SPEECH PERCEPTUAL ABILITIES OF CHILDREN WITH SPECIFIC READING DIFFICULTY(DYSLEXIA)

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ABSTRACT

A group of 13 children with specific reading difficulty (SRD), 12 chronological-age and 12 reading-age controls were tested on a battery of speech-perceptual, psychoacoustic and reading tests. As a group, the SRD children performed worse than controls on all reading tasks, on the speech identification tasks, on discrimination tasks involving consonant clusters contrasts, and in their discrimination of stop consonants in nonsense VCVs. However, only a sub-group (30%) of SRD children showed high error rates in the speech discrimination tasks whilst the rest of the SRD group performed within norms. For this sub-group, discrimination performance was particularly poor for consonant contrasts differing in a single feature which was not acoustically salient, and errors were not limited to stop contrasts. Poor performance was also obtained in the identification tests, especially when the number of acoustic cues marking the contrast was reduced. Their performance did not differ from controls for the psychoacoustic tasks but they showed higher error rates in their reading of nonwords. It is concluded that only a proportion of SRD children show a speech perceptual weakness which seems to be related to a poor ability to discriminate phonemes which are acoustically similar.

1. INTRODUCTION

It has been proposed that one possible contributing factor to literacy problems is a slight deficit in auditory processing, which may lead to the child having difficulties in establishing strong phonological categories. An early attempt at specification of a basic perceptual limitation in a language-disabled population came through the work of Tallal and her colleagues [e.g. 1] who concluded that developmental dysphasics had problems with discriminating consonant-vowel (CV) syllables because of "the brief duration of the discriminable components", and had particular problems in discriminating such stimuli when they were presented in rapid succession. A number of studies with SRD children [e.g. 2,3] have also shown poorer than normal categorization of minimal pairs differing in stop consonant place of articulation and it has been suggested this might be due to slight but significant deficits in the ability to process transient cues such as bursts and rapid formant transitions. These investigations have focused almost exclusively on plosive place (and voicing) contrasts, and give little information as to possible problems with other speech contrasts such as fricatives, affricates and consonant clusters which include complex combinations of acoustic patterns. Also, as the synthetic stimuli used by Godfrey et al. [2] and others were often stylized and did not contain an initial burst, children might have had difficulties in labeling these sounds because they lacked redundancy of cue information. There is therefore a need for speech tests involving a wider range of consonant contrasts and synthetic stimuli which model natural speech tokens more closely.

2. METHODOLOGY

2.1. Subjects

The experimental group comprised thirteen children (9 boys and 4 girls) with reading problems. Children were aged between 9 and 12 (mean: 10;4 years), had English as their mother-tongue, a reading-delay within the range of 18-36 months (mean delay: 27 months, mean reading age: 8;1 yrs), and no current or earlier problems with speech production. The chronologically age-matched (CA) control group comprised twelve children between the ages of 9 and 11 years (mean: 10;1 yrs). The reading-age matched (RA) control group also comprised twelve children aged between 7;6 years to 8;6 years (mean: 8;1 years). Both control groups included 8 boys and 4 girls.

2.2. Test material

The children were evaluated on a test battery which included reading tests, natural speech discrimination tests, identification tests based on synthesized stimuli, and psychoacoustic tests.

Reading tests. Three lists of 20 regular, irregular and nonwords were prepared. Standard tests of reading [4] and non-verbal intelligence [5] were also presented.

Speech discrimination tests. A battery of four "same-different" speech discrimination tests was prepared. The test material is described below.

- *Natural minimal pair discrimination test.* Evaluates listeners' ability to discriminate consonant contrasts in the context of real-word minimal pairs. The test included 16 minimal pairs (e.g. date-gate) with the initial consonant differing in one feature only (either place of articulation or voicing).
- *Consonant-cluster discrimination test (Substitution condition).* Included monosyllabic words containing initial clusters. A contrast was made by substituting the second consonant of a given word to generate another word (e.g. snack-smack). 8 different pairs were used and the test included 160 trials.
- *Consonant-cluster discrimination test (Omission condition*). Included monosyllabic words with an initial two-consonant cluster, where the removal of

the second consonant generated another word (e.g. sweet-seat). 8 different pairs were used and the test included 160 trials.

- *Intervocalic consonant discrimination test*. Included nonwords with a vowel-consonant-vowel (VCV) structure, in which the consonant alone varied. The consonant in the 15 different paired-VCVs had the same manner of articulation but differed in either voicing or place of articulation (aga-aka). There were 240 trials in total.

Speech identification tests.

- *Synthetic speech pattern identification tests*. Six-step continua were prepared for the pairs DATE-GATE and SUE-ZOO and presented in a two-alternative forced-choice identification task using an adaptive procedure. Each contrast was presented in several test conditions in which the cues to the contrast (e.g. burst frequency and formant transition for the /d-g/ contrast) were presented combined or singly [6].

- *Nonsense-word repetition test*. This test consists in getting children to repeat nonwords of between 2 and 5 syllables (40 words in total).

Psychoacoustic tests. Tests from the Early Auditory test battery developed by Bailey [7] were used. These were presented as "same-different" discrimination tests in which a reference stimulus was paired with of one five stimuli differing in a given dimension. The battery included a gap detection test (gaps from 0 to 20 ms), a formant frequency discrimination test (formant frequency change between 0 Hz and 200 Hz), a formant frequency modulation detection test (modulation from 0 to 300 Hz), and a pitch discrimination test (F0 difference of 0 to 20 Hz).

