EFFECTS OF CLASSROOM NOISE AND REVERBERATION ON THE SPEECH PERCEPTION OF BILINGUAL CHILDREN LEARNING IN THEIR SECOND LANGUAGE

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1 INTRODUCTION

Understanding speech through noise is a skill that develops well into a child's adolescent years and becomes adult-like at approximately the age of 15. [1,2] The developmental listening disadvantage for younger children is of particular concern in schools because the teaching of early educational skills may take place in noisy settings. Furthermore, bilingual children learning in their second language (L2) appear to be at a double jeopardy when listening under adverse conditions (noise, reverberation, background babble).[3,4,5] In fact, these children, in a short space of time, generally acquire the same lexical and morpho-syntactic skills, as their monolingual peers, but they don't reach an identical level of phonological skills in L2.
The aim of this study was to determine the effects of noise on speech perception skills in 15 typically developing immigrant children, (aged 6-10) learning through their L2, and to compare the results with those relative to 15 monolingual, Italian-only-speakers (IO) matched peers.

2 MATERIAL AND METHODS

Thirty typically developing children, 17 males and 13 females, ranging in age from 6 years to 10 (mean = 7,9), participated in the study. Fifteen were immigrant children (8 were born in Romania, 5 children were Arabs and 2 Albanians) and the number of years since the second language was first learned ranged from 2 to 4. Thus, the age of acquisition of the second language ranged from 3 to 8. All bilingual children used L2 at school and during recreational time, and spoke the native language at home. The control group was represented by 15 typically developing IO speakers, matched for gender, age and school proficiency. All children were recruited from two primary schools in Ferrara (Italy) and ranged from average to very good.
All participants demonstrated a hearing threshold equal or better than 20 dB for the frequencies 250, 500, 1000, 2000, 4000, 8000 Hz; normal otoscopy and acoustic immittance test. Children with neurological, cognitive and communicative disorders were excluded. Bio-anagraphical and scholastic data for all children are reported in Tab. 1.

Tab. 1. Bio-anagraphical and scholastic data from both experimental and control groups of children

Experimental group	Age (yrs)	Sex	L1	N° of years lived in Italy	School proficiency	Control group	Age (yrs)	Sex	School proficiency
S1	9	M	Romanian	2	good	C1	9	M	good
S2	9	F	Romanian	2	good	C2	9	F	average
S3	7	M	Romanian	2	good	C3	7	M	good
S4	7	M	Romanian	2	good	C4	6	M	good
S5	7	M	Arab	3	good	C5	7	M	very good
S6	6	F	Arab	3	very good	C6	6	F	good
S7	7	M	Arab	3	good	C7	7	M	good
S8	9	M	Romanian	2	good	C8	9	M	good
S9	10	F	Albanian	4	very good	C9	10	F	very good
S10	10	F	Romanian	3	very good	C10	9	F	very good
S11	8	M	Romanian	2	average	C11	9	M	good
S12	8	F	Albanian	2	good	C12	7	F	good
S13	10	F	Arab	2	good	C13	10	F	good
S14	8	F	Arab	4	good	C14	8	F	good
S15	6	M	Romanian	2	good	C15	6	M	good
SD	1.38						1.43		
Mean	8						8		

All children underwent the following audiological tests:
otoscopy
pure tone audiometry
acoustic immitance
speech audiometry with ipsilateral energetic masking
speech audiometry with contralateral informational masking.
Full evaluation had a duration of 30 mins for each child and was divided into three 10 mins sessions, with two break intervals.
The speech material used as a target signal was represented by lists of Italian words specifically validated for children's audiometry and was presented monaurally. A competitive message was presented contralaterally to the primary message at 50 dB HL and was represented by:
1) an energetic masking, i.e. cocktail party noise, presented ipsilaterally to the primary message
2) an informational masking, i.e. a passage from a novel by Conrad, whose silent pauses had been eliminated. The speech-to-noise ratio to obtain 50% Italian word intelligibility had been measured for the two different competitive speech tests, by using an adaptive 2 dB steps method. Briefly, when the child gives a correct response, the speech message intensity is lowered by 2 dB and when the response is zero, the primary signal is raised by the same intensity.
S/N ratio was calculated as the median in 6 track inversions at least, and after two trial lists. All the following test variables have been randomized: right vs. left ear presentation, word list sequences, time ordered sequences of the two different speech tests.

