environments. Our findings suggest that reducing the noise generated by the children might be beneficial for their peers. This reduction can be obtained through a design strategy (e.g., an acoustic treatment of the classroom [9]) or a pedagogical strategy (aimed at raising the children's awareness of noise [10]).

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