The Effects of an Audio–Visual Training Program in Dyslexic Children

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A research project was conducted in order to investigate the usefulness of intensive audio–visual training administered to children with dyslexia involving daily voicing exercises. In this study, the children received such voicing training (experimental group) for 30 min a day, 4 days a week, over 5 weeks. They were assessed on a reading task before and after the training. A significant benefit to the experimental group was found after training. These preliminary results underline the role of the phonological components of dyslexia. Copyright © 2004 John Wiley & Sons, Ltd.

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INTRODUCTION

The aim of this study was to determine whether computer training designed to increase phonemic awareness has a remedial effect on reading skills in dyslexic children. Developmental dyslexia is diagnosed in children who fail to acquire age-appropriate reading skills after 2 years of schooling in the absence of other cognitive dysfunctions such as poor vision and/or neurological deficits and despite normal intelligence and adequate reading tuition (Stanovitch, 1988).

It is now very well established that learning to read requires the child to construct a system of connections between the letter strings of printed words (orthography) and the phonemic sequence that comprise spoken words (phonology). It is generally agreed that many dyslexics fail to develop adequate phonological skills and, more precisely, they exhibit difficulties in recognizing printed words.

The underlying cause of phonological deficits in dyslexic children is unclear. Some researchers have suggested that the phonological processing deficit in

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dyslexia may reflect a more fundamental deficit in the processing and integration of rapid sequences of transient signals in the nervous system (Tallal, Miller, Jenkins, & Merzenich, 1997, for a review). According to the rapid processing hypothesis, deficits in processing transient rapid acoustic signals impair the ability to discriminate the acoustic cues that are necessary to distinguish phonemes. This impairment compromises the development of strong and stable phonological representations which, in turn, leads to the difficulties in phonological processing observed in dyslexia. The hypothesis that developmental dyslexia may result from a general, non-specific deficit in perceiving rapidly changing auditory signals is a current subject of debate. Only a small minority of dyslexics appear to have perceptual difficulties (Joanisse, Manis, Keating, & Seidenberg, 2000). Numerous papers have reported failures to confirm aspects of Tallal's hypothesis (Bishop, Carlyon, Deeks, & Bishop, 1999; Mody, Studdert-Kennedy, & Brady, 1997; Nittrouer, 1999; Studdert-Kennedy, 2002). These authors conclude that the deficits in speech perception that are frequently observed in impaired readers are phonetic and not auditory in origin. However, the data obtained by Habib *et al*. (2002) contradict the predictions of detractors of the temporal processing theory of dyslexia. It thus appears that altering the temporal characteristics of the speech used in the phonological exercises proposed to dyslexic children may contribute significantly to improving their phonological skills and their reading abilities. However, numerous studies do find auditory deficits in dyslexic, but only in a subgroup ranging from a few isolated participants to 50% of the dyslexic population studied (Adlard & Hazan, 1998; Mody *et al*., 1997; Rosen & Manganari, 2001; Ramus *et al*., 2003; Share, Jorm, MacLean, & Matthews, 2001). More many authors have shown that there is no reliable relationship between performance on rapid auditory processing tasks and phonological skills and reading ability (Heiervang, Stevenson, & Hugdahl, 2002; Marshall, Snowling, & Bayley, 2001; Share *et al*., 2001). Thus, it is argued that auditory deficits do not predict phonological deficits.

The hypothesis that a phonological deficit plays a central causal role in developmental dyslexia is widely established (Snowling, 2001; Ramus, 2001). Numerous studies suggest that the phonological deficits of dyslexic children cannot be explained in terms of impairments in low-level auditory mechanisms but reflect higher-level language weakness (Snowling, 2000). One hypothesis proposed to explain the reading difficulties of dyslexic children is that they come to the task of learning to read with poorly specified phonological representations (Swan & Goswami, 1997).