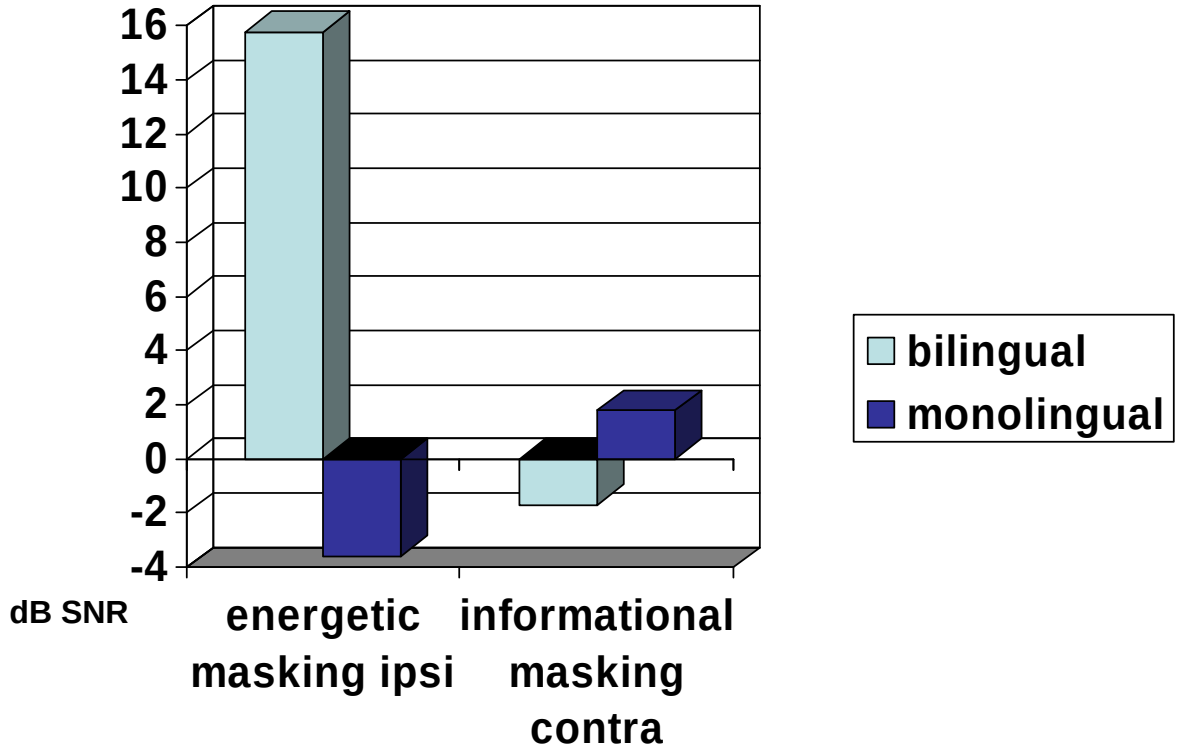
3 RESULTS

The values of SNRs to obtain a 50% intelligibility (corresponding to the speech reception threshold) for every child for both groups are reported in Tab 2.

Tab. 2. SNRs to obtain a 50% intelligibility for every child for both groups

	Energetic masking	Informational masking	Energetic masking	Informational masking
P1	25.8	-5	-12.3	-7
P2	27	-6	-3	4
P3	-7	-2.5	3.7	5.5
P4	14	7	-1	-3.3
P5	17.5	-1	-9.5	-3
P6	3.7	-11.8	-3	-2.5
P7	21	3	-5.3	3
P8	10.5	7	-11	-1
P9	7	0.5	-1.5	1
P10	17.7	-7.3	-6	3.5
P11	26	4	-8.3	1.5
P12	14	-4.3	7	9
P13	25.3	5.5	-2.3	4.7
P14	23.5	-6	1.5	5.5
P15	11.7	-9.3	-3	6.7
SD	9.7	6.0	5.4	4.4
Mean	15.8	-1.7	-3.6	1.8

For the experimental group of L2 learning children the SNR were:
15.8 dB (SD 9.7; range 25.8 / -7) with energetic ipsilateral masking
- 1.7 dB (SD 6.0; range 7/ -11.8) with informational contralateral masking
For the control group of monolingual IO speakers the SNR ratio were:
-3.6 dB (SD 5.4; range 7/ -12.3) with energetic ipsilateral masking
-1.8 dB (SD 4.4; range 9/ -7) with informational contralateral masking.
Statistical analyses showed a significant difference between the two groups for the mean SNR under the condition of ipsilateral energetic masking ($p = 0{,}001$). On the contrary, no significant difference was demonstrated between the two groups regarding the condition of contralateral informational masking.
Mean SNRs for both groups are reported in Fig.1



4 DISCUSSION

Our data seems to demonstrate that under adverse conditions, non-native speech communication in children tends to be less effective. In fact, bilingual children, who acquired L2 after the age of 3, require a 19.4 dB better SNR than native listeners in a test of word recognition.
Subject selection has been controlled in order to obtain two groups of children, carefully matched regarding anagraphic characteristics, school proficiency and lexical/morpho-synctactic skills. We used two different masking signals that have completely different effects: energetic ipsilateral masking and informational contralateral masking. The first has an exclusively peripheral and acoustic effect probably eliminating many acoustic features of low energy. The second has a central effect and probably interferes with the selective attention, the memory and superior language processing. With ipsilateral energetic masking, the immigrant children demonstrated the necessity of a SNR of 15.8 dB with statistically significant differences with respect to Italian children who instead needed a SNR of -3.6 dB. It's reasonable to think that the immigrant children need a larger redundancy of acoustic features in respect to the children whose native language is Italian, for a correct phonological analyses of the verbal message. On the other hand, the contralateral informational masking didn't demonstrate a significant difference between the two groups. This excludes the role of central cognitive factors (i.e. memory, selective attention) or semantic factors and is consistent with the teacher's report that the immigrant children displayed a competency in the Italian language (comprehension, production, reading and writing) that was normal for their age. Thus, the difference between the two groups would be secondary to diverse phonological skills.

There is no data in literature that is in agreement to the exact critical period beyond which phonological skills can't be fully acquired and consolidated.[6] Nevertheless, in our group of bilingual children, the acquisition of L2 was between the ages of 3 and 8 years, i.e. most probably beyond the above mentioned period.

In conclusion, the recommended level of classroom noise and reverberation is based on studies that evaluated speech intelligibility in normal monolingual children. Nevertheless, the number of immigrant children is probably increasing in developed countries and for them a recommended 15 dB SNR may be insufficient for adequate scholastic achievements. We hope that this audiological data will be used and directly applied to more engineering-oriented disciplines associated with speech communication (i.e speech intelligibility in room acoustics, design of communication systems).

5 REFERENCES

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