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In-home auditory training using audiovisual stimuli on a tablet computer: Feasibility and preliminary results

Takeshi Sato [a], Tomoko Yabushita [b], Shuichi Sakamoto [c], Yukio Katori [a], Tetsuaki Kawase [a,b,d,*]

[a] *Department of Otolaryngology-Head and Neck Surgery, Tohoku University Hospital, Sendai, Miyagi, Japan*
[b] *Department of Audiology, Tohoku University Graduate School of Medicine, Sendai, Miyagi, Japan*
[c] *Research Institute of Electrical Communication, Tohoku University, Sendai, Miyagi, Japan*
[d] *Laboratory of Rehabilitative Auditory Science, Tohoku University Graduate School of Biomedical Engineering, Sendai, Miyagi, Japan*

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A B S T R A C T

Objective: To examine the feasibility and possible effects of in-home auditory training using audiovisual speech stimuli on a tablet computer for patients with hearing loss using a hearing aid (HA) or a cochlear implant (CI).

Methods: In total, 11 patients with hearing loss (mean age, 60.2 ± 13.7 years) who had been using an HA or CI for more than 1 year were examined. As auditory training, the participants listened repeatedly to audiovisual speech stimuli on a tablet computer for 3 months. Speech intelligibility for trained words, untrained words, and monosyllables presented at a sound pressure level of 70 dB were assessed before and at 1, 2, and 3 months after training.

Results: Eight out the 11 patients completed 3 months of in-home auditory training. Three of these patients withdrew from the training before completing the protocol, mainly because of "boredom from recurring simple tasks". Significant improvements in speech intelligibility were found for the trained and untrained words after the 3-month training period ($p < 0.05$), but no significant differences were found for monosyllables.

Conclusion: In-home auditory training using a tablet computer could help improve auditory quality of life in patients with hearing loss using an HA or CI. But the further comparative studies using other existing method will be necessary to establish the practical importance of the present method.

1. Introduction

Sound vibrations in the air are transmitted to the inner ear via the ear drum and ossicular chain. The hair cell system located in the inner ear converts the sound vibrations into electrical signals that are transmitted to the cochlear nerve. Therefore, the hair cell system is very important with regard to mechano-electrical transduction in the inner ear. However, if damaged, this important transducer system cannot be repaired. Consequently, various types of auditory prostheses, such as hearing aids (HAs) and cochlear implants (CIs), have been developed to restore hearing in patients with sensorineural hearing loss.

Generally, using a hearing prosthesis improves both the quality and quantity of auditory information that can be relayed from the ear to the brain. However, it is well-known that speech intelligibility is poor soon after starting to use these prostheses, but can be improved over time; this process is known as the "rehabilitation" and/or "acclimatization" process in HA and CI users [1,2]. In this auditory rehabilitation process, it is important for users to adapt to the speech sounds processed by these

* Corresponding author.
E-mail address: kawase@orl.med.tohoku.ac.jp (T. Kawase).

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devices by taking part in as many opportunities for conversations as possible. In this context, one of the most effective ways to facilitate this process is "auditory" training using a device-based system [3–10]. Although most studies investigating this issue to date have used auditory speech stimuli as training materials in device-based auditory training systems, the results of recent studies on normal individuals with simulated hearing loss have suggested the potential effectiveness of audiovisual stimuli as training materials [11–14].

Therefore, in the present study, considering the possible advantages of auditory training using "audiovisual stimuli" (audio speech stimuli presented simultaneously with moving images of utterances) compared with audio-only stimuli [11–14], we assessed the effectiveness of auditory training using audiovisual stimuli in participants using an HA or CI.

Although the usefulness of auditory training using audio-stimuli on a conventional PC has been reported [3,4], in the present study, considering the fact that the elderly are among those who most frequently are in need of auditory training, we used a tablet computer, which can be operated more intuitively than a PC via a touch panel.

For this purpose, we developed a tablet computer-based in-home auditory training system incorporating audiovisual stimuli for patients with hearing loss using an HA or CI to assess its feasibility and possible effects on speech intelligibility.

2. Materials and methods

2.1. Participants

This study enrolled 11 patients with hearing loss using an HA or CI for more than 1 year (1 man, 10 women; mean age, 60.2 ± 13.7 years; age range, 36–74 years). Detailed information about the participants is shown in Table 1. The present study was approved by the ethics committee of the Tohoku University Graduate School of Medicine, and written informed consent was obtained from all participants in accordance with the requirements of the ethical committee. The present study was carried out in accordance with the guidelines of the Declaration of Helsinki (1991).