Many studies of computer software have shown its potential to enhance phonological awareness in children with reading difficulties. Computer-based reading instruction is a relatively new and promising approach for learning phonemic awareness (Torgersen & Barker, 1995). Computer-aided learning is often promoted as an environnement that is flexible. The qualities of computers that are relevant to instruction in phonemic awereness included digitized speech and high-quality graphics, immediate feedback and gamelike presentation to maintain child interest (Mioduser, Tur-Kaspa, & Leitner, 2000). The existing literature has shown that segmented speech feedback is often effective in increasing phonological awareness (Olson, Wise, Ring, & Johnson, 1997; Van Daal, Reitsma, & Van Der Leig, 1994). These studies have compared children who have been exposed to different forms of speech segmentation (whole word feedback or segmented word (onset-rime) feedback). The most common method of training phonological skills (Mitchell & Fox, 2001; Wise, Ring, & Olson, 1999) involves different sub-lexical units such as rime, syllable or phoneme. However, the results of research which aim to train children in phonological awareness in order to improve their reading ability are mixed. Some computer based interventions are not so successful. For instance, Olson *et al.* (1997) and Wise and Olson (1995) both report improved phonological awareness but poor results in word recognition.

A phoneme awareness deficit and the resulting decoding weakness characterize dyslexic children. In particular, most reading errors are due to confusions between phonemes differing by minimal traits (especially voiced–unvoiced oppositions). Dyslexics may have poorer categorical perception of certain contrasts (Adlard & Hazan, 1998; Serniclaes, Sprenger-Charolles, Carré, & Démonet, 2001). In this view, the deficit is speech specific according to the phonetic model (Rosen, 2003; Rosen & Manganari, 2001; Serniclaes *et al.*, 2001). According to the phonetic model we think that dyslexic children are impaired in the selection of acoustic properties to process phonemic categories. This failure to correctly represent short sounds and fast transitions would cause further difficulties in reading tasks. However, the phonetic feature process in reading is a question that is not well documented in dyslexia.

In this study, we hypothesize that a specific audio–visual training supporting phonetic feature perception could help dyslexic children to specify phonemic representations. Accordingly, they should not confuse close phonemes on voicing features which could facilitate written word processing. To our knowledge, no computer-based training using the simultaneous presentation of phonological units with orthographic units has been used with children with reading disabilities and we further hypothesized that audio–visual training will boost matching between visuo-orthographic patterns and phonological units.

METHOD

Participants

Fourteen dyslexic children were selected from a dyslexic population at a specialized school. They had normal or corrected-to-normal vision and no neurological deficits or overt physical handicap. From this group, all the children who met the following two criteria were selected: an overall IQ score of 70 or more on the French version of the WISC-R and reading retardation of at least 18 months behind their chronological age (see Table 1). These children were separated into two equal groups, group A (mean age 9; 10 years) and group B (mean age 10; 4 years). No significant difference was found on chronological age of the two groups ($p>0.10$).

The two subgroups were strictly matched on educational and cognitive levels as well as for their reading level which was assessed just before the training using two standardized word reading tests (Lefavrais, 1986; Ecalle, 2003).

A battery of neuropsychological, phonological and visual tests was administered to each individual before the experiment. These tests are routinely used to assess reading impaired children in French dyslexic centers. Statistical analyses

Table 1. List of dyslexic children with the type of dyslexia (phonological dyslexia PD, surface dyslexia SD, mixed dyslexia MD), chronological age (CA) and reading age (RA) identified using the Ecalle test

	Group A			Group B	
	CA	RA		CA	RA
D1 (MD)	125	82	D8 (PD)	134	91
D2 (PD)	134	87	D9 (PD)	117	77
D3 (PD)	116	79	D10 (PD)	114	80
D4 (SD)	121	87	D11 (MD)	133	81
D5 (PD)	145	92	D12 (SD)	111	92
D6 (PD)	107	78	D13 (PD)	119	94
D7 (MD)	120	83	D14 (MD)	100	77

Table 2. Group characteristics

		Group A		Group B	
Lefavrais test	Word reading time	87	81–93	88	81–93
	Word reading accuracy	86	78–90	86	78–93
Ecalle test	Word reading accuracy	84	79–92	85	77–94

Mean of reading age and range in months.

confirmed that before the training period there were no significant differences in the scores on the two reading-skill tests ($F<1$). The ''*La pipe et le rat*'' Test (Lefavrais, 1986) measures speed and accuracy of word recognition, and has proved to be a reliable and valid test of isolated word decoding efficiency (Ecalle, 2003) (see Table 2).

