ANNALS OF PSYCHOLOGY/ROCZNIKI PSYCHOLOGICZNE
2023, XXVI, 3, 215–240
DOI: https://doi.org/10.18290/rpsych2023.0013

ROLE OF VISUAL SPEECH CUES (CUED SPEECH) IN FOREIGN LANGUAGE LEARNING BY HEARING SCHOOL-AGE CHILDREN

Olga Grabowska-Chenczke[1], Piotr Francuz[2], and Bibianna Bałaj[3]

[1]Faculty of Economics, Poznań University of Life Sciences
[2]Institute of Psychology, John Paul II Catholic University of Lublin
[3]Faculty of Philosophy and Social Sciences, Nicolaus Copernicus University in Toruń

In this study, we aimed to determine the role of visual speech cues in the process of foreign language learning by hearing school-age children. Our experiments used Cued Speech, a method designed for people who are deaf or hard of hearing. We expected that the principles of the method might also be beneficial for people with normal hearing because they may help distinguish the sounds of foreign speech that are difficult to hear. This study mainly focused on the effects of speech perception. We tested 126 Polish junior high school students (66 girls and 60 boys) with a normal range of phonemic hearing and language aptitude. We envisaged that foreign language learners using visual speech cues would achieve a higher score on a test of foreign language than learners who had studied the language in the traditional manner. We also formulated a hypothesis concerning the interaction of training type and training conditions on the effectiveness of foreign language learning: that the difference in the effects of foreign language learning between participants who received visual or executive training and typical training would be more significant in the presence of auditory distractors than in their absence. We observed interactions between conditions and types of training for speech sound identification. Under

Olga Grabowska-Chenczke, https://orcid.org/0000-0002-1154-667X; Piotr Francuz; Bibianna Bałaj, https://orcid.org/0000-0001-5066-7493. Correspondence concerning this article should be addressed to Olga Grabowska-Chenczke, Uniwersytet Przyrodniczy w Poznaniu, ul. Wojska Polskiego 28, 60-637 Poznań, Poland; e-mail: olga.grabowska@up.poznan.pl.

Piotr Francuz (1960–2020) supervised the experiment design and worked on the first draft. We would like to express our gratitude to Ms Leena Hasselman, Project Manager for Association LapCI ry and Finnish National Association for Cochlear-Implanted Children in Helsinki, Finland, for her invaluable cooperation and support during the recordings of Finnish speech sounds used in the experiments.

Handling editors: Marta Białecka, Nicolaus Copernicus University in Toruń, Magdalena Szubielska, John Paul II Catholic University of Lublin. Received 21 Sept. 2022. Received in revised form 27 Feb. 2023, 19 July 2023. Accepted 25 July 2023. Published online 9 Oct. 2023.

conditions of auditory distraction, foreign language learners using Cued Speech scored significantly higher than learners who had traditional training.

Keywords: speech perception; foreign language learning; auditory distraction; Cued Speech; visual speech cues.

The development of language among hearing people is an inevitable process that occurs regardless of the country, the characteristics of the language, and the user's specific abilities. Newborns can identify the sounds of disyllabic words at 24 hours of age (Swain et al., 1993) and 4-week-old babies can identify words 42 hours from the time of first exposure (Ungerer et al., 1978). From the earliest age, children, similar to adults, benefit from the tips of formants, the patterns of intonation, and phrasal segments. In this way, they develop linguistic competence and communication skills (Houston et al., 2003; Johnson & Jusczyk, 2001; Kuhl et al., 2003; Mandel et al., 1994).

Canadian infants can distinguish Czech speech sounds, even though adult Canadians do not hear the difference between them (Werker & Tees, 1984). Babies 8 to 10 months old can differentiate sounds that are not present in the surrounding linguistic environment (Werker & Pegg, 1992). We can conclude that newborns can make all possible distinctions between speech sounds regardless of the time and place of their birth. Narrowing the perception of speech sounds only to those present in the native language occurs at about 1 year of age (Werker & Tees, 1984).

Psycholinguists often distinguish between language acquisition and language learning (Krashen, 1981). Language acquisition occurs automatically and spontaneously in young children through their undisturbed contact with the language in its natural environment (Woodhouse et al., 2009). On the contrary, even though language learning is possible at any age, it requires effort and motivation (Dörnyei, 2013). The process of language acquisition involves the notion of a sharply defined critical period—the optimal time needed by children to master basic language skills in a natural environment—for acquisition, but the age of offset (the end of critical period) is still under discussion (Hartshorne et al., 2018). The deterioration of these skills contributes to a significant loss of the ability to identify and differentiate phonemes in foreign languages among adults (Kuhl, 2010; Kuhl et al., 2005).

Experimental studies of human behaviour and functional imaging data provide evidence for two types of mental representations in speech processing, conscious and unconscious, relating unconscious representations of phonemes to speech perception and production (Morais & Kolinsky, 1994). Research shows that the acquisition of phonemic awareness does not emerge spontaneously and that it may elicit supplementary and perhaps more efficient procedures to cope with spoken words (Morais

& Kolinsky, 1994, 2017). Morais and Kolinsky (2002) claimed that the recognition of spoken language includes the unconscious and mandatory operations of perceptual mechanisms that are biologically determined and require critical experiences in early childhood. Therefore, one should not confuse perception with awareness.

Because lipreading is known to improve auditory speech understanding, especially when speech is degraded, the process is crucial for understanding speech in challenging conditions (Bourguignon et al., 2020). Language users benefit from lipreading because it compensates rather specifically for the deficiencies in audition (Summerfield, 1992). In noise, when the auditory representation of the resonances in the mid- to high frequencies is often distorted, lipreading can play a complementary role. The identification of speech sounds or the intelligibility of sentences presented in noise improves when the listener can view the talker's face (Hardison, 2021; MacLeod & Summerfield, 1987). In a noisy environment, viewing a speaker's lip movements contributes to speech comprehension (Hardison, 2003).

However, sometimes articulatory cues and lipreading still lead to vagueness, especially among persons who are deaf or hard of hearing. Cued Speech serves as a system designed to reduce lipreading ambiguity (Alegria et al., 2010). In addition, among hearing learners when phonetic demands are high—for example, in noise—both facial and gestural input can help with non-native tone perception (Hannah et al., 2017).

The Principles of Cued Speech

To eliminate difficulties in mastering the language of deaf people, in 1966 Robert Orin Cornett (1967) developed a method of "manual verbal signs" and called it Cued Speech, a system of hand gestures carried out simultaneously with visible articulatory movements of speech organs.

