Long-term Effects of Auditory Training in Severely or Profoundly Deaf Children

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Despite new technological advances in the rehabilitation of audition in profoundly deaf children, auditory training remains a fundamental part of their education. Consequently, it is necessary to learn what kind of stimuli, what kind of auditory tasks, and what kind of learning procedures generate faster and more long-lasting benefits. The present study evaluates a training program that includes numerous nonlinguistic stimuli that tap into several means of cognitive processing. The program is based on an implicit learning procedure and was tested with six severely or profoundly deaf children. The first results demonstrate an improvement in nonlinguistic performances on both accuracy and processing times. These results were evident immediately after the auditory training, and most of the effects remains stable 6 months later. Moreover, the children show a better discrimination of linguistic sounds. These results open the possibility of new approaches in speech therapy.

Key words: **auditory training; transfer of learning; deaf children**

Introduction

Despite remarkable advances, such as cochlear implants, in the field of auditory rehabilitation in deaf children, benefits are nevertheless variable on account of such intrinsic factors as intelligence and socioeconomic situation as well as the child's age at time of implantation. The organization of the auditory cortex is indeed linked to auditory experience.[1,2] Thus, children receiving implants at an early age perform more like their hearing peers in different preverbal skills,[3] in music processing,[4] and in language abilities.[5] In children undergoing implantation at a later time, auditory training stays fundamental and must start as soon as transmission of sounds is possible. Auditory training is known to produce neural plasticity, which is shown for adult musicians at the cortical level[6] and at the brain stem level[7] or for children with language impairments.[8] We may assume that auditory training would have similar positive effects in deaf children, although studies investigating this issue are rare.[9] To work out an auditory program, four types of questions have to be considered:

(1) What kind of stimuli should be used? Do simple or complex stimuli provide the best auditory benefits? And are linguistic or nonlinguistic stimuli the most relevant?
(2) How long should auditory training last?
(3) What kind of learning procedure should be used? Is explicit learning more efficient than implicit learning in deaf children?
(4) Which tasks are necessary? Do simple or complex tasks allow better performances in language skills?[10]

In the present study, we used four categories of auditory stimuli (environmental sounds, music, voices, and abstract sounds) in an implicit learning program that was designed to tap into four main auditory processes.[11] The study aimed to assess the possibilities of transfer to

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untrained linguistic tasks, such as phonetic discrimination. Children were notably asked to evaluate the similarity of two items that were differing or not in one phonetic dimension (oral versus nasal vowels, voiceless or voiced consonants).

Method

Participants

Four profound and two severely deaf children (mean age = 9 years) participated in the study. Five of them benefited from a bilingual (French Sign Language [LSF]/spoken language) education, but were poor speakers. One child was an LSF user due to his deeper pathology (profound deafness class 3 and lower gains from his hearing aids). During the experiment, no new hearing-aid tuning was done and the children followed their usual schooling and therapies. Parents or caregivers were informed about the experiment and have given written consent.

Material

The experiment employed a sounding platform with four games designed to tap into the four main auditory means of processing (identification, discrimination, Auditory Scene Analysis [ASA], and auditory memory). The platform was connected to a computer and worked with a self-made software called "sounds in hand." Four categories of sounds were used: environmental sounds, voices, music, and abstract sounds.

Procedure

Children were invited to interact with the sounding platform for one session (of a half-hour duration) weekly for 20 weeks. Two auditory tests were conducted in a playful way during each session and we assumed that the games would allow an auditory implicit learning. In the identification task, children stood in front of the keyboard and had to match figurines corresponding to the presented sound. In the discrimination task, the children introduced a magnet into a hole. The polarity of the magnet may or may not change a single characteristic—the tempo, the pitch, or the timbre—of the sound. In the ASA task, each hole of the checkerboard was filled with a magnet checker. At the beginning of the game, an auditory scene containing two or more streams was presented. Moving some of these magnets removed one of these streams. The memory task was a span task—run with the keyboard. Participants were asked to reproduce a short sequence of two to five sounds. During the course of the program, the difficulty of the four games was increased by crossing the complexity of sounds (from environmental sounds to abstract sounds) and the complexity of tasks (from identification to memory). This procedure allowed a progressive increase in difficulty and a stimulating variability of the contents of the auditory games.

Experimental Design

Before the study, the children underwent a pretest session that evaluated (*1*) their performances (accuracy and speed) with some auditory games of the training program, and (*2*) their performance in a phonetic discrimination test (which was not trained by this method). This test involved a similarity judgment. It was composed of 36 items opposing oral versus nasal vowels, voiced and voiceless consonants in mono- and bi-syllabic nonwords. The pretest (T1) was replicated just after training (T2) and 6 months later (T3). We expected better performances on T2 (compared to T1) and similar performance between T2 and T3.

Results

Figure 1 shows the accuracy and processing times for each task before, just after, and 6 months after training.

