Effectiveness of the Haptic Chair in Speech Training

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ABSTRACT
The 'Haptic Chair' [3] delivers vibrotactile stimulation to several parts of the body including the palmar surface of the hand (palm and fingers), and has been shown to have a significant positive effect on the enjoyment of music even by the profoundly deaf. In this paper, we explore the effectiveness of using the Haptic Chair during speech therapy for the deaf. We conducted a 24-week study with 20 profoundly deaf users to validate our initial observations. The improvements in word clarity observed over the duration of this study indicate that the Haptic Chair has the potential to make a significant contribution to speech therapy for the deaf.

Categories and Subject Descriptors
K.4.2 [**Computers and Society**]: Social Issues—Assistive technologies for persons with disabilities; H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—Haptic I/O;

General Terms
Human Factors

Keywords
Haptic feedback, Speech therapy

1. INTRODUCTION
In our previous work, we developed a 'Haptic Chair' to enhance the musical experience of the Deaf using vibrotactile feedback [3]. During the earlier user studies, it became apparent that the Haptic Chair had the potential to be more than just a tool for enhancing the pleasure of 'listening to music'. In this paper, we explore ways to make the speech therapy sessions both more effective and more enjoyable for the students. We focus on the speech therapy sessions conducted at the Dr. Reijntjes School for the Deaf, Sri Lanka (www.shoolforthe deaf.lk). In a typical speech therapy session at the school, a deaf user and a speech therapist sit in front of a mirror. The deaf user watches the speech therapist's lip movement in the mirror and tries to mimic those movements. We observed that the users are often able to mimic the lip movement, but either they generate no sound or they generate sound very different from the example provided by the therapist. This is not surprising given the lack of audible feedback. Furthermore, it was also clear that many profoundly deaf students did not enjoy the speech therapy sessions, which is a common problem worldwide.

Almost a century ago, Gault [2] proposed a method of presenting speech signals *via* a vibrator placed on the skin. This provided a motivation for exploration of vibrotactile feedback for speech therapy and education. The concept underlying the Haptic Chair [3] is to generate vibrotactile stimulation from audio signals, delivering them to different parts of the body through the chair without adding any additional artificial effects into this communications channel by signal-processing the original audio output. The design of the Haptic Chair was extended so that users would be able to sense amplified vibrations produced by their own voice as well as others such as teachers or therapists. With this modification, we saw immediate effects on the awareness the profoundly deaf users had of whether they were matching the sound production pattern accompanying lip movements they could see. Our results suggest that this kind of display can, to some extent, function as an effective substitute for the traditional 'Tadoma' [5] method of speech instruction wherein students touch the throat or lips of their teachers.

There is a long history of research on the use of electronic speech training aids to improve speech therapy and a comprehensive overview of such devices can be found in [1]. Recently, software applications have been developed to provide alternative forms of speech therapy. Examples include *SpeechViewer III* (www.synapsea daptive.com) and *Tiga Talk* Speech Therapy Games (www. tigatalk.com). These tools provide visual feedback by transforming spoken words and sounds (phonetic sounds) into imaginative graphics or animations of lip-movements. This visual feedback is intended to reduce the need for constant guidance by a therapist. However, based on our previous work, when the speech therapist is present, we believe that, vibrotactile feedback might be a more effective additional sensory input. The mechanism of providing a tactile sensation through the Haptic Chair is quite similar to the common technique used by deaf people, called 'speaker listening'. In speaker listening, deaf people place their hands or feet directly on audio speakers to feel vibrations produced by audio output. However, the Haptic Chair provides a tactile stimulation to most of the body simultaneously in contrast to 'speaker listening' where only one part of the body is stimulated at any particular instant and not necessarily within an optimal frequency range. This is important since feeling sound vibrations through different parts of the body plays an important role [4].

2. METHOD

2.1 Participants
Twenty students (eleven boys and nine girls; median age nine years ranging from six to eleven years) from the Dr. Reijntjes School for the Deaf, Sri Lanka took part in the study. All were profoundly deaf (eight born deaf, 11 were deaf before the age of one year, and one before the age of two years). The speech therapist of the school helped us conduct the study and the participants were told that they could stop taking part at any time.