Cued Speech enriches the visual continuum of speech sounds with gestures, enabling the deaf to identify phonemes and spoken words. Hand movements allow deaf people to visualize sounds, and they serve as simple cues that help in combining sounds into words and meaningful utterances. The visualization of sounds in Cued Speech does not replace the process of speaking; facial expressions still accompany it. The aim of supporting gestures (cues) is to emphasize the prosodic course of the auditory stimulation and help the person follow the pace and rhythm of speech. Cued Speech allows people with limited auditory perception to have visual access to the stream of speech segments. The process of visual differentiation works similarly to auditory differentiation and therefore enables the identification of the acoustic and perceptual structure of spoken phonemes in the language (Krakowiak, 1996; Leybaert et al., 2010, 2011).

The crucial function of Cued Speech is to support the differentiation and identification of speech sounds (Rees et al., 2017). Cued Speech allows the storage of mental multisensory representations of sounds. On the basis of these representations (visual–auditory–kinaesthetic), a perceptual basis of language is formed. The effectiveness of Cued Speech also depends on the learner's ability to focus attention (Leybaert et al., 2010) and on their performance in visual analysis and synthesis (MacDonald & McGurk, 1978). The kinaesthetic efficiency of speech organs and the motivation to communicate with other people play essential roles. Multisensory memory involves the representation of speech sounds and patterns of their articulation and spelling (Aparizio et al., 2017; Schwartz et al., 2004). Cued Speech involves auditory, visual, and physical modalities in speech perception, which relies heavily on multisensory representations.

The basic principle of Cued Speech is that distinctive hand movements accompany speech sounds that look similar on the lips during articulation. By looking at both the speaker's lips and hand movements, a person who is deaf or hard of hearing can differentiate and identify the sequence of sounds. Cued Speech enables the listener to distinguish sounds by reading the speaker's lips, especially when the sounds have the same place of articulation (e.g., English bilabials /p/ and /b/). In Cued Speech, every sound in the language must look different: When sounds look alike on the mouth they have to be cued differently, so it is done through gestures. To learn Cued Speech, it is necessary to master the system of handshapes and hand placements for vowels and consonants that occur in the given language (https://www.cuecollege.org).

Cued Speech in Foreign Language Learning

Teaching language with Cued Speech stresses the importance of perception and articulation. Cued Speech helps learners see the boundaries between the various particles of speech and focus their attention on the essential elements of prosody. Hoetjes and Maastricht (2020) discussed the role of co-speech gestures in teaching novel speech sounds in foreign language learning and they highlighted the impact of the different types and complexity level of gestures on various aspects of learning. However, other studies have yielded mixed results on the role of gestures in second-language speech perception, both null results (Hirata et al., 2014; Hirata & Kelly, 2010; Li et al., 2020, 2021; Xi et al., 2020) and positive results (Baills et al., 2019; Zhen et al., 2019).

The traditional foreign language teaching model pays attention to the role of prosody and articulation to a much lesser extent than in Cued Speech. In the standard

teaching model, students are more often required to adhere to grammatical correctness and the meaning of single words and phrases (Domagała-Zyśk, 2013).

Perception of foreign speech sounds is often associated with the simultaneous perception of auditory distraction (e.g., internal or external noise). Therefore, we assume that, especially in the early stage of foreign language learning, the efficiency of speech sound processing will depend on the impact of distractors. When one is acquiring proficiency in a language, distractors significantly affect speed and accuracy (Lewis et al., 2010) and the automatization of speech sound processing (Bayard et al., 2019). On the other hand, the differentiation of speech sounds depends on the impact of multisensory stimulation. White-Schwoch et al.'s (2015) research on the biological constraints on preliteracy during early childhood suggests that the neural processing of consonants in noise is fundamental for language and reading development. Similar findings were reported by Hayes (2003), Lehmann and Murray (2005), and Schwartz et al. (2004). We still know little about why, despite distraction, both linguistic processing of multimodal stimuli and encoding coherent mental representations are possible.

The main concern in our study was the impact of type of training on the effectiveness of foreign language learning. Because the process of language learning, especially the perception of foreign speech sounds, often occurs in the presence of distractors, we also sought to determine the best conditions for language learning in the presence and absence of auditory distractors.

We tested the hypothesis that learners who received visual and executive training provided with Cued Speech would achieve a higher score on a foreign language learning test than those who received typical training. We used Finnish as a foreign language and Vinkki Puhe (Finnish Cued Speech) as visual speech cues applied to the Finnish language (https://vinkkipuhe.fi). The samples of Finnish Cued Speech are presented in the Supplemental Material. We defined language learning effects as having specific indicators: differentiation of speech sounds and identification of speech sounds. We defined the speech sound differentiation index by the arithmetic mean calculated from the measurements of the effects of the tasks in which the participants distinguished the speech sounds of the Finnish language. The speech sounds identification index was defined by the arithmetic mean calculated from the measurements of the effects of task performance, in which the participants identified the speech sounds of the Finnish language.

Moreover, we formulated a hypothesis concerning the interaction of training type and training conditions on the effectiveness of foreign language learning: that the difference in the effects of foreign language learning between participants who received visual or executive training and typical training would be bigger in the presence of auditory distractors than in their absence. We expected the differ-

ences for the selected indicators of the foreign language learning process (ie. differentiation and identification of speech sounds).

METHOD

Participants, Materials and Procedure

We worked with 126 Polish junior high school students (66 girls and 60 boys) who ranged in age from 14–16 years (M = 15.42, SD = 0.54).The participants were Polish native speakers, who had never learned a chosen foreign language (Finnish) or any of the Finno-Ugric languages. All participants had a normal range of phonemic hearing and language aptitude. Phonemic hearing was tested by the method developed by Szeląg and Szymaszek (2006) that allows the diagnosis of the ability to differentiate between consonant oppositions and the indication of phonemic hearing deficits that underlie the impaired reception of speech sounds.

The language aptitude test for middle school students developed by Kuliniak (2002) was used to test language abilities. The test allows for the diagnosis of language predispositions in the area of five competences: stylistic sense and the ability to use correct sentence structures, vocabulary and phraseology, the ability to see analogies and distinguishing grammatical forms on the basis of the Polish language, the ability to distinguish correct grammatical forms on the basis of a foreign language (Latin) and the ability to draw conclusions and build rules governing a foreign (fictitious) language. Table S1 presents the results in the language aptitude test obtained by the students (see the Supplemental Material).