2.2. Auditory training

For the auditory training, the participants listened repeatedly to audiovisual speech stimuli by means of an audiovisual training system (Fig. 1) in which audiovisual speech stimuli were presented on a tablet computer (iPad, Apple Inc., Cupertino, CA, USA) using a prototype application developed for the present study. Audiovisual recordings of eight lists of 50 four-mora Japanese words (400 words in total) spoken by a trained Japanese female speaker were made. The word lists were selected from phonetically-balanced Japanese word lists developed for a spoken-word intelligibility test (FW03) [15,16] that consist of four word-familiarity ranks (lower, lower-middle, upper-middle, and high familiarities). The recorded word lists were obtained from the Speech Resources Consortium (http://research.nii.ac.jp/src/en/index.html). The words ranked as upper-middle familiarity were used in the present study.

2.3. Assessment of speech intelligibility

Speech intelligibility for 40 trained words selected from the word lists used in the training session, 40 untrained words selected from word list not used in the training session, and 50 Japanese monosyllables (57-s word lists, Japan Audiological Society, 1983) presented at a sound pressure level of 70 dB were assessed before and at 1 and 3 months after training.

2.4. Statistics

The speech intelligibility of the trained words, untrained words, and monosyllables were then compared for differences between before and after the auditory training. The speech intelligibility of the monosyllables showed a normal distribution both before and after the auditory training, so repeated-measures one-way analysis of variance (ANOVA) was applied for the statistical analysis, whereas that of both the trained and untrained words showed a non-normal distribution; therefore, the Friedman test and pairwise multiple comparisons were applied. SPSS Statistics (version 21; IBM, Armonk, New York, USA) was used for the statistical analysis.

Table 1
Participants background.

Case	Age (y)	Sex	Device	Wearing ear	Wearing duration (y)	Average threshold (aided condition, dB)	Maximum word recognition score (%, aided condition)	MMSE	Completed 3-month training
1	50	Female	CI	R	6	20.0	28	29	
2	52	Female	CI	R	7	20.0	2	24	
3	67	Female	CI	L	2	28.8	36	27	(2 month)
4	36	Female	HA	R + L	8	46.3	14	30	(1 month)
5	74	Male	HA	R	4	27.5	54	25	
6	64	Female	CI	R	4	46.3	42	30	
7	41	Female	CI	R	1	23.5	80	28	
8	60	Female	HA	R + L	3	27.5	72	30	
9	77	Female	HA	R + L	6	25.0	42	29	
10	68	Female	HA	L	2	32.5	78	30	(1 month)
11	73	Female	HA	R	5	33.8	32	26	

MMSE: mini-mental state examination.

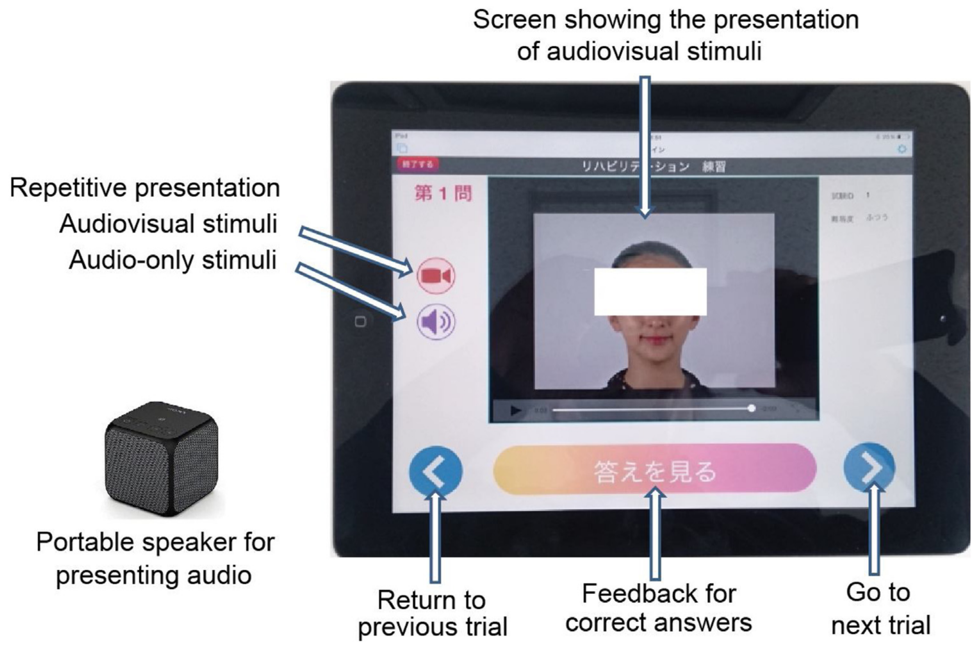

Fig. 1. Stimulus presentation screen of the audiovisual training system developed for the present study.
Users can listen repeatedly to trained words, select stimuli (audiovisual or audio only), and receive feedback on correct answers via touch panel operation.