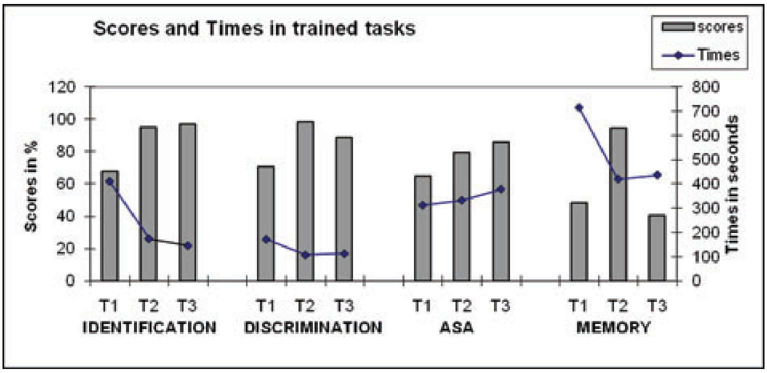

Figure 1. Scores and processing times in trained tasks (three periods of measurement: T1 = before training; T2 = after training; T3 = 6 months later).

In the identification task, an ANOVA reflected a main effect of period of test [$F(2,33) = 18.32$; $P < 0.0001$]. Performances were higher in T2 and T3 [$F(1,33) = 25.12$; $P < 0.0001$] and [$F(1,33) = 29.64$; $P < 0.0001$], respectively, compared with T1. The difference between T2 and T3 was not significant. The ANOVA also showed a main effect of processing times. Times between T1 and T2 decreased significantly [$F(1,33) = 24.0$; $P < 0.0001$]. This decrease was also observed in T3 [$F(1,33) = 31.3$; $P < 0.0001$]. Differences beween T2 and T3 are not significant. Training led to an improvement of performances in auditory discrimination [$F(2,33) = 6.4$; $P < 0.001$]. Performances were higher in T2 than in T1 [$F(1,33) = 12.49$; $P < 0.001$] and in T3 than in T1 [$F(1,33) = 5.27$; $P < 0.03$]. The short decrease observed after T2 was not significant. Processing times decreased significantly [$F(2,33) = 3.5$; $P < 0.039$] between T1 and T2 [$F(1,33) = 5.8$; $P < 0.02$] and between T1 and T3 [$F(1,33) = 4.8$; $P < 0.03$]. The performances on the ASA task improved, but the difference reached statistical signifiance only between T1 and T3 [$F(1,33) = 7.15$; $P < 0.01$]. There were no effects of training on processing times. Auditory training resulted in an improvement of scores on the memory task [$F(2,33) = 24.03$; $P < 0.0001$] with a increase between T1 and T2 [$F(1,33) = 30.18$; $P < 0.001$]. However, this effect did not persist in T3. The training also involved reduced processing times [$F(2,33) = 8.9$; $P < 0.001$], which was found between T1 and T2 [$F(1,33) = 14.17$; $P < 0.001$] and which remained stable in T3.

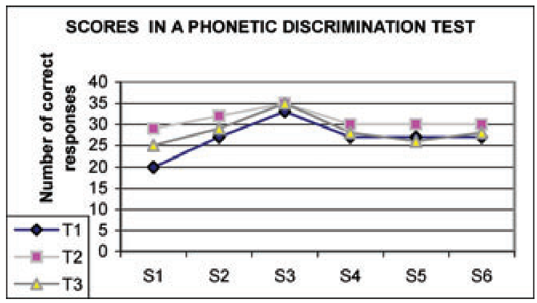

Figure 2. Scores obtained in the phonetic discrimination test for each participant.

Figure 2 shows the scores for each participant in the phonetic discrimination test. Auditory training resulted in an improvement of the performances on the phonetic discrimination test, between T2 and T1: *t*-paired sample test [$t(17) = 5.11$; $P < 0.000$] and between T3 and T1 [$t(17) = 2.4$; $P < 0.02$].

Discussion

The change in performance between T1 and T2 demonstrates that children were able to improve their auditory performances even in the absence of any technological tuning in their hearing aids. This suggests that they gained benefits from auditory training over a rather short period. It may be argued that the absence of a control group does not allow to us to disentengle the specific effect of the training program used from those of the usual schooling and therapies. However, the fact that performances did not continue to improve between T3 and T2 suggests that the usual schooling and therapies were not responsible of the improvement between T1 and T2. Several informal observations suggested that an ecologically valid and stimulating auditory program increased the motivation of children for sound processing, which results in an overall improvement in performance. The most striking finding was to show that auditory training had a positive side effect on the phonetic discrimination test, for which there was no training. These results open new perspectives in speech therapy. Phonetic differences are indeed fundamental in speech reception and are usually regularly trained in deaf children. The redundancy of this task, which is considered essential, is boring. So, since nonlinguistic stimuli allow an improvement in linguistic performance, it appears possible to avoid the repetitiveness, and thus the "boring" element, of phonetic material.

Conflicts of Interest

The authors declare no conflicts of interest.

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