We designed a Finnish language course that was based on Cued Speech principles. The course consisted of six lessons presented in the Supplemental Material. Each lesson ended with a final test, which verified the learner's level of language proficiency. Depending on the type of training, the program of Finnish language courses differed by the presence or absence of Cued Speech performed by teachers during audiovisual recordings and the students' level of commitment to use Cued Speech. We randomly divided participants into three equal size groups (42 students in each group) according to the main factor: type of training. Diversity of training ensured three variants of learning a foreign language: (a) Typical training, which consisted of phonetic and writing exercises in the Finnish language. Participants did not receive any extra stimulation, and they did not use Cued Speech. We based the course on a typical foreign language course with teachers who did not use Cued Speech; (b) Visual training, during which participants were asked to

attentively listen to Finnish speech sounds and watch accompanying hand movements (Cued Speech performed by the teacher). Participants did not perform Cued Speech themselves; and (c) Executive training, during which participants were asked not only to attentively listen to Finnish speech sounds and watch accompanying hand movements (Cued Speech) performed by the teacher but also to simultaneously imitate the movements themselves. By performing Cued Speech themselves, participants became involved not only in the process of speech sound perception but also in performing motor activities relevant to speech processing.

The structure of each lesson was developed in cooperation with native Finnish speakers who were also fluent users of Finnish Cued Speech. Audiovisual recordings took place at LapCI ry (The Finnish Association of Cochlear Implant Recipient Children) in Helsinki. Each lesson began with the presentation of the main topic (e.g., numbers, colors, countries, nationalities, simple forms of greetings). Next, the audiovisual dialogues were presented twice. In the dialogues, we used words and phrases related to the main topic. The participants were initially familiarized with the alphabet of the Finnish language and its sound representation. They learned the basic vowel and consonants oppositions. Each lesson took approximately 30 minutes on average.

To investigate the effect of auditory distractors on foreign language learning, we diversified the training conditions in the above-mentioned types of training. We used two training conditions: (a) the presence of distractors and (b) the absence of distractors. We accompanied speech sounds with auditory distractions presented as noise superimposed on the text spoken by the teacher. We introduced distractors only to differentiate and identify speech sounds in a ratio of about 1:1 compared with the sounds presented without distraction. The aim of introducing distraction was to approximate the conditions of foreign language learning to the natural learning conditions, that is, less-than-perfect sound conditions in which a speech signal is produced and received.

We presented audiovisual recordings in the Finnish language course via a multimedia projector (Acer X1160 DLP) and loudspeakers (Logitech X-230). We ensured the optimum level of lighting and sound systems in the classroom. The experimental learning conditions were as close as possible to the conditions of the natural classroom environment. We provided the participants with questionnaires and performance tests, including auditory perception tasks and writing tests.

Data Analysis

Data was analyzed by using SPSS Statistics for Windows, Version 26.0 (IBM SPSS Statistics for Windows, Version 27.0, IBM Corp.). The analyses were conducted to obtain answers specifying the effect of types (three levels: typical, visual cued, executive cued) and conditions of training (two levels: with or without distractors) on the process of learning a foreign language. For this purpose, two-way ANOVA with between-subject factors was used.

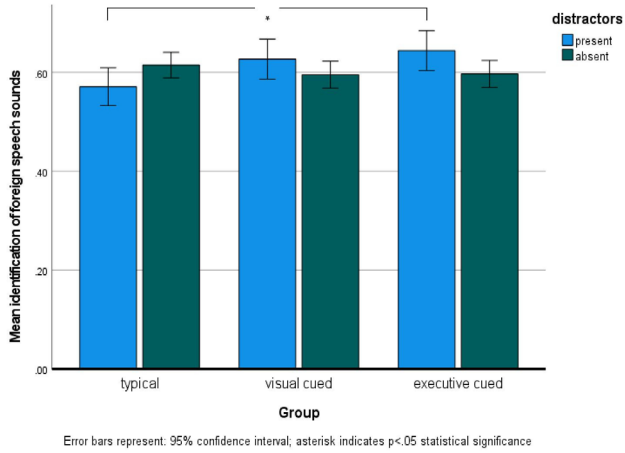
RESULTS

Effect of Types and Conditions of Training on the Identification of Foreign Speech Sounds

There were no statistically significant differences in the identification of foreign speech sounds between learners who received different types of training, $F(2, 118) = 1.14$, $p = .324$. No statistically significant differences in the effect of identifying foreign speech sounds between different training conditions were observed, $F(1, 118) = 0.91$, $p = .343$. However, we obtained statistically significant results when estimating the effect of the interaction of types and conditions of training on the process of identification, $F(2, 118) = 5.44$, $p = .006$, $\eta_p^2 = .084$ (see Figure 1).

Figure 1

Effect of Interaction of Types and Conditions of Training on Foreign Speech Sound Identification



Note. Error bars represent 95% confidence interval.
*$p < .05$.

An analysis of the interaction confirmed our second hypothesis. In the distractor conditions, the group of learners who were performing Cued Speech in a Finnish language course (executive training) received higher scores than learners who received typical training. The difference between groups, shown by the contrast analysis, $F(2, 118) = 3.77$, $p = .031$, was statistically significant. In the absence of distractors, there were no differences in the effects of foreign speech sound identification between the Cued Speech groups of learners (visual and executive training) and the typical training group (see Table S2 in the Supplemental Material).

Effect of Types and Conditions of Training on the Differentiation of Foreign Speech Sounds

Statistically insignificant result was obtained in relation to the influence of the main effect of the training conditions on the speech sounds differentiation process, $F(1, 118) = 0.00$, $p = .960$, and in relation to the influence of the main effect of the type of training on the process of differentiation of speech sounds, $F(2, 118) = 0.98$, $p = .379$, as well as in relation to the interaction between the conditions and the type of training, $F(2, 118) = 0.33$, $p = .397$. There was no effect of training conditions (presence or absence of distractors) and no interaction between types and conditions of training on the differentiation of foreign speech sounds.

DISCUSSION

In the present study, we aimed to find out whether visual speech cues (Cued Speech) effectively support the process of foreign language learning among people with normal hearing. We expected that the introduction of Cued Speech principles in the early stages of learning would increase performance on the tests of differentiation and identification of foreign speech sounds. We also verified a significant effect of the interaction between the types of learning a foreign language (usage vs. non usage of Cued Speech) and the conditions in which the process occurs (presence vs. lack of distractors).

Our hypothesis that learners who received visual and executive training that included Cued Speech would achieve higher scores on a test checking the identification of foreign speech sounds than those who undergo typical training was not confirmed.

