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Brain and Language 88 (2004) 21–25
Brain and Language
www.elsevier.com/locate/b&l

Effect of intensive training on auditory processing and reading skills

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Accepted 27 May 2003

Abstract

This study assessed the ability of seven children to accurately judge relative durations of auditory and visual stimuli before and after participation in a language remediation program. The goal of the intervention program is to improve the children's ability to detect and identify rapidly changing auditory stimuli, and thereby improve their language-related skills. Children showed improved accuracy on a test of auditory duration judgement following the intervention without analogous improvements in the visual domain, supporting the assertion that intensive training with modified speech improves auditory temporal discrimination. However, these improvements did not generalize to reading skills, as assessed by standard measures of phonological awareness and non-word reading.

Keywords: Language; Specific language impairment; Dyslexia; Reading; Temporal processing; Remediation

1. Introduction

It has been proposed that training with acoustically modified speech can improve the auditory language skills of individuals with specific language impairment (SLI) and dyslexia (Habib et al., 1999; Tallal, Merzenich, Miller, & Jenkins, 1998; Tallal et al., 1996). SLI is generally characterized as a difficulty with age-appropriate use of expressive and receptive language without other cognitive impairments and is thought to affect 3–10% of children (Bishop, 1994). In addition to their linguistic difficulties, individuals with SLI are often found to also have deficits in non-linguistic domains such as planning complex oral-motor patterns, working memory, sound perception, and visual imagery (Joanisse & Seidenberg, 1998).

According to some research, approximately 50% of children with specific language impairment have reading problems when tested in second and fourth grades (Catts, Fey, Tomblin, & Zhang, 2002). Although the cause of SLI remains controversial, some suggest that it is due to a deficit processing input in the auditory domain (Skipp, Windfuhr, & Conti-Ramsden, 2002; van der Lely & Christian, 2000) and others that the deficit is specific to grammar (Bishop, 2000; Sahlen, Reuterskiold-Wagner, Nettelbladt, & Radeborg, 1999). The role of audition has also been examined in developmental dyslexia, a reading disorder that affects 5–10% of the population. Individuals with dyslexia fail to achieve normal reading skills despite adequate intelligence, educational opportunities, and socioeconomic status (Shaywitz, Shaywitz, Fletcher, & Escobar, 1990). Several studies have reported that children with SLI and dyslexia cannot differentiate between rapidly changing consonant–vowel (CV) syllables when presented at normal speed (Tallal, Miller, & Fitch, 1993; Tallal et al., 1996). It has been suggested that this ability is important for language acquisition and the development of phonological awareness and reading skills (Talcott et al., 2000; Tallal et al., 1993) and that deficits in this domain may result in impaired language facility including reading.

The intervention program studied here attempts to address such deficits by modifying normal speech in such a way that the most rapidly changing components are extended in time by 50% and amplified by up to 20 dB (Nagarajan et al., 1998; Tallal et al., 1996). These increases in duration and volume are designed to enhance the salience of the fastest-changing components of

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doi:10.1016/S0093-934X(03)00157-3

speech, facilitating their perception by the listener. This modified speech is embedded in computer games that are presented to children over the course of the training, which usually lasts about 6 weeks. During training, the speed and volume of the CV syllables are gradually returned to the levels found in normal speech. Hence, at the end of training, the speech presented by the program is almost the same as normal speech in terms of volume and rate of presentation (Tallal et al., 1996).

This program has been studied in a laboratory setting, exposing children with SLI to the acoustically modified speech for three hours a day, five days a week for four weeks (Merzenich et al., 1996; Tallal et al., 1996). Following training, the children improved by approximately 2 years on standardized measures of speech discrimination and language processing, improvements that endured at least 6 weeks after training (Tallal et al., 1996). In a second experiment, conducted by the same investigators, children with SLI were recruited and divided into two groups. One group received training with the modified speech while the other received equal training using unmodified speech. After 4 weeks of training, both groups showed improvements on measures of receptive language skills, but the group that received training with the modified speech showed significantly greater improvements (Merzenich et al., 1996; Tallal et al., 1996).