3. Results

3.1. Feasibility of in-home auditory training using a tablet computer

Eight of the 11 patients completed 3 months of in-home auditory training (Table 1, right column). Three patients (cases 3, 4, and 10) withdrew from the training before completing the protocol: two (cases 3 and 4) because of "boredom from recurring simple tasks", and one (case 10) because of having insufficient time to spend on the training.

3.2. Effects on speech intelligibility

According to the pre-established protocol, the effects of in-home auditory training using audiovisual speech stimuli presented via a tablet computer on speech intelligibility were examined for the eight patients who completed the 3-month in-home auditory training protocol. Speech intelligibilities for trained words, untrained words, and monosyllables, which were assessed before and after the audiovisual training (at 1, 2, and 3 months), are shown in Fig. 2. Data are plotted as different symbols based on the device (HA or CI) and age (less or more

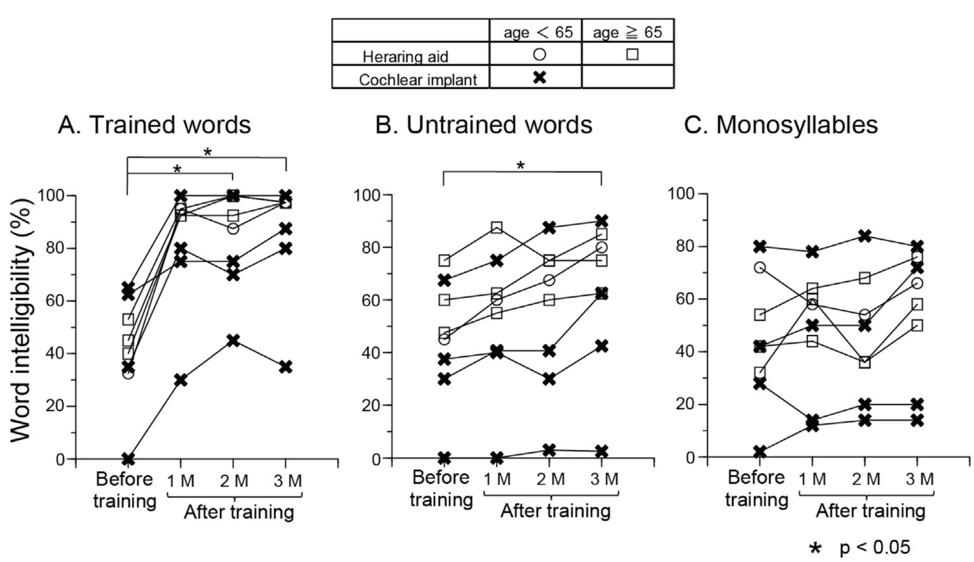

Fig. 2. Effects of in-home auditory training using audiovisual speech stimuli presented on a tablet computer on speech intelligibility.
Speech intelligibilities are shown for trained words, untrained words, and monosyllables, which were assessed before and at 1, 2, and 3 months after the training (A: trained words, B: untrained words, C: monosyllables). Data are plotted as different symbols based on the device (HA or CI) and age (less or more than 65 years of age).

Table 2
Average and standard deviation of each word intelligibility.

	Trained words				Untrained words				Monosyllables			
	Before training	After training			Before training	After training			Before training	After training		
		1M	2M	3M		1M	2M	3M		1M	2M	3M
Average	41.625	82.5	83.75	86.5625	45.3125	52.59375	54.84375	62.5	44	47.5	45.25	54.5
SD	20.65144	22.79568	19.45691	21.91451	23.73355	26.57669	28.20681	28.5982	24.9342	23.51291	23.61446	25.11118

SD = standard deviation.

than 65 years of age). The amount of data was relatively small for conducting a precise analysis based on device type and/or age, but no apparent differences were observed.