The statistical analysis detected an interaction of the effects of training type (typical, visual, executive) and the presence or absence of distractors. Under audi-

tory distraction conditions, learners who received visual and executive training with Cued Speech scored better on the foreign speech sounds identification test than those who underwent typical training. In challenging circumstances (i.e., the presence of distractors), learners benefit from visual cues when they identify speech sounds. Based on these findings, we claim that language learners with unimpaired hearing can benefit from Cued Speech principles in such a way that every time they have difficulty identifying foreign speech sounds, they can use the accompanying visual cue to make the sound more visible and therefore more distinctive.

We expected that learners who received visual and executive training provided with Cued Speech would achieve a higher score in the test of differentiation of foreign speech sounds than those who underwent typical training. The results did not confirm our expectations.

Our results do not necessarily mean that potential interlocutors should learn the full range of Cued Speech in advance. From an ecological perspective, it seems that, to improve the process of foreign language learning, it may be beneficial to implement the idea of distinguishing the similar but unfamiliar sounds with hand gestures, as occurs in Cued Speech. We already know that viewing hand gestures during face-to-face communication affects speech perception and comprehension. Pilling and Thomas (2011) suggested that exposure to audio-visual speech can drive learning at an auditory perceptual level. Other findings suggest a common neural substrate for processing speech and gesture given that canonical speech perception areas in the temporal cortices may process and integrate not only auditory cues but also visual cues during speech perception. Speech-accompanied gestures affects social communication and provides a close link between hand action and language (Hubbard et al., 2009).

The significant effect of the interaction of types and conditions of training on foreign speech sound identification, although seemingly surprising, can be explained by the mechanism of attention involved in the learning process. In language learning, attention serves both as a mechanism for selection and perception of stimuli (Niżegorodcew, 2007; Stevens et al., 2009). Because attention selects and focuses on important stimuli, distractors may increase the level of mobilization of cognitive abilities to process language data. Attention may also facilitate the process of selection by using sensitive cognitive filters that juxtapose signals and noise.

The characteristics of the inhibition processes partially explain the obtained results given that the process serves as a mechanism for monitoring and reducing interference in cognitive resources. During the selection process, the cognitive system eliminates irrelevant information, simultaneously preventing the subject from performing unwanted neuronal, mental, and behavioural activities. Studies of the effectiveness of motor response inhibition in the "stop signal paradigm" (Logan,

1982) have shown that inhibition is a very demanding and intentional process that interferes with current activities. However, the interference that results from inhibition is weaker than the mutual interference of simultaneous operations (Logan, 1982; Logan & Cowan, 1984).

In a situation of competing signals and noise (distractors), we can observe the phenomenon of competing units. A stimulus that suddenly appears draws attention, triggers the cognitive mechanisms of control, and immediately initiates a set of learned responses to this stimulus. Suppose the interfering stimulus appears not to be associated with a set of learned and automatic reactions and does not fit the data stored in the long-term memory. In that case, the cognitive system switches to controlled data processing accompanied by the attention system. As a result of the increased involvement of control mechanisms and attention, the process of stimulus detection occurs under conditions that compensate for the deficits associated with distraction. The interaction results indicate the critical role of Cued Speech in speech sound perception carried out under conditions of distraction. Therefore, it is likely that the compensatory function of Cued Speech (visual listening) determines its effectiveness among deaf or hard-of-hearing language learners and hearing students (Krakowiak, 1995, 2006).

Methods of improving perceptual-motor integration are mostly a part of therapy for children with specific language development disorders and dyslexia (Sparks & Miller, 2000). However, it seems that we need to introduce similar foreign language teaching methods to students who have limited access to multisensory language data in traditional school settings. Children with dyslexia usually experience cross-modal integration disorders and thus difficulties in transforming visual and auditory data. Learners of a foreign language often experience similar challenges in the perception of foreign speech sounds, especially when they do not have the opportunity to observe the speaker's mouth movements and when they cannot benefit from multimodal representations.

The conclusions from research that has examined the language abilities of speech sound differentiation and identification are part of the current discussion on the possibility of rebuilding or restoring an inborn perceptual sensitivity to phonemes (e.g., Birdsong, 2018; DeLuca et al., 2019; Elsabbagh et al., 2013; Hartshorne et al., 2018; Kissling, 2015; Liu et al., 2020; Mayberry & Kluender, 2018; Newport, 2018; Pallier, 1997; Werker, 2018; Werker & Tees, 2005; White et al., 2013). Knowledge of the cognitive determinants of foreign language learning also allows for further research in the psychology of language and foreign language teaching. It seems necessary to formulate practical guidance for those who create professional multimodal tools to support the learning process in different age groups.

The advantages of the Cued Speech method, which was initially designed to support learning by deaf learners, allow us to integrate research results on speech perception among hearing persons as well as those who are deaf and hard of hearing. The results of interdisciplinary research can also help verify hackneyed or colloquial views on the process of gaining skills in foreign languages under both natural conditions and in the school setting. Still, further attempts to explore the cognitive processes and personality factors that determine language acquisition are essential.

This study is a step toward the development of methods that would help differentiate and identify the sounds of a foreign language more effectively. Thus, such methods could help foreign language learners restore their sensory sensitivity (Podlewska, 2013) to the phonological level. Nevertheless, further research exploration and integration with different areas of language development study are necessary. The limitations of the present study include the short time of foreign language training (only a few lessons). Controlling the level of familiarity with visual cues and the level of proficiency in the performance of the cues among participants with normal hearing may be useful. The study presents results only for speech sound identification and differentiation. Other areas of speech perception (e.g., categorization and discrimination of different classes of speech sounds) may be susceptible to the impact of visual speech cues and therefore require further investigation. Taking into account neuroscientific findings on multimodal speech research (Cearon & Feltes, 2020; Hardison, 2021), studying the impact of the simultaneous presence of visual speech cues, head and eyebrow movements, and beat gestures on speech perception accuracy is also promising.

CRediT Author Statement

Olga Grabowska-Chenczke (40%): conceptualization, methodology, software, validation, formal analysis, resources, writing (original draft), supervision, writing (review and editing).

Piotr Francuz (30%): conceptualization, methodology, writing (original draft), supervision.

Bibianna Bałaj (30%): software, validation, formal analysis, supervision, writing (review and editing).