Reading skills, including non-word decoding, and phonological awareness were not assessed by these studies (Merzenich et al., 1996; Tallal et al., 1996). Although additional investigations have been performed outside the laboratory in clinics and classrooms, enrolling individuals diagnosed with SLI, attention deficit disorder, autism, and dyslexia (Tallal, 2000; Tallal et al., 1998), reading gains have not been reported to date. Language skills, however, were assessed by professionals in the clinics and the authors reported that significant improvements were observed on standardized measures of speech and language, regardless of which measures were used by the various clinics. Results from these studies have led the authors to conclude that the Fast For Word program is effective for individuals with a range of language and communication disorders (Tallal et al., 1998; Tallal, 2000).

Further support for acoustically modified speech as an effective intervention comes from an investigation in 12 children diagnosed with pure phonological dyslexia (Habib et al., 1999). Experimenters subdivided their population into an experimental group that received intervention using the modified speech and a control population that received training using normal speech. Their results indicated that after 5 weeks of training, the experimental group showed significantly greater improvements on a phonological task in which they had to identify the non-rhyming word in a set of four words than did the control group (Habib et al., 1999).

These results suggest that training with modified speech improves receptive language and phonological skills in children. However, it has not yet been determined whether these improvements in oral language are due to an increased ability to accurately perceive and process auditory stimuli or if they might be better explained by other mechanisms. For example, the intense monitoring of stimuli on the computer screen might lead children to attend more effectively. A related question, which pertains to all intervention programs, is whether the improvements are specific to the particular tasks that comprise the program or if the observed gains generalize to other skills, such as reading.

This study addressed two questions: first, can the original findings from a laboratory setting reported by Tallal et al. (1996) be reproduced in a clinical setting? Specifically, are there measurable gains in auditory processing that are not directly trained by the intervention program? Second, does training with acoustically modified speech result in reading gains? To address the first question, subjects were recruited from and tested at a local clinic. Although this allowed for less stringent inclusion/exclusion criteria for the subject population and administration of the intervention program, it more accurately represented the environment in which the intervention program was delivered to these children. To address the question of the specificity of training, a task measuring the ability of participants to accurately judge relative duration in both the auditory and the visual domain was administered to children participating in the program. Previous studies have used measures of oral language skill, but not reading achievement, as outcome measures (Tallal et al., 1996). Further, these language outcome measures and the actual intervention program share many common features, so that improvement in these tasks is not unexpected. In the present study, the tasks were designed to be an independent measure of auditory duration judgement not specifically trained. The visual modality was chosen as a control condition in which improved performance is expected if the intervention induces general changes in attention (or other) processes and not in auditory processes per se. It was hypothesized that subjects would improve on the auditory duration judgment task but not on the visual task. It was further hypothesized that intervention would improve skills associated with non-word decoding and phonemic awareness, skills related to reading acquisition.

2. Methods

2.1. Intervention

All subjects participated in the intervention program Fast ForWord (Scientific Learning Corporation, Berkeley, CA) until they had achieved accuracy scores of 90% correct on five of the seven tasks that comprise the program. This criterion is defined as completion of the training and achievement of good temporal processing skills. Children participated in the intervention for 100 min a day, five days a week for approximately 4–6 weeks.

2.2. Judgement of duration

Each task (auditory and visual) was broken into four blocks, each of which lasted approximately 4 min and the entire experiment, including both components, lasted 30–40 min. Trials were presented via SuperLab v. 1.0 (Cedrus Corporation, San Pedro, CA) on a Macintosh Powerbook 1400c (Apple Computer, Cupertino, CA). Data on duration judgment accuracy and response time were acquired.

