THE STRUCTURE OF LIP-READING DIFFERENT LINGUISTIC STIMULI IN PRELINGUALLY DEAF CHILDREN

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recived: march'98.
accepted: september'98.

Original scientific paper
UDK: 376.33

The results of two (older and younger) groups of deaf children, attending different educational programs, in lip-reading four types of linguistic stimuli (nonsense syllables, isolated words, meaningful sentences and sentences expressing unexpected events) were factor analyzed. The results of the investigation showed that there was a difference in the structure of lip-reading ability between the two groups of deaf children. The structure of lip-reading ability was more differentiated in the group of older deaf children than in the group of younger deaf children. Possible explanations of the results are elaborated.

INTRODUCTION

The structure of linguistic stimulus itself may be considered as a factor influencing lip-reading achievement. On every level of complexity, from vowels and consonants in nonsense syllables, to meaningful words and sentences, there are certain properties of linguistic stimuli which are related in a particular way to lip-reading achievement.

It is known, for example, that lip-reading nonsense syllables in postlingually deaf adults (Hanin, cited in Boothroyd, 1988), as well as in prelingually deaf children (Bradarić-Jončić, 1997) is less accurate than lip-reading words and sentences. Deaf children achieve better in lip-reading isolated words than in lip-reading the same words in the sentence (Clouser, 1976; Erber & McMahon, 1976; Green, Green & Holmes, 1981; Beasly & Flaherty-Rintelmann, cited in French - St-George & Stoker, 1988; Bradarić-Jončić, 1997). Although sentences theoretically offer the lip-reader more contextual information, coarticulation effects make the borders between words and phrases less visible, and thus the lip-reading of words in sentential context becomes less successful (Erber, 1979). Regarding the number of syllables in a word, the children most successfully lip-read two-syllable words, then three-syllable words, while they most inefficiently lip-read monosyllable words (Erber, 1974), which do not contain enough visual cues for correct identification. The word functioning as a subject in a sentence is lip-read more easily than the word functioning as an object (Erber & McMahon, 1976; Bradarić-Jončić, 1997), and sentences of SVO structure are more successfully identified than sentences of OVS structure (Bradarić-Jončić, 1997). The length and syntactic complexity of a sentence significantly influence the lip-reading achievement of deaf children (Clouser, 1976; Schwartz & Black, cited in Erber, 1979). Sentences of OVS structure are linguistically more complex, especially in the Croatian language. Thus the child must know morphological rules well in order to understand the relationship expressed in the sentence, and this puts greater demands on his/her short-term memory. In addition, sentences of SVO structure are used more commonly in everyday communication and in the rehabilitation process than OVS sentences.

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According to the common speech perception model (Horga, 1995), speech perception may be considered as a process of analyzing, comparing, and active synthesizing of sensory information with information or expectations stored in the long-term memory. In a situation when sensory data are insufficient or partial, in speech signal processing the receiver relies highly on the use of experiential data (linguistic knowledge and knowledge about the world). On the contrary, when experiential data are missing, in speech processing one relies more on detailed sensory data analysis.

Regarding the type of data overwhelming in speech signal processing, two basic processing strategies may be involved: the top-down strategy and the bottom-up strategy (Yeni-Komshian, 1993). In everyday communication, both types of strategies are employed symultaneously, depending on the communication context and on properties of linguistic stimuli.

This common model of speech perception may also be applied to the process of visual speech perception.

In visual speech perception, at least two types of processes are involved: the first one is the visual-analytic (Gailey, 1987) or sensory process (Risberg and Agelfors, cited in Rodda and Grove, 1987), and the other is the problem-solving (Gailey, 1987) or conceptual memory process (Risberg and Agelfors, cited in Rodda and Grove, 1987).

Heavy dependence on visual-analytic processes is involved when lip-reading stimuli of the lowest linguistic level, such as nonsense syllables, where no other sources of linguistic redundancy (Boothroyd, 1988) than phonological can be used. That's why the lip-reading of this lowest-level linguistic structure is less successful than lip-reading words and sentences.