REFERENCES

Alegria, J., Charlier, B. L., & Mattys, S. (1999). The role of lip-reading and cued speech in the processing of phonological information in French-educated deaf children. *European Journal of Cognitive Psychology*, *11*(4), 451–472. https://doi.org/10.1080/095414499382255

Aparicio, M., Peigneux, P., Charlier, B., Balériaux, D., Kavec, M., & Leybaert, J. (2017). The neural basis of speech perception through lipreading and manual cues: Evidence from deaf native users of cued speech. *Frontiers in Psychology*, *8*, Article 426. https://doi.org/10.3389/fpsyg.2017.00426

Baills, F., Suárez-González, N., González-Fuente, S., & Prieto, P. (2019). Observing and producing pitch gestures facilitates the learning of mandarin Chinese tones and words. *Studies in Second Language Acquisition*, *41*(1), 33–58. https://doi.org/10.1017/S0272263118000074

Bayard, C., Machart, L., Strauß, A., Gerber, S., Aubanel, V., & Schwartz, J.-L. (2019). Cued speech enhances speech-in-noise perception. *Journal of Deaf Studies and Deaf Education*, *24*(3), 223–233. https://doi.org/10.1093/deafed/enz003

Birdsong, D. (2018). Plasticity, variability and age in second language acquisition and bilingualism. *Frontiers in Psychology*, *9*, Article 81. https://doi.org/10.3389/fpsyg.2018.00081

Bourguignon, M., Baart, M., Kapnoula, E. C., & Molinaro, N. (2020). Lip-reading enables the brain to synthesize auditory features of unknown silent speech. *Journal of Neuroscience*, *40*(5), 1053–1065. https://doi.org/10.1523/JNEUROSCI.1101-19.2019

Cornett, R. O. (1967). Cued Speech. *American Annals of the Deaf*, *112*, 3–13.

DeLuca, V., Miller, D., Pliatsikas, C., & Rothman, J. (2019). Brain adaptations and neurological indices of processing in adult second language acquisition: Challenges for the critical period hypothesis. In J. W. Schweiter (Ed.), *The handbook of the neuroscience of multilingualism* (pp. 192–218). Wiley-Blackwell. https://doi.org/10.1002/9781119387725.ch8

Domagała-Zyśk, E. (2013). *English as a foreign language for the deaf and hard of hearing persons in Europe*. Wydawnictwo KUL.

Dörnyei, Z. (2013). Motivation in second language learning. In M. Celce Murcia, D. M. Brinton, & M. A. Snow (Eds.), *Teaching English as a second or foreign language* (4th ed., pp. 518–531). Heinle Cengage ELT.

Elsabbagh, M., Hohenberger, A., Campos, R., Van Herwegen, J., Serres, J., de Schonen, S., Aschersleben, G., & Karmiloff-Smith, A. (2013). Narrowing perceptual sensitivity to the native language in infancy: Exogenous influences on developmental timing. *Behavioral Sciences*, *3*(1), 120–132. https://doi.org/10.3390/bs3010120

Hannah, B., Wang, Y., Jongman, A., Sereno, J. A., Cao, J., & Nie, Y. (2017). Cross-modal association between auditory and visuospatial information in mandarin tone perception in noise by native and non-native perceivers. *Frontiers in Psychology*, *8*, Article 2051. https://doi.org/10.3389/fpsyg.2017.02051

Hardison, D. M. (2003). Acquisition of second-language speech: Effects of visual cues, context, and talker variability. *Applied Psycholinguistics*, *24*(04), 495–522. https://doi.org/10.1017/s0142716403000250

Hardison, D. M. (2021). Multimodal input in second-language speech processing. *Language Teaching*, *54*(2), 206–220. https://doi.org/10.1017/S0261444820000592

Hartshorne, J. K., Tenenbaum, J. B., & Pinker, S. (2018). A critical period for second language acquisition: Evidence from 2/3 million English speakers. *Cognition*, *177*, 263–277. https://doi.org/10.1016/j.cognition.2018.04.007

Hayes, E. A., Tiippana, K., Nicol, T. G., Sams, M., & Kraus, N. (2003). Integration of heard and seen speech: A factor in learning disabilities in children. *Neuroscience Letters*, *351*(1), 46–50. https://doi.org/10.1016/s0304-3940(03)00971-6

Hirata, Y., & Kelly, S. D. (2010). Effects of lips and hands on auditory learning of second-language speech sounds. *Journal of Speech, Language, and Hearing Research*, *53*(2), 298–310. https://doi.org/10.1044/1092-4388(2009/08-0243)

Hirata, Y., Kelly, S. D., Huang, J., & Manansala, M. (2014). Effects of hand gestures on auditory learning of second-language vowel length contrasts. *Journal of Speech, Language, and Hearing Research*, *57*(6), 2090–2101. https://doi.org/10.1044/2014_JSLHR-S-14-0049

Hoetjes, M., & van Maastricht, L. (2020). Using gesture to facilitate L2 phoneme acquisition: The importance of gesture and phoneme complexity. *Frontiers in Psychology*, *11*, Article 575032. https://doi.org/10.3389/fpsyg.2020.575032

Houston, D. M., Tincoff, R., & Jusczyk, P. W. (2003). 7.5-month-olds' memory for words after a 1-week delay. In D. Houston, A. Seidl, G. Hollich, E. Johnson, & A. Jusczyk (Eds.), *Jusczyk Lab Final Report.* Retrieved September 14, 2023, from http://hincapie.psych.purdue.edu/Jusczyk/pdf/Memory.pdf

Hubbard, A. L., Wilson, S. M., Callan, D. E., & Dapretto, M. (2009). Giving speech a hand: Gesture modulates activity in auditory cortex during speech perception. *Human Brain Mapping*, *30*(3), 1028–1037. https://doi.org/10.1002/hbm.20565

Johnson, E. K., & Jusczyk, P. W. (2001). Word segmentation by 8-month-olds: When speech cues count more than statistics. *Journal of Memory and Language*, *44*(4), 548–567. https://doi.org/10.1006/jmla.2000.2755

Kissling, E. M. (2015). Phonetics instruction improves learners' perception of L2 sounds. *Language Teaching Research*, *19*(3), 254–275. https://doi.org/10.1177/1362168814541735

Krakowiak, K. (1995). *Fonogesty jako narzędzie formowania języka dzieci z uszkodzonym słuchem.* Wydawnictwo UMCS.

Krakowiak, K. (2006). *Studia i szkice o wychowaniu dzieci z uszkodzeniami słuchu.* Wydawnictwo KUL.

