THE PERCEPTION OF STOP CONSONANT SEQUENCES IN DYSLEXIC AND NORMAL CHILDREN

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ABSTRACT

Previous research has revealed that dyslexic children may be more sensitive to backward-masking effects in auditory perception than control children. In this study, we asked whether a CV transition masks a preceding VC transition to a greater extent in dyslexic children than in controls. The results suggest that dyslexic children are severely impaired on the discrimination of VC sequences, regardless of whether these sequences are followed or not by a CV sequence. These results provide further evidence that dyslexia is associated with a deficit in the perception of speech.

1. INTRODUCTION

It now seems established that dyslexia is associated with deficits in auditory and visual perception [1, 2, 3]. According to the so-called temporal processing deficit theory [4, 5], these deficits stem from a general impairment in the temporal processing of sensory information by the brain. Dyslexic children would have difficulty processing short and/or rapidly-changing sensory events. During the last few years, this theory has been widely debated, and many issues have been raised which relate to the clinical aspects of developmental dyslexia, but also and above all to the nature of the basic processes that are involved in the perception of speech. One major issue is whether the difficulty encountered by dyslexic children show up in the perception of rapid spectral variations, or in that of sounds that follow one another rapidly [6, 7]. These are two semi-independent dimensions: the first one has to do with the temporal organization of the speech signal, and the second one with the intrinsic dynamics of the processing system. This distinction is central to current studies on the perception of speech, and has prompted the development of models accounting for the time course of information processing in speech perception. Empirically, however, it is difficult to tell apart the influence of the temporal structure of speech, on the one hand, and that of the intrinsic dynamical properties of the processing system, on the other hand, on the listener’s behavior.

Massaro [8] dealt with this issue in a series of experiments based on the auditory backward-masking paradigm. In this paradigm, the listener is presented with two acoustic stimuli with a silent interval of variable duration in between. The listener’s task is to identify the first stimulus. Massaro’s results show that the proportion of correct responses gradually increases as the interval between the stimuli is longer, and tends toward an asymptotic value when this interval exceeds a certain threshold. In Massaro’s model, this is accounted for by assuming that the first stimulus ($S_1$) is briefly held in a preperceptual auditory store. When $S_2$ occurs, it would replace $S_1$ in the preperceptual auditory store, and terminate the processing of the first sound. This backward-masking phenomenon would no longer occur when the interval between the onset of $S_1$ and that of $S_2$ exceeds 250 ms, as $S_1$ would then be no longer available in the preperceptual memory. Importantly, this paradigm allows us specifically to explore the dynamics of the processing system, i.e. the speed of processing and the duration of the auditory memory.

According to several authors, backward masking has an effect on how VCV sequences are perceived by the listener. In such sequences, it has been often shown that the CV transition perceptually prevails on the VC transition. When a $VC_a$ segment is artificially combined with a $C_bV$ segment so that the formant transitions in $VC_a$ and $C_bV$ point to different places of articulation, the listener tends to give more weight to the $C_bV$ transition [9, 10, 11]. Massaro [12] hypothesizes that the $C_bV$ transition prevents the $VC_a$ from being fully processed.

Several studies recently examined whether dyslexic children are more sensitive to auditory backward masking than control children [13, 14, 15]. [15] found a deficit in SLI children compared with control children on a task that involved detecting a tone immediately followed by a noise. Similar results were found by [14] in dyslexic children, but the deficit in backward masking had no simple relationship to the children’s performance in the perception of speech sounds. [13] found that the threshold for detecting a brief backward-masked tone was not significantly higher in LI children compared with control children.

The present work is concerned with the time course of information processing in the perception of stop consonant sequences in dyslexic children, control children, and adults.

2. METHOD

The goal of our experiment was to explore backward-masking effects of CV transitions on VC transitions in $VC_aC_bV$ sequences. Subjects were asked to compare these sequences with $VC_bV$ sequences in a discrimination task. We hypothesized that it would be more difficult for the subjects to perceive the difference between the $VC_aC_bV$ sequence and the $VC_bV$ sequence if the $VC_a$ transition is masked by the $C_bV$ transition in the first sequence. The extent of backward-masking effects was measured by comparison with a control condition, in which the subjects had to discriminate $VC_a$–$VC_b$ pairs.
2.1. Stimuli

The stimuli were built from 5 basic sequences: /d/ (VCV, CVV), /g/ (CVV), /d/ (VCV, CVV), /g/ (CVV). The 3 first sequences were used in the condition with masking and the 2 others in the control condition. The /d/ and /g/ sequences were generated first using Sensyn, the Klatt synthesizer as made available by Sensimetrix. The values of the Klatt control parameters were derived from 2 natural sequences recorded beforehand by a trained phonetician, and submitted to a detailed acoustic analysis using ESPh/xwaves. Figure 1 shows the variations in frequency of the derived from 2 natural sequences recorded beforehand by a trained phonetician, and submitted to a detailed acoustic analysis using ESPh/xwaves. We hypothesized that backward-masking effects would decline as the initial portion (vowel + 40 ms of the following voice bar) of offset of V. The first sequences were used in the condition with masking and the 2 others in the control condition. The /d/ and /g/ sequences were generated first using Sensyn, the Klatt synthesizer as made available by Sensimetrix. The values of the Klatt control parameters were derived from 2 natural sequences recorded beforehand by a trained phonetician, and submitted to a detailed acoustic analysis using ESPh/xwaves. Note that the VC and CV formant transitions are asymmetrical in each sequence. The duration of each vowel is set to 150 ms. The interval between V1 and V2 is 110 ms-long in the figure.