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2.2 Procedure

All participants were asked to articulate the test cases (20 words) at the beginning of the study (week 0). The speech therapist judged the clarity of each of the spoken words on a continuous scale of 0 to 1. A very clearly spoken word was given a score 1 and a completely unclear word was given a score 0. In addition, we asked an independent listener who was a native speaker of Sinhalese (a professional language instructor), to judge the clarity of each of the words. The speech therapist and the independent listener were in the same room while listening. However they were not allowed to discuss any kind of information regarding the evaluation. This helped mitigate any bias in the speech therapist's judgment. The initial assessment was used to divide the participants into two groups with similar speech abilities: (1) *The Experimental group:* received speech therapy while they were sitting in the Haptic Chair; and, (2) *The Control group:* received speech therapy while they were sitting on the standard chair used by the speech therapist at the deaf school. With a pilot study, we excluded the possible bias (psychological effect) of sitting on a standard chair and on the Haptic Chair. All the participants received voice feedback through headphones and visual feedback from the mirror. Only the experimental group received the additional vibrotactile feedback through the Haptic Chair. Participants from both groups received speech therapy for 1.5 hours per day over a period of 24 weeks. After every four-week block, the speech therapist and the independent listener assessed the clarity of the same test cases. This assessment was done without using the Haptic Chair in order to make a fair comparison. In addition, the independent listener was not aware of which students were in the control and experimental groups.

2.3 Results

Four participants (out of the 20) did not complete the entire study. One from the experimental group (after eight weeks) and three from the control group (two after eight weeks, one after 12 weeks) dropped out from the study. Their scores were included in the calculation of means during the period of their participation. Figures 1 and 2 show the mean score for each of the groups assessed by the speech therapist and the independent listener respectively. Both the speech therapist's and the independent listener's assessments showed a similar trend. However, as might be expected, the independent listener's scores were lower than the speech therapist's scores. This might have been due to the fact that the speech therapist was more familiar with the individual students' accents. All participants showed an increase in performance with time. This is expected due to the familiarity they gain with the test word set as well as the teaching that is part of the therapy.

Based on the speech therapist's assessment (Figure 1), there was no significant difference in performance between the two groups during the first eight weeks. However, from week 12 onwards, the group who used the Haptic Chair performed significantly better than the control group. At the end of the 24th week, the experimental group's performance score was significantly higher, $t(14) = 2.55$, $p < 0.05$, than that of the control group. From the independent listener's assessment (Figure 2), the two groups showed similar performance during the first 12 weeks. The experimental group performed significantly better from week 16 onwards. At the end of week 24, on average subjects in the group that used the Haptic Chair were able to pronounce 75% percent of the test words clearly. This score is significantly higher, $t(14) = 5.39$, $p < 0.001$, than the score of the group who went through the standard speech therapy program.

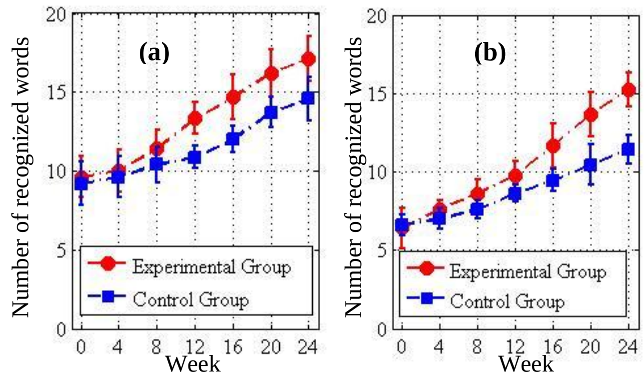

Figure 1: Average number of words recognized after every 4-weeks with 95% confidence interval; (a) by the speech therapist (b) by the independent evaluator

We asked the speech therapist and the independent listener to provide qualitative observations such as general speech ability, voice quality, omission of certain sounds and other general comments. The speech therapist reported that the Haptic Chair was intuitive to include and use in the speech therapy sessions. Both the speech therapist and the independent listener agreed that the participants who used the Haptic Chair were more enthusiastic about attending speech therapy sessions.

3. CONCLUSION AND FUTURE WORK

We conducted a 24-week long study to evaluate the effectiveness of the Haptic Chair in speech therapy sessions for profoundly deaf students. Our results suggest that the additional vibrotactile feedback provided by the Haptic Chair had a positive impact on speech learning in this context. In future work, we will explore the possibility of providing customized (e.g. separated by frequency bands) vibrotactile feedback through different vibration elements to different locations on the body. Moreover, we are focusing on extending the Haptic Chair concept into a wearable device. We hope that these future works will lead to more effective uses of the vibrotactile channel for communication *via* speech for the profoundly deaf.

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