Krakowiak, K., & Sękowska, J. (1996). *Mówimy z fonogestami. Przewodnik dla rodziców i przyjaciół dzieci i młodzieży z uszkodzonym słuchem*. Wydawnictwa Szkolne i Pedagogiczne.

Krashen, S. D. (1981). Second language acquisition and second language learning. Pergamon.

Kuhl, P. K. (2010). Brain mechanisms in early language acquisition. *Neuron*, *67*(5), 713–727. https://doi.org/10.1016/j.neuron.2010.08.038

Kuhl, P. K., Conboy, B. T., Padden, D., Nelson, T., & Pruitt, J. (2005). Early speech perception and later language development: Implications for the "Critical Period." *Language Learning and Development*, *1*(3–4), 237–264. https://doi.org/10.1080/15475441.2005.9671948

Kuhl, P. K., Tsao F.-M., & Liu H.-M. (2003). Foreign-language experience in infancy: Effects of short-term exposure and social interaction on phonetic learning. *Proceedings of the National Academy of Sciences*, *100*(15), 9096–9101. https://doi.org/10.1073/pnas.1532872100

Kuliniak, R. (2013). Testy predyspozycji językowych. Instytut Badań Kompetencji.

Lehmann, S., & Murray, M. M. (2005). The role of multisensory memories in unisensory object discrimination. Brain Research. *Cognitive Brain Research*, *24*(2), 326–334. https://doi.org/10.1016/j.cogbrainres.2005.02.005

Lewis, D., Hoover, B., Choi, S., & Stelmachowicz, P. (2010). Relationship between speech perception in noise and phonological awareness skills for children with normal hearing. *Ear and Hearing*, *31*(6), 761–768. https://doi.org/10.1097/AUD.0b013e3181e5d188

Leybaert, J., & LaSasso, C. J. (2010). Cued speech for enhancing speech perception and first language development of children with cochlear implants. *Trends in Amplification*, *14*(2), 96–112. https://doi.org/10.1177/1084713810375567

Leybaert, J., Aparicio, M., & Alegria, J. (2011). *The role of cued speech in language development of deaf children.* Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199750986.013.0020

Li, P., Baills, F., & Prieto, P. (2020). Observing and producing durational hand gestures facilitates the pronunciation of novel vowel-length contrasts. *Studies in Second Language Acquisition*, *42*(5), 1015–1039. https://doi.org/10.1017/S0272263120000054

Li, P., Xiaotong, X, Baills F., & Prieto, P. (2021). Training non-native aspirated plosives with hand gestures: Learners' gesture performance matters. *Language, Cognition and Neuroscience*, *36*(10), 1313–1328. https://doi.org/10.1080/23273798.2021.1937663

Liu, D., Wang, S., Gao, Q., Dong, R., Fu, X., Pugh, E., & Hu, J. (2020). Learning a second language in adulthood changes subcortical neural encoding. *Neural Plasticity*, 2020, Article 8836161. https://doi.org/10.1155/2020/8836161

Logan, G. D., & Cowan, W. B. (1984). On the ability to inhibit thought and action: A theory of an act of control. *Psychological Review*, *91*(3), 295–327. https://doi.org/10.1037/0033-295X.91.3.295

Logan, G. D. (1982). On the ability to inhibit complex actions: A stop-signal study of typewriting. *Journal of Experimental Psychology: Human Perception and Performance*, *8*, 778–792. https://doi.org/10.1037/0096-1523.8.6.778

MacDonald, J., & McGurk, H. (1978). Visual influences on speech perception processes. *Perception & Psychophysics*, *24*(3), 253–257. https://doi.org/10.3758/BF03206096

MacLeod, A., & Summerfield, Q. (1987). Quantifying the contribution of vision to speech perception in noise. *British Journal of Audiology*, *21*(2), 131–141. https://doi.org/10.3109/03005368709077786

Mandel, D. R., Jusczyk, P. W., & Nelson, D. G. (1994). Does sentential prosody help infants organize and remember speech information? *Cognition*, *53*(2), 155–180. https://doi.org/10.1016/0010-0277(94)90069-8

Mayberry, R. I., & Kluender, R. (2018). Rethinking the critical period for language: New insights into an old question from American Sign Language. *Bilingualism: Language and Cognition*, *21*(5), 886–905. https://doi.org/10.1017/S1366728917000724

Morais, J., & Kolinsky, R. (1994). Perception and awareness in phonological processing: The case of the phoneme. *Cognition*, *50*(1), 287–297. https://doi.org/10.1016/0010-0277(94)90032-9

Morais, J., & Kolinsky, R. (2002). Literacy effects on language and cognition. In L. Bäckman & C. von Hofsten (Eds.), *Psychology at the turn of the millennium, Vol. 1: Cognitive, biological, and health perspectives* (pp. 507–530). Psychology Press/Taylor & Francis.

Morais, J., & Kolinsky, R. (2017). The consequences of phonemic awareness. In B. D. Gelder & J. Morais (Eds.), *Speech and reading* (pp. 317–337). Routledge. https://doi.org/10.4324/9781315111810-16

Newport, E. L. (2018). Is there a critical period for L1 but not L2? *Bilingualism*, *21*(5), 928–929. https://doi.org/10.1017/S1366728918000305

Niżegorodcew, A. (2007). Uwaga w procesie nauki języka obcego. In J. Majer & J. Nijakowska (Eds.), *Język – Poznanie – Zachowanie. Studia nad psycholingwistycznymi aspektami przyswajania języka* (pp. 52–67). Wydawnictwo Uniwersytetu Łódzkiego.

Pallier, C., Bosch, L., & Sebastián-Gallés, N. (1997). A limit on behavioral plasticity in speech perception. *Cognition*, *64*(3), B9–B17. https://doi.org/10.1016/S0010-0277(97)00030-9

Pilling, M., & Thomas, S. (2011). Audiovisual cues and perceptual learning of spectrally distorted speech. *Language and Speech*, *54*(4), 487–497. https://doi.org/10.1177/0023830911404958

Podlewska, A. (2013). Cued speech as an empirically-based approach to teaching english as a foreign language to hard of hearing students. In E. Domagała-Zyśk (Ed.), *English as a foreign language for the deaf and hard of hearing persons in Europe*. Wydawnictwo KUL.