The auditory task contained a fixation point that was present at the center of the screen for the entire experiment. For each trial, an 800 ms tone was followed by an inter-stimulus interval of 500 ms and then a tone of variable duration. The duration of this tone differed from the first tone by between 10 and 3200 ms. The order of presentation was pseudorandom and a staircase procedure was not used. Following the second tone, subjects responded by pressing one of two marked keys to indicate whether the second tone was longer or shorter than the first. After responding, subjects automatically advanced to the next trial; no feedback was provided. After every seventh trial, a picture of an animal appeared on the screen for 2 s to make the task more stimulating. All tones were presented at 1000 Hz via headphones at a level of 78 dB.

In the visual form of the experiment, the timing was the same but the auditory tone was replaced with a yellow smiley face subtending 2° of visual angle and placed at the center of a white background on the computer screen. As with the auditory experiment, subjects had to judge whether the second stimulus was a longer or shorter duration than the first stimulus. Visual stimuli were presented on a computer monitor 0.4 m from the subject.

2.3. Subjects

Subjects were recruited from a group of children who, for a fee, were receiving the modified speech intervention program at a private suburban clinic. The selected population is therefore representative of the sample typically enrolled for intervention in terms of background, age, and language ability. The children attended the clinic over the summer and their participation resulted from one or several factors, such as clinician's recommendation, parental concern or poor academic performance.

Seven subjects (four male, three female) were recruited and had a mean age of 8.07 years ($SD = 1.19$). They were tested on the duration judgement tasks at the beginning and completion of training. During these two testing sessions, subjects were also given two measures of phonological awareness, the Word Attack subtest (Form A and B) of the Woodcock Diagnostic Reading Battery (Woodcock, 1997), which tests non-word reading, and the Phoneme Deletion subtest of the Phonological Awareness Test (Robertson & Salter, 1997). A second form of this test was generated for post-intervention testing by matching the words on the original form for word length and frequency using the MRC Psycholinguistic Database (Culling, 1990). The average standard score on the Word Attack subtest before training was 108 ($SD = 29$) and it was 85 ($SD = 21$) on the Phoneme Deletion subtest.

Practical considerations led to the selection of the two tests of reading-related skills: both have been normalized so that data from this study could be compared with a large reference population. Second, they could be performed quickly using pencil and paper and within a time frame acceptable to the private clinic setting. Third, the phoneme deletion task assesses sublexical processing and hence provides a measure of phonemic awareness. Phonemic awareness serves as a strong predictor of reading ability (Wagner & Torgesen, 1987) and has not been assessed in previous studies investigating the outcomes of acoustically modified speech intervention.

3. Results

Data collected from the duration judgment study were analyzed using a 2×2 repeated-measures ANOVA (Modality $\times$ Day) to examine both accuracy and reaction time. For accuracy, there was a significant main effect of day ($F(1, 12) = 6.36$, $p < .05$), indicating that subjects performed more accurately after training than before training. There was also a significant interaction of day by modality ($F(1, 12) = 6.36$, $p < .05$). Post-hoc paired t tests indicated that subjects were significantly more accurate on the auditory task after training than before training (73% correct vs. 61% correct; $t(6) = 3.27$, $p < .05$) but not on the visual task (60% correct vs. 60% correct; $t(6) = 0$, *n.s.*), as shown in Fig. 1. There were no significant effects for the reaction time data. After training, the average standard score on the Word Attack task was 110 ($SD = 27$) and 90 ($SD = 20$) on the Phoneme Deletion subtest. This represented no significant improvement from the pretest values on either the Word Attack ($t(6) = 0.53$, *n.s.*) or Phoneme Deletion ($t(6) = 1.14$, *n.s.*) tasks. Hence, gains in the ability to perceive auditory durations did not generalize to changes in skills related to reading.