In the specialized school, reading was taught with an emphasis on grapheme-to-phoneme conversion and reading out loud rather than whole-word recognition and silent reading for comprehension. Our sample of 14 dyslexic has been selected by their education authority to receive a similar remedial teaching. This remedial instruction was an extension of the mixed approach to reading instruction.

Procedure

The experiment was conducted over a 13-week period as Table 3 illustrates.

In the first training session, the children in group A received the audio–visual training whereas the seven other children formed the control group (B). An increase in the performances on word reading was expected for group A. After a second training session for group B only, it was expected that the training effect would persist in group A and the difference between the groups would disappear.

Training

The children were trained individually using one exercise of the program developed by Danon-Boileau and Barbier (2000), for a period of 5 weeks, 4 days a

Table 3. Design of testing and training sessions

	Testing session 1	Training session 1	Testing session 2	Training session 2	Testing session 3
Week	1	2, 3, 4, 5, 6	7	8, 9, 10, 11, 12	13
Group with training	A–B	A	A–B	B	A–B
Group without training		B		A	

week. Each training session lasted 30 min. This training (10 h) focused on voicing opposition between two items of six pairs of phonemes: /p/-/b/; /t/-/d/; /k/-/g/; /f/-/v/; /s/-/z/ et /ch/-/j/. The participants listened to a CV syllable (/pa/) and decided between two printed alternatives (*pa* or *ba*) differing in their voicing. Immediately after the participants had listened to the syllable, a basket-ball fell from the top of screen and the child pressed one of two keys (left or right) to put the ball in the basket corresponding to *pa* or *ba*. During the training periods, the children were not exposed to any other phonological training program.

Tests

The participants were tested individually over three sessions all during normal school hours. The aim of these tests was to examine phonological recoding skills. In a word recognition test, a forced-task choice was used in which the children had to find a target word among five items consisting of the orthographically correct word (e.g., bateau, *boat*), and four pseudowords, namely a homophone (bato), a visually similar item (baleau), an item sharing the same initial letters (batte) and an item containing an illegal letter sequence (btaeua). The target words were presented in three conditions: orally, with a picture and in a categorization task. No analysis was run on the conditions. The normative data for this test were obtained from first, second and third graders (Ecalle, 2003). The target word and homophone scores were combined to create a composite phonological coding score (max: 36).

Results

An ANOVA was conducted on the results, which revealed a significant interaction between group and test, $F(2, 24)=7.47$, $p<0.003$, $\eta^2=0.38$. The interaction is shown in Figure 1. In testing session 2, the pattern of results differed between groups: the experimental group (A) exhibited significant gains (+3.6) in word recognition, $F(1, 6)=9.28$, $p<0.02$, $\eta^2=0.61$. A marginal difference (5.1) emerged between groups A and B in testing session 2, $F(1, 12)=3.42$, $p<0.09$, $\eta^2=0.22$. In testing session 3, we observed that performances did not differ between groups ($F<1$), thus indicating that performances in group B increased

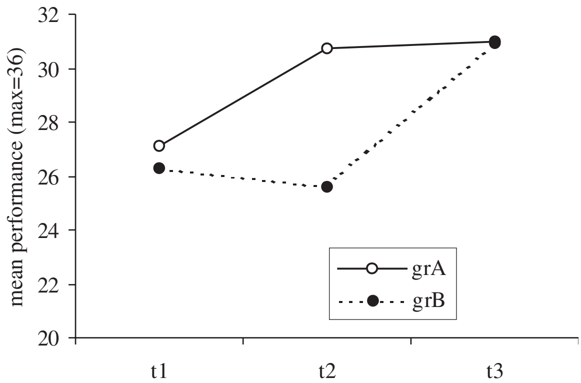

Figure 1. Mean performance in two groups of dyslexic children in three testing sessions (t1, t2, t3).

significantly (+5.3), $F(1,12)=35.1$, $p<.001$, $\eta^2=0.85$ and that performances in group A persisted at the same level as in testing session 2 ($F<1$).