2.3. Test procedure

Tests were administered to each child individually in a quiet room within the school or home. The natural-speech discrimination tests and psychoacoustic tests were recorded on audio-cassette and presented via headphones to the right ear only. The synthetic speech pattern identification tests were run using speech pattern audiometry software [6] on a portable PC.

3. RESULTS

3.1. Reading and standardized tests

A one-way analysis of variance for unbalanced groups (General Linear Models procedure) was used to test the main effect of subject-group. The mean regular word error-rate for the experimental group differed significantly from that of either control group [$F(2,34) = 14.41$; $p=0.0001$], as shown by Duncan's Multiple Range test. Performance within "normal range" was defined as being within one standard deviation of reading-age control means. Nine of the 13 SRD children performed below this level. There was also a significant effect of subject-group on the irregular word-list scores [$F(2,34) = 24.39$; $p=0.0001$], and eleven of the 13 SRD children performed below norm. Finally, the experimental group was less accurate at nonword reading than both control groups [$F(2,34) = 41.02$; $p= 0.0001$] with all 13 experimental children performing below norm.

	Regular wds	Irregular words	Nonwords
EXP	18.1 (14.1)	40.8 (21.4)	58.5 (19.5)
CA	0.8 (1.9)	7.9 (5.4)	12.5 (12.9)
RA	2.9 (4.5)	9.6 (4.5)	15.8 (11.0)

Table 1: Mean error percentages for experimental (SRD) children and controls for the word reading tests. Standard deviation measures are given in brackets.

For the standard tests, the difference in scores between groups for Raven's test of non-verbal intelligence was not significant ($p>0.05$) but the experimental group obtained significantly lower scores than the two control groups on the Neale reading accuracy test [$F(2,34)= 62.20$; $p= 0.0001$] and on the Neale reading comprehension test [$F(2,34)= 8.52$; $p=0.001$].

3.2. Speech discrimination tests

	Cluster omission	Cluster sub.	VCV	Minimal Pair	Rep. test
EXP	5.59 (10.1)	6.41 (8.3)	6.15 (9.1)	7.14 (4.0)	23.3 (14.7)
CA	0.51 (0.6)	0.77 (1.0)	1.92 (1.6)	4.61 (2.3)	9.4 (6.0)
RA	1.03 (1.9)	1.97 (3.0)	1.82 (1.4)	4.89 (2.4)	10.0 (7.3)

Table2: Mean results on the speech discrimination and nonsense word repetition test. Standard deviation measures are given in brackets.

For the Cluster Omission test, the effect of listener group just failed to reach significance. For the Cluster Substitution test, the effect of listener group was significant [$F(2,34)=4.05$; $p<0.05$] and post-hoc analyses showed that error rates for the experimental group were significantly higher than those for both control groups. The effect of minimal pair was also significant [$F(7,34)=2.88$; $p<0.01$]. The three pairs which differed in one feature only (place of articulation) had the three highest mean error rates whilst two pairs differing in three features (manner, place and voicing) had the lowest error rates.

For the VCV discrimination test, data was analyzed in terms of error percentages overall and within each consonant category classified in terms of manner of articulation (plosives, fricatives, nasals, glides). The main effect of subject group was not significant ($p>0.05$). However, the effect of consonant category was significant [$F(4,34) =$

8.37; p=0.0001] as was the subject group by consonant category interaction [F(8,34)=3.36; p= 0.0015]. Post-hoc analyses revealed that the subject groups differed significantly in their error scores for plosives [F(2,34)=3.82; p=0.0319] with the experimental group performing worse than control groups. The difference in error scores for other consonant categories failed to reach significance, although a higher error rate was always obtained by the experimental group.

For the natural minimal-pair discrimination test, the number of discrimination errors made overall by the experimental group did not differ significantly from those of the control groups. 5 of the 13 experimental children performed below norm, whilst only 2 of the chronological- and 1 of the reading-age controls did.

3.3. Speech identification tests

The gradient of each identification function was calculated and used as a basis for statistical analyses. A significant difference between groups was obtained for both combined-cue tests. For the DATE-GATE test, the main effect of subject group was significant [F(2,33)= 3.52; p=0.0411], and the experimental group had a significantly less steep function than the reading-age controls. For the SUE-ZOO test, the effect was also significant [F(2,32)= 3.80; p=0.0330], and a significantly shallower gradient was obtained for the experimental group than for reading-age controls. On average, identification functions obtained for the single-cue functions were less steep than for the combined-cue functions, but the difference between listener groups did not reach significance for any of the reduced-cue conditions.

For the word repetition test, an analysis was made of the nonwords incorrectly repeated per word-length. The effect of subject group was highly significant [F(2,34)=7.22; p< 0.005] and the experimental group gave significantly higher error scores than both control groups. The main effect of syllable length was also highly significant [F(3,34)=25.26; p= 0.0001] as was the interaction between subject group and syllable length [F(6,34)=2.59; p< 0.05]. The subject groups did not differ in their error rates for the two-syllable words, but the experimental group made more errors when repeating longer nonwords.

3.4. Psychoacoustic tests

For none of the four psychoacoustic tests was the effect of subject group significant. The effect of stimulus pair was in all cases significant and in the expected direction.

3.5. Results for sub-group of experimental children

Individual scores were examined to assess whether all children within the experimental group were showing a similar pattern of performance. Performance within "normal range" was again defined as being within one standard deviation of reading-age control means. Four experimental children were found to be performing below norm on at least three out of the four natural-speech discrimination tests. Only one out of the 25 control children did so. The performance of this sub-group of 4 children showing perceptual weakness (PW sub-group) was examined in more detail.

Tests of reading accuracy. