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 (S1) is briefly held in a preperceptual auditory store, and that the second stimulus (S2) is then presented, masking effect.

2. METHOD

The goal of our experiment was to explore backward-masking effects of CV transitions on VC transitions in VCₐCV sequences. Subjects were asked to compare these sequences with VCₐV sequences in a discrimination task. We hypothesized that it would be more difficult for the subjects to perceive the difference between the VCₐCV sequence and the VCₐV sequence if the VCₐ transition is masked by the CVₐ 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 VCₐ-VCₐ pairs.
2.1. Stimuli
The stimuli were built from 5 basic sequences: /"d"/ (VCaV), /"G"/ (VCbV), /"dG"/ (VCaCbV), /"d/" (VCbG), and /"Gd"/ (VCaV). The 3 first sequences were used in the condition with masking and the 2 others in the control condition. The /"ed"/ et /"eg"/ sequences were generated first using Sensyn, the Klatt synthesizer as made available by Sensimetrics. 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 ESPS/awaves. Figure 1 shows the variations in frequency of the first 3 formants between the onset and offset of V1, on the one hand, and V2, on the other hand, for the synthetic sequences /"es"/ et /"eg"/. 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.

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 F2 (for /t/ or /d/) or F3 (for /l/) with a 5-ms friction 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 /"ed"/ sequence by combining the first vowel of /"es"/ with the voice bar, the burst, and the final vowel of /"eg"/. There was no burst for /d/ in /"ed"/, 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 /"ed"/, /"eg"/ and /"ed"/ 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 /"ed"/ and /"eg"/ sequences were generated by taking the initial portion (vowel + 40 ms of the following voice bar) of /"es"/ and /"eg"/, 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 9–13.3 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 the mean, 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) /"ed"/ et /"eg"/, (2) /"ed"/ et /"ed"/, and (3) /"ed"/ et /"eg"/, 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) /"ed"/ et /"ed"/, (2) /"ed"/ et /"ed"/, and (3) /"ed"/ et /"ed"/. 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 test 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
represents the average $d'$ values in the second test, as a function of the duration of the V1-V2 interval, for each group of subjects.

Figure 2 first reveals substantial differences between the controls and the Dyslexics 1 in the first test. These differences were highly significant ($F(3, 41) = 22.532, p < .001$). The dyslexics' performance was much poorer than that of the younger control children (RA controls; $F(1, 23) = 19.665, p < .001$). Within the control subjects, performance seemed to improve with age but this trend was not significant.

Marked differences between the controls and the dyslexics were also observed in the second test. The Dyslexics 1 had the lowest level of performance, regardless of the duration of the V1-V2 interval, while the Dyslexics 2 seemed to perform slightly better. As regards the controls, discrimination seemed easier 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 ($F(4, 32) = 2.402, p = .065$).

The magnitude of backward-masking effects was determined by comparing the performance in the second test with that in the first test for each subject. For the RA controls, these effects proved significant for the shortest V1-V2 interval (50 ms; $F(1, 8) = 14.048, p < .01$). For the CA controls, performance was significantly lower in the second test than in the first test when the V1-V2 interval was comprised between 50 and 170 ms (50 ms: $F(1, 9) = 19.676, p < .005$; 90 ms: $F(1, 9) = 6.761, p < .03$; 130 ms: $F(1, 9) = 12.964, p < .01$; 170 ms: $F(1, 9) = 6.644, p < .05$). For the adults, masking effects were observed for the V1-V2 intervals comprised between 50 and 130 ms (50 ms: $F(1, 9) = 23.917, p < .002$; 90 ms: $F(1, 9) = 16.313, p < .005$; 130 ms: $F(1, 9) = 9.972, p < .02$), and they were also significant at 210 ms ($F(1, 9) = 12.476, p < .01$). For the Dyslexics 1, performance was lower in the second test compared with the first test for V1-V2 intervals ranging from 50 to 130 ms (50 ms: $F(1, 15) = 5.677, p < .05$; 90 ms: $F(1, 15) = 6.386, p < .05$; 130 ms: $F(1, 15) = 7.955, p < .02$).

4. DISCUSSION

The main goal of this experiment was to determine whether dyslexic children are more sensitive to backward masking in the perception of speech than control children. Recent studies revealed higher-than-normal backward masking effects in SLI children [15] and dyslexic children [14], in the detection of tones. These results suggest that acoustic information may be integrated over a longer temporal window in dyslexics than in controls. The identification of an acoustic stimulus would therefore be perturbed by a following masker to a greater extent in dyslexics. We extended these investigations to the perception of speech stimuli, and asked whether, in a VC\textsubscript{C},C\textsubscript{V} sequence, the C\textsubscript{V} transition exerts a greater masking effect on the VC\textsubscript{C},C\textsubscript{V} transition in dyslexics than in controls.

Our results provide us with a partial answer to this question. Backward-masking effects in the perception of VC\textsubscript{C},C\textsubscript{V} sequences were measured using the responses to the VC sequences as a baseline. The results showed that it was quite difficult for the Dyslexics 1 to discriminate the VC pairs (recall that the Dyslexics 2 were not tested on these pairs). Because of this major deficit in the control condition, the masking effects observed in the Dyslexics 1 were relatively reduced. In other words, the effect of backward masking may have been minimized as the Dyslexics-1 children's performance in the control condition was already close to floor.

The difficulty encountered by the Dyslexics 1 in discriminating the VC sequences (/d/ and /g/) raises a number of issues. The main acoustic difference between the two sequences related to the final F2 transition, which fell (1710-1610 Hz) over the last 40 ms for /d/, and rose (1770-2210 Hz) over the last 60 ms for /g/. Thus, there was a deviation of +600 Hz in the offset frequency of F2 between /d/ and /g/. The fact that such differences in the direction, duration, and offset frequency of the F2 transition were difficult to detect for dyslexic children provide further evidence for the idea that these children have a deficit in the identification of speech sounds.

The deficit observed here seems all the more remarkable since previous work has shown that the place of stop articulation is easier to identify for the listener in a VC sequence than in a CV sequence (see [17] for ex.). This phenomenon has been ascribed to the order in which the stable part of the vowel and the transition follow each other in each sequence. In a CV sequence, the stable part of the vowel would perceptually predominate on the transition, owing to backward masking, or to a temporal integration process which would give more weight to more recent information. In a VC sequence, the transition follows the stable part and would therefore be perceptually more salient.

Importantly, 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