When lip-reading sentences and discourse, the lip-reader is able to take advantage not only of phonological and lexical constraints, but also other sources of linguistic redundancy, such as semantic, morphosyntactic and even thematic constraints. This enables the lip-reader to use a different information processing strategy, which for this type of linguistic stimuli is more efficient. Thereby the lip-reader's flexibility in adjusting the processing strategies to the properties of the speech signal may be considered to be a factor that influences his/her lip-reading accuracy.

The necessery prerequisite of the use of linguistic constraints is a certain level of linguistic proficiency. Even with approximately equal linguistic skills, postlingually deaf adults differ in their skill of making use of linguistic redundancy. Skilled lip-readers make better use of phonological, lexical, semantical and thematical constraints than poor lip-readers (Hanin, cited in Boothroyd, 1988). Willingness to guess freely, as a personality trait, according to some authors (Montgomery & Demorest, 1988) could contribute to this difference between skilled and poor lip-readers.

The results of the investigations mentioned above, which directly or indirectly deal with information processing strategies in the lip-reading activity were, however, obtained on samples of postlingually deafened and hearing adults. The question that arises is: what are the information processing strategies in prelingually deaf people (especially in children), and which factors do they depend on?

THE AIM

The purpose of this investigation was to test the assumption that differences among deaf children in their achievements in particular linguistic and psychological skills, which result in different levels lip-reading achievement, result also in a different structure of their lip-reading activities.

The factor structure of the achievement in lip-reading different linguistic stimuli (nonsense syllables, isolated words, meaningful sentences, and sentences expressing unexpected events) in the group of older, linguistically more competent deaf children may be expected to be more differentiated than the factor structure of this activity in the group of younger, linguistically less competent deaf children.

METHOD

Subjects

The sample consisted of 14 younger prelingually deaf children, attending grades 3, 4 and 5, and 14 older prelingually deaf children, attending grades 6, 7 and 8, who had an average pure tone hearing threshold of 81 dB and above, with hearing loss acquired by the age of two, and who were without any additional handicaps.

The two groups of children differed significantly regarding their linguistic skills (table 1). The older children scored significantly better on the receptive (RECEPTIVE) and expressive vocabulary (EXPRESS) measures, as well as in morphological (MORPHOL) and syntactic (SYNTAX) skills. They also had superior visual-analytic skills, a longer short-term memory span for digits (MEMORY), measured by the Digit memory subtest of the Hiskey Nebraska Test, as well as better residual hearing (HEAR), than did the younger children. The results in the lip-reading of nonsense syllables were considered to be a measure of visual-analytic skills (SYLLAB).

The data on the grades and educational programs that the children attended are presented in table 2.

It can be seen that groups of younger and older deaf children differed also in terms of the educational settings they attended. The younger group consisted of children attending a daily oral program (N= 9) and a residential total communication program (N=5), while the older group consisted of children attending either oral (N=5) or integrated (N=9) setting.

Differences in chronological age, aided auditory performance, and quantity and type of educational background most likely contributed to the differences in linguistic competence between the groups.

Instruments and procedure

All of the lip-reading and linguistic skills tests (mentioned above) were developed at the Department of Hearing Impairments, for the purposes of the project

Table 1 Differences between younger (g1) and older (g2) deaf children in terms of linguistic skills, short-term memory span, and residual hearing

	Mg1	Mg2	SDg1	SDg2	F	p
MORPHOL	32.86	54.07	12.02	5.18	36.75	.0000
SINTAX	2.43	6.14	1.16	1.17	71.45	.0000
EKSPRESS	48.00	94.21	19.29	13.45	54.06	.0000
RECEPTIVE	25.57	51.86	10.19	2.68	87.01	.0000
MEMORY	6.85	9.29	2.41	2.19	7.75	.0099
HEAR	102	93	7.59	10.52	9.05	.0058