DISCUSSION

Overall, these results show the impact of audio–visual training on the subject of voicing on the performances of dyslexic children in a word reading task. This type of training leads children to connect print and phonology. The observed training effect should be interpreted with caution, given the small size of the dyslexic sample. However, these results underline the role of phonological components in dyslexia.

Dyslexic children have great difficulty in the segmental analysis of words, and consequently in the acquisition of grapheme–phoneme correspondences. There are currently robust arguments pointing to the existence of an elementary phonological disturbance as of the level of the sounds themselves. This impairment may lie at the root of the confusions between voiced and unvoiced consonants or the observed matching errors between a sound and one of two written forms. Thus, phonological system deficits may affect not only the manipulation but also the production and discrimination of sounds.

This phonological impairment concerning voicing which characterizes dyslexic children might be alleviated by means of audio–visual training which requires children to process the phonetic features both in the visual and auditory modalities. Phonological representations could be specified by training which involves both phonological and orthographic units. The mapping between these two units could be made easier if implemented in a computerized remedial program.

Beyond providing evidence for the effectiveness of this audio–visual training, these results contribute to an understanding of the nature of reading difficulties and successful training. More precisely, why might training that focuses children's attention on spelling–sound mappings have an impact on reading-related skills beyond decoding ability? Our audio–visual training improved children's reading skills by helping them to develop *ortho-phonological representa-*

tions. This result is consistent with other studies. The impact of phonological awareness training on phonological awareness and reading skills has been examined in two recent quantitative meta-analyses (Bus & van Ijzendoorn, 1999; Ehri *et al*., 2001). These demonstrated that speech-only approaches are minimally effective at impacting reading abilities. The results of the meta-analysis conducted by Ehri *et al*. (2001) showed that the scale of the reading improvement obtained using phonological awareness training with letters was roughly twice that obtained using similar speech-only activities. The assumption that the presence of letters might serve to perceptually anchor elusive phoneme sounds has been advanced (Adams, Treiman, & Pressley, 1998). Thus, specific training in letter–sound associations might directly impact reading abilities (Ehri *et al*., 2001). The effectiveness of phonological awareness based on methods that emphasize orthographic to phonological mappings has also been recently demonstrated (McCandliss, Beck, Sandak, & Perfetti, 2003).

Finally, our empirical observations and our position are consistent with reading interventions simulated with a recent connectionist model of reading developement (Harm, McCandliss, & Seidenbery, 2003). These authors present the mapping hypothesis which ''holds that phonological awareness interventions influence word recognition processes via the quality of the letter–sound mapping representations (rather than by the quality of the phonological representations *per se)*'' (Harm *et al*., 2003, p. 162). The simulations replicated the empirical findings, thus indicating that the remediations that include training on spelling–sound regularities are more effective than those targeting phonological awareness alone.

In another study, a connectionist model of reading acquisition intended to simulate detailed aspects of developmental dyslexia (Harm & Seidenberg, 1999) was used to explore why certain kinds of remediations are more effective than others. This model represents a further extension of the theoretical framework developed by Seidenberg and McClelland (1989) and Plaut *et al*. (1996) to understand normal and impaired reading acquisition. It differs from previous simulations of reading in that it incorporates a trainable phonological system as the output of the model. This phonological system was implemented as a set of low-level phonetic features such as voicing, plosives etc. with a set of weighted connections between such features.

To summarize, the effectiveness of the present training method during a relatively short training period might be attributed to two factors. First, we trained the children in voicing. In line with the phonetic model, we think that the phonological deficits in dyslexic children may be partly due to impairments in the phonetic organisation of phoneme detectors (Serniclaes *et al*., 2001; Krifi, Bedoin & Mérigot, 2003). Second, this training required the children to process this phonetic feature both in hearing and reading. In line with a connectionist model of reading development (Harm & Seidenberg, 1999; Harm *et al*., 2003), we think that trainings involving spelling–sound regularities are more effective than those including phonological awareness alone.

If knowledge of phonemes is closely connected to knowledge of orthography then training methods that emphasize this connection should be more effective. If we are to develop an optimal training method, the factors underpinning the beneficial effects of this present audio–visual method have to be identified. Another aspect of our ongoing research using electro-physiological methods will hopefully provide information about these issues (Veuillet, Magnan, & Ecalle, in press).

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