Based on the results of the Friedman test and pairwise multiple comparisons, the speech intelligibilities for the trained and untrained word were significantly improved at 2 and 3 months after training ($p < 0.05$), and at 3 months after training ($p < 0.05$), respectively. On the other hand, no significant differences in speech intelligibility were observed for monosyllables, although the mean intelligibility tended to be slightly improved (one-way repeated-measures ANOVA). Average and standard deviation of each word intelligibility are shown in Table 2.

4. Discussion

In the present study, we conducted a preliminarily examination of the feasibility and possible effects of in-home auditory training using audiovisual speech stimuli presented via a tablet computer for patients with hearing loss using an HA or CI. Eight of the 11 participants completed 3 months of training, which resulted in some significant improvements in speech intelligibility.

4.1. Auditory training using a tablet computer

In the auditory rehabilitation process, it is important for patients who wear an HA or CI to adapt to the speech sounds processed by these devices by taking part in as many opportunities for conversation as possible. People of all ages use HAs and CIs, but opportunities for conversation tend to be less frequent in the elderly compared with younger individuals, which can lead to suboptimal device use and inadequate auditory rehabilitation.

Taking such circumstances into account, we considered the possibility of in-home auditory training using a tablet computer. Although the usefulness of auditory training using audio stimuli on a conventional PC has been reported [3,4], considering the fact that the elderly are among those who most frequently are in need of auditory training, in the present study, we used a tablet computer, which can be operated more intuitively than a PC via a touch panel. Moreover, most previous reports have used "audio" stimuli for the auditory training [3–10]. In the present study, we decided to use audiovisual stimuli (audio-speech stimuli presented simultaneously with moving images of utterances), which have been reported to offer possible advantages compared with audio-only stimuli [11–14].

Three of the 11 participants withdrew from the study before completing all 3 scheduled months of training because of boredom or a lack of time. None of the participants complained of difficulties in operating the device or of dissatisfaction due to system malfunctions. However, some of the participants who completed the training commented that they became "bored because the training contents were too simple" or that they would like "quantitative as well as qualitative variation in the training contents". Since the main purpose of the present study was to examine the feasibility of in-home auditory training using a tablet computer, we used only a prototype system with relatively simple iterative training contents. Improving the quantity and quality of the stimuli, as well as the presentation of the training system so that it is more enjoyable for the users, would be important for practical application in the future.

4.2. Training effect

In the present study, the in-home auditory training was carried out in individuals who had been using an HA or CI for more than 1 year, which seems to be the time required for the effects of a hearing device on speech intelligibility to stabilize [19]. Nevertheless, significant improvements were observed for the speech intelligibility of not only trained, but also untrained words. As the main purpose of the present single-arm study was to verify the feasibility of auditory training using a tablet computer, no control group was used. Therefore, careful interpretation of the training effects on speech intelligibility is required. However, the results suggest that repetitive in-home auditory training using audiovisual speech stimuli on a tablet computer could help improve speech intelligibility among HA and CI users, even in the relatively chronic phase of auditory rehabilitation.

Although significant improvements were observed in the speech intelligibility of both trained and untrained words, no significant improvements were seen for monosyllables. Regarding the effects of auditory training for elderly individuals, the possible involvement of training effects on cognitive function has been speculated as a mechanism for improved speech intelligibility [8]. The present results, that is, significant improvements in speech intelligibility for trained and untrained words, but not for monosyllables, may be consistent with this hypothesis, i.e., the improvement of speech intelligibility may not be the result of improvements in monosyllable perceptibility, but rather, may be related to the effects of training on cognitive function in regard to speech perceptibility.

4.3. Significance of auditory training

Hearing loss has recently been reported to be a risk factor for dementia or depression in the elderly, and thus, the prevention of hearing loss is important for avoiding these conditions [17–21]. Deteriorated communication ability due to hearing loss is thought to reduce motivation to participate in society, and this type of social isolation can lead to depression, especially among the elderly; in fact, it has been reported that a deterioration in auditory quality of life (QOL) is a risk factor for depression among the elderly [17,20]. In addition, a decrease in auditory stimulation from the peripheral to central nerves due to hearing loss has been reported to inhibit cognitive function and increase the risk of developing dementia [21].

However, to our knowledge, no clear evidence as to whether appropriate auditory management using an HA or CI contributes to delaying the onset of dementia and depression has been presented. However, at a minimum, improved auditory communication through appropriate auditory management seems to have some positive effects on auditory QOL among the elderly. In this sense, in-home auditory training using a tablet computer could help facilitate improvements in auditory QOL and the rehabilitation/acclimatization process by providing users with more opportunities to listen to new speech sounds.

Conflict of interest

The authors declare no conflict of interest.

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