M = mean SD = standard deviation F = F ratio p = probability

	ORAL DAILY PROGRAM	TC PROGRAM /RESIDENTIAL/	INTEGRATED
GRADE 3	2	1	-
GRADE 4	2	3	-
GRADE 5	5	1	-
GRADE 6	2	-	2
GRADE 7	1	-	3
GRADE 8	2	-	4

Table 2 Number of participants according to grade and educational program

entitled Communication Disorders in Primary School-Aged Children, conducted at the Department of Hearing Impairments and the Department of Logopedics at Faculty of Special Education and Rehabilitation, University of Zagreb.

Four measurements of lip-reading achievement were used. All examinations were carried out by daylight in the classroom, in groups of 3 children (from the same class), wearing no sensory aids, sitting at a distance of about 5 feet in front of the talker, who spoke quietly, but not voicelessly. The task was to write down what had been said. The talker in each testing was a female student of Logopedics with whom the participants were not familiar. Before starting the examination on every test, several practice items had been administered to ensure that respondents understood the task.

The Nonsense Syllable lip-reading test consisted of 25 C1-V-C2 syllables, including 5 vowels (/a/, /e/, /i/, /o/, /u/) and 19 consonants (/p/,/b/, /m/, /f/, /v/, /l/, /r/, /t/, /d/, /n/, /ts/, /z/, /s/, /tʃ/, /ʒ/, /ʃ/, /k/, /g/, /h/) of the Croatian language (appendix 1). All of the syllables were without meaning.

The scoring was done letter by letter. Thus, the score for the variable SYLLAB represents the total number of correctly recognized (written) vowels and consonants in all of the syllables analyzed.

The efficiency of recognizing 5 vowels in medial position in a syllable was analyzed on syllables /pef/, /bɑm/, /mid/, /vug/, /ʒon/.

The efficiency of recognizing 19 consonants in the initial position in a syllable was analyzed on syllables /pef/, /tʃab/, /tsim/, /tɑk/, /hep/, /bɑm/, /ʒev/, /zav/, /giʃ/, /mid/, /ʃutʃ/, /non/, /sotʃ/, /kots/, /faʒ/, /res/, /ler/, /vug/

The efficiency of recognizing 19 consonants in the final position in a syllable was analyzed on syllables /pef/, /tʃab/, /tɑk/, /hep/, /bɑm/, /ʒev/, /zev/, /dits/, /giʃ/, /mid/, /ʃutʃ/, /res/, /hat/, /non/, /faʒ/, /zeh/, /ler/, /gul/, /vug/, /ʃiz/.

The maximal possible score on this test was 43 (5+19+19).

The Isolated Words lip-reading test consisted of 73 words (two - and three-syllable concrete nouns) divided into 5 subtests. Each subtest had a matching picture which determined the contextual frame for lip-reading words included in that subtest. Every word in the test had a graphical representation.

In the subsample of younger children, scores on the receptive vocabulary test varied from 16 to 39 words from a total number of 65 words , and in the subsample of older children the scores on this test varied from 48 to 56 words. Since almost all words from the Receptive Vocabulary test were included in the Isolated Words lip-reading test, it is clear that not all the words to be lip-read were in frame of the receptive vocabulary knowledge of the younger lip-readers.

Before lip-reading the words from each subtest, the children were instructed to look carefully at the picture. The score for the variable WORDS is the total number of correctly recognized words from all 5 subtests. The maximum possible score for this variable was 73.

The Sentence lip-reading test consisted of 37 sentences, of which 32 were meaningful sentences, loosely linked to a context, but without an obvious story-line, and 5 sentences expressed unexpected events (for example: "Tomorrow they will cook a book"). The last type of sentence was considered to be a measure of fast change in the use of appropriate information processing strategy. Children were not told that some sentences would be unusual or funny. Sentences were thematically divided into 3 subtests ("In the kitchen", "In the room" and "At the seaside"), each with a picture which determined the lip-reading context.