Rees, R., Fitzpatrick, C., Foulkes, J., Peterson, H., & Newton, C. (2017). Can explicit training in cued speech improve phoneme identification? *Deafness & Education International*, *19*(1), 13–21. https://doi.org/10.1080/14643154.2017.1281595

Schwartz, J.-L., Berthommier, F., & Savariaux, C. (2004). Seeing to hear better: Evidence for early audio-visual interactions in speech identification. *Cognition*, *93*(2), B69–B78. https://doi.org/10.1016/j.cognition.2004.01.006

Sparks, R. L., & Miller, K. S. (2000). Teaching a foreign language using multisensory structured language techniques to at-risk learners: A review. *Dyslexia*, *6*(2), 124–132. https://doi.org/10.1002/(SICI)1099-0909(200004/06)6:2<124::AID-DYS152>3.0.CO;2-3

Stevens, A. A., & Weaver, K. E. (2009). Functional characteristics of auditory cortex in the blind. *Behavioural Brain Research*, *196*(1), 134–138. https://doi.org/10.1016/j.bbr.2008.07.041

Summerfield, Q. (1992). Lipreading and audio-visual speech perception. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *335*(1273), 71–78. https://doi.org/10.1098/rstb.1992.0009

Swain, I. U., Zelazo, P. R. & Clifton, R. K. (1993). Newborn infants' memory for speech sounds retained over 24 hours. *Developmental Psychology*, *29*(2), 312–323. https://doi.org/10.1037/0012-1649.29.2.312

Szeląg, A., & Szymaszek, E. (2006). Test do badania słuchu fonematycznego dzieci i młodzieży. GWP.

Ungerer, J. A., Brody, L. R., & Zelazo, P. R. (1978). Long-term memory for speech in 2 to 4-week-old infants. *Infant Behavior and Development*, *1*, 177–186. https://doi.org/10.1016/S0163-6383(78)80028-9

Werker, J. F. (2018). Perceptual beginnings to language acquisition. *Applied Psycholinguistics*, *39*(4), 703–728. https://doi.org/10.1017/S0142716418000152

Werker, J. F., & Pegg, J. E. (1992). Infant speech perception and phonological acquisition. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 131–164). Timonium.

Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior & Development*, *7*(1), 49–63. https://doi.org/10.1016/S0163-6383(84)80022-3

Werker, J. F., & Tees, R. C. (2005). Speech perception as a window for understanding plasticity and commitment in language systems of the brain. *Developmental Psychobiology*, *46*(3), 233–251. https://doi.org/10.1002/dev.20060

White, E., Hutka, S., Williams, L., & Moreno, S. (2013). Learning, neural plasticity and sensitive periods: Implications for language acquisition, music training and transfer across the lifespan. *Frontiers in Systems Neuroscience*, *7*, Article 90. https://www.frontiersin.org/articles/10.3389/fnsys.2013.00090

White-Schwoch, T., Woodruff Carr, K., Thompson, E. C., Anderson, S., Nicol, T., Bradlow, A. R., Zecker, S. G., & Kraus, N. (2015). Auditory processing in noise: A preschool biomarker for literacy. *PLoS Biology*, *13*(7), Article e1002196. https://doi.org/10.1371/journal.pbio.1002196

Woodhouse, L., Hickson, L., & Dodd, B. (2009). Review of visual speech perception by hearing and hearing-impaired people: Clinical implications. *International Journal of Language & Communication Disorders*, *44*(3), 253–270. https://doi.org/10.1080/13682820802090281

Xiaotong, X., Li, P., Baills, F., & Prieto, P. (2020). Hand gestures facilitate the acquisition of novel phonemic contrasts when they appropriately mimic target phonetic features. *Journal of Speech, Language, and Hearing Research*, *63*(11), 3571–3585. https://doi.org/10.1044/2020_JSLHR-20-00084

Zhen, A., Van Hedger, S., Heald, S., Goldin-Meadow, S., & Tian, X. (2019). Manual directional gestures facilitate cross-modal perceptual learning. *Cognition*, *187*, 178–187. https://doi.org/10.1016/j.cognition.2019.03.004

SUPPLEMENTAL MATERIAL

Sample Tasks and Performance Tests Done by Students

LESSON 1

Exercise 1: Put the parts of the dialogue in order (insert letters: A, B, C).

Leena: _____
Annina: _____
Leena: _____

Exercise 2: Complete the dialogue with the missing words or phrases.

Leena: _____
Annina: Terve. Mitä _____?
Leena: Kiitos, ei _____.

Exercise 3: Put the parts of the dialogue in order (insert letters: A, B, C).

Annina: _____
Leena: _____
Annina: _____
Leena: _____

Exercise 4: Complete the dialogue with the missing words or phrases.

Annina: Hei, _____ olen Annina. Kuka sinä olet?
Leena: Minä olen Leena. Mitä _____ kuuluu?
Annina: Hyvää _____. Entä sinulle?
Leena: No,_____ tavallista.

Exercise 5: For each pair of the words, choose if the vowels sound the same or different. If they are the same, cirle YES. If they are different, circle NO.

*Example: **A**sia – **A**asia* (NO)

1. YES NO
2. YES NO
3. YES NO
4. YES NO
5. YES NO
6. YES NO
7. YES NO
8. YES NO

Exercise 6: Write the missing letters.

1. s ____ ma
2. p ____ lo
3. ____ ni
4. t ____ kki
5. h ____ lly
6. k ____ vi
7. v ____ ne
8. l ____ ppi

LESSON 2

Exercise 1: Put the parts of the dialogue in order (insert letters: A, B, C).

Leena: _____
Annina: _____
Leena: _____

Exercise 2: Complete the dialogue with the missing words or phrases.

Leena: Ai, hyvää päivää, Annina! _____ kuuluu?
Annina: Kiitos _____ . Entä sinulle?
Leena: _____ hyvää.

Exercise 3: Put the parts of the dialogue in order (insert letters: A, B, C).

Annina: ____
Leena: ____
Annina: ____

Exercise 4: Complete the dialogue with the missing words or phrases.

Annina: Moi! _____ menee?
Leena: Kiitos kysymästä, _____ hyvin. Entä sinulla?
Annina: Oikein mukavasti,_____.

Exercise 5: For each pair of the words, choose if the consonants sound the same or different. If they are the same, cirle YES. If they are different, circle NO.

Example: viisi – vessa (NO)

1. YES NO
2. YES NO
3. YES NO
4. YES NO
5. YES NO
6. YES NO
7. YES NO
8. YES NO

Exercise 6: Write the missing letters.

1. uu ____ o
2. kau ____ a
3. si ____ en
4. ____ arkka
5. e ____ en
6. ____ itra
7. ____ adio
8. hi ____ i

LESSON 3

Exercise 1: Put the parts of the dialogue in order (insert letters: A, B, C, D, E, F).