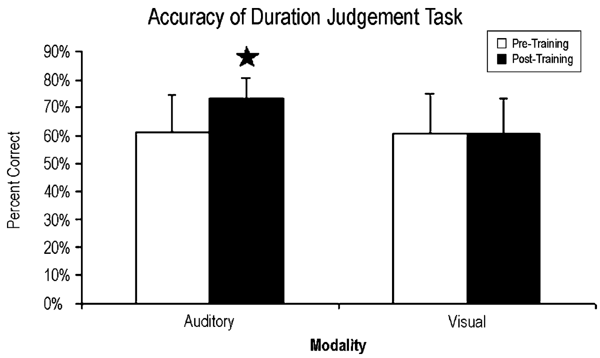

Fig. 1. Group accuracy data for auditory and visual modalities. There is a significant difference between pre- and post-training for the auditory modality ($p < .05$) but not for the visual modality.

4. Discussion

In these studies, the effect of an intervention program using acoustically modified speech on the judgement of non-linguistic sensory information in the auditory and visual modalities was measured. If performance had improved on both the auditory and the visual duration judgment tasks following training, it could be concluded that the training affected a general system (such as attention). Our results from a small group of children suggest that improvements were limited to the auditory system, tentatively supporting the proposition that the program improves the ability to perform fine discrimination only in the auditory modality. Previous studies of training using modified speech have reported improvements on phonological tasks with groups of only six subjects (Habib et al., 1999), supporting the view that the effect detected in the current study of seven subjects is genuine and not an artifact of small sample size.

A second hypothesis of this study was to explore possible relationships between auditory temporal processing skills and reading in children undergoing intervention training in a private clinic setting. Although the initial studies of the Fast ForWord program by Tallal et al. (1996) and Merzenich et al. (1996) did not assess the effect of training on reading skills, their subsequent work suggests that the program can assist individuals with developmental dyslexia (Tallal, 2000; Tallal et al., 1998). Studies by Habib et al. (1999) identified improvements in phonological awareness following training with acoustically modified speech. Another study identified a significant positive correlation between reading skills and sensitivity to changing auditory and visual stimuli (Talcott et al., 2000), suggesting that improvements in auditory duration judgement might be correlated with improvements in readings skills. The results of the present study did not support this hypothesis. Although subjects successfully completed the intervention program and demonstrated improvements on an auditory duration judgement task, they did not show improvement on reading skills, as assessed by tests of phonemic awareness and non-word reading. Only one child showed a minor improvement on a standardized non-word decoding task while the rest remained unchanged. This apparent contradiction of previous findings may be resolved in future studies, which could recruit more subjects, obtain more extensive behavioral measures, including measures of reading comprehension and receptive and expressive language and obtain long-term, follow-up data.

The results of the current study indicate that some children who undergo training with acoustically modified speech do show improvement on the judgement of auditory durations. However, these changes are not accompanied by improvements on standardized measures of reading, illustrating the need for further research to establish the relationship between reading and auditory temporal processing. Recently, some researchers have questioned the assertion that the linguistic difficulties observed in children with SLI and dyslexia result from a temporal processing deficit in the auditory system. Instead, these authors argue that the ability to detect the changes in pitch that characterize the formant transitions of phonemes is not a temporal processing task at all, but a sensory processing task that must be accomplished rapidly. Instead of an "auditory temporal processing deficit," they suggest that there is a specific deficit in the phonological representations in individuals with SLI and dyslexia (Mody, Studdert-Kennedy, & Brady, 1997: Studdert-Kennedy, Mody, & Brady, 2000) and a weakness in the ability to identify similar phonemes (Adlard & Hazan, 1998). Our results in this study support this assertion, as improvements on a task in which subjects improved in their ability to accurately perceive auditory durations did not generalize to improvements on reading skills.

To our knowledge, the present study is the first independent demonstration of the effects of training with modified speech on sensory perception conducted in a clinical setting. More studies are necessary to characterize the exact relationship between performance on auditory temporal processing, reading skills and reading remediation.

Acknowledgments

We wish to acknowledge the staff of the National Speech and Language Therapy Center, especially Sabra Gelford and Betty Soret.

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