![Fig. 1. Variations in frequency of the first 3 formants in the two basic synthetic sequences.](image)

A voice bar throughout the stop closure was synthesized by lowering F1 to 180 Hz and by introducing a -40 dB spectral tilt between 0 and 3 kHz. The burst for the stop was synthesized by exciting F3 (for /g/) or F4 (for /d/) with a 5-ms frication noise immediately preceding the onset of V2. The frequency of F3 and that of F4 were identical in the burst and at the onset of V2. The output sampling frequency was 10 kHz.

We then generated the /d/ sequence by combining the first vowel of /d/ with the voice bar, the burst, and the final vowel of /d/. There was no burst for /d/ in /d/, in accord with the fact that the closure for the second stop generally precedes the release for the first stop in a two-stop sequence in French.

The /d/ and /g/ sequences were each used to generate 5 stimuli, by varying the duration of the interval between the offset of V1 and the onset of V2 from 50 to 210 ms in steps of 40 ms. We hypothesized that backward-masking effects would decline as this interval becomes longer.

Finally, the /d/ and /g/ sequences were generated by taking the initial portion (vowel + 40 ms of the following voice bar) of /d/ and /g/, respectively.

2.2. Subjects

Five groups of subjects took part in the experiment. The first one (Dyslexics 1) was made up of 16 children (11 females, 5 males, mean age 8.9 years, range 7.1–10.9 years) with a phonological developmental dyslexia. All the children met the following selection criteria: a) reading age (as established using the Alouette test) lower than chronological age by 18 months at least; b) absence of neuropsychological deficits (WISCIII and PM47); c) no hearing impairment. The second group (Dyslexics 2) comprised 9 children (1 female, 8 males, mean age 11.2 years, range 9–13.5 years) with a severe phonological developmental dyslexia. The selection criteria included a normal non-verbal IQ, an absence of sensory, motor or attentional deficits, and a predominantly phonological dyslexia defined as a reading and/or writing performance below 2 standard deviations from normal, along with a significant impairment on phonological awareness tasks. These children were participating in a two-year intensive remediation program as boarders in a specialized school in Southern France. The third group (RA controls) comprised 9 7-year-old children (5 females, 4 males) matched with the dyslexics on reading age. The fourth group (CA controls) was made up of 10 10-year-old children (5 females, 5 males) matched with the dyslexics on chronological age. The fifth group (adult controls) comprised 10 adults (4 females, 6 males, mean age 25.1 years, range 20–29 years) all students in phonetics in our laboratory. None of the control subjects had any known hearing disorder.

2.3. Experimental design

Each subject took part in two tests. In the first test (control condition, without masking), subjects were presented with 3 pairs of stimuli, (1) /d/-/g/ (2) /d/-/d/, and (3) /g/-/g/ in an AX discrimination task. Pair 1 was presented eight times and Pairs 2 and 3 four times each, in a random order. There was a 500-ms interval between the two stimuli in each pair, and a 5.2-s interval between pairs. The subjects listened to the stimuli over headphones in a quiet room. For each pair, they were instructed to indicate whether the two stimuli were identical or different, by pointing to either of two pictures, one showing two identical cartoon characters and the other showing two different characters. Their response was written down by the experimenter. The test was preceded by a short training phase in which the subject was told whether her/his responses were correct or not.

In the second test (with masking), the subject had to perform an AX discrimination task on the three following pairs of stimuli: (1) /g/-/g/ (2) /d/-/g/, and (3) /g/-/g/ in an AX discrimination task. The pairs were presented in five blocks, with the V1-V2 interval decreasing from 210 ms to 50 ms from the first to the last block. Within each block, Pair 1 was presented eight times and Pairs 2 and 3 four times each. The second test was identical to the first one on all other aspects. The total duration of the experiment was about 15 minutes.

This experimental design was used to assess two main hypotheses: (1) backward-masking effects are more reduced when the V1-V2 interval is longer; (2) dyslexic children are more sensitive to backward-masking effects than control children.

Owing to a technical problem, the first test was not administered to the Dyslexics-2 children. The results obtained with these children in the second test are nevertheless reported.

3. RESULTS

In the first test, the proportions of hits (H) and false alarms (FA) were computed and converted into a d’ value, with

\[ d' = z(H) - z(FA) \]

where z is the inverse of the normal distribution function. Extreme proportions were corrected using the 1/(2N) rule [16]. In the second test, a d’ value was calculated for each subject and each V1-V2 interval.

The main results are presented in Figure 2. The horizontal dotted lines represent the average d’ value for the adults (a), the CA controls (b), and the RA controls (c), in the first test. The curves
The main goal of this experiment was to determine whether dyslexic performance was lower in the second test compared with the first test. This was tested by comparing the performance in the second test with that in the first test for each subject. For the RA controls, these effects proved significant for the shortest V1-V2 interval (50 ms: F(1,8) = 14.048, p < 0.01). For the CA controls, performance was significantly lower in the second test than in the first test when the V1-V2 interval was longer. The trend was significant for the adults (F(4,36) = 3.888, p < .02), and marginally significant for the RA controls (F(4,32) = 2.462, p = .065).

The magnitude of backward-masking effects was determined by comparing the performance in the second test with that in the first test for each group of subjects. The deficit shown by the dyslexics was found for two different groups (Dyslexics 1 and 2), with a different mean age, and which were tested independently by different experimenters. The responses provided by the Dyslexics 2 in the second test clearly suggest that VC sequences are difficult to discriminate for them too. Electrophysiological investigations should be conducted to determine whether this deficit shows up at a pre-attentional level. Another important issue for future work is whether the tests presented here could be useful to the clinician in the detection of dyslexias.

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6. REFERENCES


*Fig. 2.* Discriminability values for the /Edg/-/Edg/ pairs, depending on the duration of the V1-V2 interval. (a) Adults, (b) CA controls, (c) RA controls, (d) Dyslexics 1, (e) Dyslexics 2.