Leena: ____
Annina: ____
Leena: ____
Annina: ____
Leena: ____
Annina: ____

Exercise 2: Complete the dialogue with the missing words or phrases.

Leena: Hyvää päivää!
Annina: Hyvää päivää, mitä _____?
Leena: _____ hyvää, kiitos. Entä sinulle?
Annina: Hyvää, kiitos.
Leena: Hyvää _____.
Annina: Näkemiin!

Exercise 3: Put the parts of the dialogue in order (insert letters: A, B, C).

Annina: ____
Leena: ____
Annina: ____

Exercise 4: Complete the dialogue with the missing words or phrases.

Annina: _____, voitteko sanoa, mitä kello on nyt?
Leena: Kello on _____.
Annina: _____.

Exercise 5: For each pair of the words, choose if the consonants sound the same or different. If they are the same, cirle YES. If they are different, circle NO.

*Example: vii**s**i – ve**ss**a* (NO)

1. YES NO
2. YES NO
3. YES NO
4. YES NO
5. YES NO
6. YES NO
7. YES NO
8. YES NO

Exercise 6: Write the missing letters.

1. s _____ ma
2. s _____ na
3. s _____ tä
4. p _____ lo
5. k _____ vi
6. m _____ dä
7. s _____
8. t _____ kki

LESSON 4

Exercise 1: Put the parts of the dialogue in order (insert letters: A, B, C, D, E, F, G).

Annina: _____
Leena: _____
Annina: _____
Leena: _____
Annina: _____
Leena: _____
Annina: _____

Exercise 2: Complete the dialogue with the missing words or phrases.

Annina: Hei Leena!
Leena: Hei Annina!
Annina: _____ kuuluu?
Leena: Kiitos hyvää. Entä _____ ?
Annina: Kiitos hyvää. Leena, Mitä sinä harrastat?
Leena: Harrastan _____ .
Annina: Ja _____ harrastan musiikkia.

Exercise 3: Put the parts of the dialogue in order (insert letters: A, B, C, D, E).

Leena: ____
Annina: ____
Leena: ____
Annina: ____
Leena: ____

Exercise 4: Complete the dialogue with the missing words or phrases.

Leena: Hei. Annina!
Annina: Hei Leena! Mitä _____ harrastat?
Leena: _____ tennistä.
Annina: Oletko kiinnostunut urheilusta?
Leena: Kyllä _____ paljon! Olen kiinnostunut tenniksestä ja _____.

Exercise 5: For each pair of the words, choose if the consonants sound the same or different. If they are the same, cirle YES. If they are different, circle NO.

*Example: vii**s**i – ve**ss**a* (NO)

1. YES NO
2. YES NO
3. YES NO
4. YES NO
5. YES NO
6. YES NO
7. YES NO
8. YES NO

Exercise 6: Write the missing letters.

1. len _____ eily
2. lento _____ allo
3. laske _____ elu
4. y _____ ärrän
5. ka _____ u
6. ka _____ is
7. po _____ as
8. ka _____ i

LESSON 5

Exercise 1: Put the parts of the dialogue in order (insert letters: A, B, C).

Annina: _____
Leena: _____
Annina: _____

Exercise 2: Complete the dialogue with the missing words or phrases.

Annina: Minkä värinen _____ autosi on?
Leena: Se on _____.
Annina: Voi, sehän _____.

Exercise 3: Put the parts of the dialogue in order (insert letters: A, B, C, D).

Leena: _____
Annina: _____
Leena: _____
Annina: _____

Exercise 4: Complete the dialogue with the missing words or phrases.

Leena: Minkä värinen _____ on?
Annina: Se on sininen.
Leena: Minkä värisiä _____ ovat?
Annina: Ne ovat vaaleanpunaisia _____ keltaisia.

Exercise 5: Underline the word that you hear.

*Example: **A**sia – **Aa**sia*

1. saama – sama
2. suuna – suna
3. ten – teen
4. poro – pooro
5. sitä – sita
6. tyki – tykki
7. jää – jaa
8. löppi – lööppi

Exercise 6: Write the names of the colors that you hear.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____

LESSON 6

Exercise 1: Put the parts of the dialogue in order (insert letters: A, B, C).

Leena: _____
Annina: _____
Leena: _____
Annina: _____

Exercise 2: Complete the dialogue with the missing words or phrases.

Leena: Oletteko _____?
Annina: Olen.
Leena: _____ englantia?
Annina: Puhun _____.

Exercise 3: Underline the word that you hear.

*Example: **A**sia – **Aa**sia*

1. suuko – suukko
2. pianno – piano
3. siten – sitten
4. lammas – lamas
5. kanu – kannu
6. siloin – silloin
7. ymmärrän – ymmärän
8. viisi – viissi

Exercise 4: Write the names of the countries that you hear.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____

Audio-Video Material—Sample Frames from the Recording

Cued Speech in Finnish—Sample Sounds

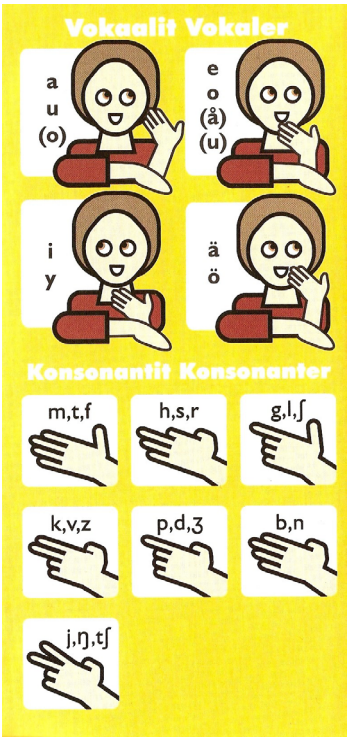


Table S1
Students' Results in the Language Aptitude Test

Types of training	*M*	*SD*
typical	26.19	5.52
visual	26.33	6.91
executive	23.19	6.42

Table S2
Foreign Speech Sound Identification in the Groups of Learners (Cued Speech vs. Non-Cued Speech)

Contrast	Contrastvalue	*SE*	*t*	*df*	Significance (two-sided)
Cued speech/No-cued speech	0.06	0.03	1.84	110	.069

Note. Comparison of the differences between the effects of identification of the foreign language sounds using typical training (contrast coefficient = 2) and the effects of identification of the foreign language sounds using visual training (contrast coefficient = 1) and executive training (contrast coefficient = 1) in tasks performed in the absence of distractors.