Sentences consisted of 4 to 7 words and 6 to 13 syllables. The linguistic complexity of the sentences varied from simple SVO sentences with the verb in the present tense, to more complex sentences including two verbs, subjects or objects, as well as perfect and future tense. Although the sentences used were relatively simple ones, not all of them were within linguistic skills of all participants. In the sentences expressing unexpected events, all words were familiar to the deaf children.

The scoring was done word for word. The score for the variable SENTEN is the total number of correctly recognized (written-spelled) words in each of 32 meaningful sentences. Every correctly written (spelled) word was given 2 points, while incorrectly written, but recognizable words were given one point. The maximum score was 300.

The score for the variable UNEXP represents the total number of correctly recognized (written) words in sentences that expressed unexpected events.

Data analysis

The data were processed by using factor analysis, with the principal components method of extraction and oblimin rotation.

RESULTS AND DISCUSSION

As can be seen in table 3, the older group was significantly (at the level .000) better at lip-reading all types of linguistic structures: nonsense syllables (SYLLAB), isolated words (WORDS), sentences expressing expected (SENTEN), as well as in lip-reading sentences expressing unexpected events (UNEXP). It may be supposed that these differences are primarily associated with differences in linguistic competence, because its measurement was included in lip-reading measures (except in the lip-reading of syllables), but also may be related, at least, to differences in memory span and in visual-analytic skills between the two groups.

The results of the factor analysis for the subsample of older children are presented in tables 4-6, and the results for the subsample of younger children are presented in tables 7-9.

In the subsample of older children, by factor analysis of the four lip-reading variables, two significant principal components were obtained, explaining about 70% of the common variance (table 4). All variables have high communalities (from .55 for WORDS to .77 for UNEXP) and high factor loadings (table 5).

The pattern and structure matrices (table 6) show that the first extracted factor correlates highly with the variables SYLLAB (about .78) and UNEXP (about .87). The second extracted factor correlates highly with the variables WORDS (.73) and SENTEN (.87). There is no correlation (r = -.03) between the two extracted factors.

In the sample of younger children, only one single factor, explaining about 76% of the common variance (table 7) was extracted. All variables (table 8) have high communalities (from .71 for UNEXP to .79 for SYLLAB), as well as high loadings (table 9) on the extracted principal component (from .84 for UNEXP TO .89 for SYLLAB).

In the act of lip-reading in the older, linguistically competent deaf children participating in this investigation, at least two unrelated factors were involved. The first factor explains their efficiency in lip-reading nonsense syllables and sentences expressing the unexpected events, and the

Table 3 Differences between groups in the lip-reading of nonsense syllables, isolated words, meaningful sentences, and sentences expressing unexpected events

	Mg1	Mg2	SDg1	SDg2	min g1	min g2	max g1	max g2
SYLLAB	13.79	17.57	3.04	2.14	7	15	18	23
WORDS	29.07	61.28	8.59	3.04	11	57	43	68
SENTEN	74.43	248.86	32.86	21.65	10	223	119	287
UNEXP	19.00	50.64	7.61	4.84	6	29	44	58

g1 = younger children g2 = older children M = mean
SD = standard deviation min = minimum score max = maximum score

second one explains their efficiency in lip-reading words and meaningful sentences. These results support the assumption that successful visual recognition of different linguistic structures is associated with the use of different information processing strategies. In situations where the use of contextual information (lexical and semantical, and even thematical constraints of language) is available to a lesser extent (as in lip-reading nonsense syllables and sentences expressing unexpected events), older lip-readers achieve poorer results and to a greater extent rely on their visual-analytic skills. Where such a possibility does exist, they achieve better results, and appearently use another type of processing strategy. Since their results on the variables SYLLAB and UNEXP mostly depend on their visual-analytic skills, the first extracted factor could be labeled as the factor of visual-analytic skills, whereas the second one could be named the factor of linguistic redundancy utilization. These results support the notion that, in the framework of their linguistic abilities, older deaf children successfully use linguistic redundancy in the act of lip-reading to fill the gaps which appear because of the poor visibility of certain speech elements.

Aside from the fact that on all four variables measured, younger deaf children in this investigation achieved significantly poorer results, their information processing strategies are not differentiated. The main factor contributing to their poorer results in lip-reading words and sentences are their poor linguistic skills, which make them less able to make the use of linguistic redundancy. At the same time, the visual-analytic skills and short-term memory span in this group of children are also still poor, and consequently, their success in lip-reading all of the types of linguistic structures is poor and characterised by the usage of a unique information processing strategy, regardless of the type of linguistic stimuli- decoding the elements of the lowest level - that is, speech sounds and groups of sounds.

Besides their age, the two groups of deaf children differed in the type of educational programs they had attended. Unlike the group of younger children, the majority of the older children (N=9) were attending a regular school. The difference between groups in terms of educational background was most likely related to the difference in their linguistic competence, their lip-reading achievements, as well as in the processing strategies they had used.

Based on the obtained results, it may be concluded that older and younger deaf children, who differ significantly in linguistic proficiency, short-term memory span and visual-analytic skills, use different information processing strategies in the act of lip-reading. This suggests that, during the education and rehabilitation process, with the deaf child's general progress in learning, these strategies gradually change, become more differentiated, more appropriate to the type of lip-reading stimuli, and thus result in an overall enhancement of the child's lip-reading ability.

These results suggest that it could be useful when training deaf children to lip-read to combine an analytic and a synthetic approach, that is, to exercise viseme recognition as well as guessing, i.e., within the boundaries of their linguistic competence, to fill in incomplete words and sentences. Exercising guessing strategies in written tasks, perhaps could generally enhance the efficiency of deaf children's utilization of linguistic redundancy.

Results of factor analysis in the subsample of older children

Table 4 Hotelling Eigenvalue (LAMBDA), percent of common variance (%) and cumulative percent of common variance

	F	LAMBDA	%	CUM
WORDS	1	1.39173	34.8	34.8
SYLLAB	2	1.33497	33.4	68.2*
UNEXP	3	.93192	23.3	91.5
SENTEN	4	.34139	8.5	100.0

** last counted eigenvalue*

Table 5 Principal component analysis and variables communalities

	F1	F2	communality
WORDS	-.02	.76	.55
SYLLAB	.76	-.26	.64
UNEXP	.88	.03	.77
SENTEN	.22	.85	.76

Table 6 Pattern and structure matrices

	Pattern matrix		Structure matrix	
	F1	F2	F1	F2
WORDS	.10	.73	-.12	.73
SYLLAB	.78	-.15	.79	-.17
UNEXP	.87	.15	.86	.13
SENTEN	.12	.87	.09	.87

Results of factor analysis in the subsample of younger children

Table 7 Hotelling Eigenvalue (LAMBDA), percent of common variance (%) and cumulative percent of common variance (CUM)

	F	LAMBDA	%	CUM
WORDS	1	3.01837	75.5	75.5*
SYLLAB	2	.50029	12.5	88.0
UNEXP	3	.24813	6.2	94.2
SENTEN	4	.23320	5.8	100.0

Table 8 Communalities

RIJEČ	.75
SLOG	.79
NEOČE	.71
REČEN	.77

Table 9 Component structure

	F1
WORDS	.87
SYLLAB	.89
UNEXP	.84
SENTEN	.88

Appendix 1 Nonsense Syllables lip-reading test

/pef/	/tʃab/	/tɑk/	/tsim/	/hep/
/bɑm/	/ʒev/	/deʒ/	/zav/	/giʃ/
/mid/	/ƒutʃ/	/non/	/sotʃ/	/hat/
/faʒ/	/ʒon/	/dits/	/zeh/	/kots/
/vug/	/ʃiz/	/res/	/ler/	/gul/

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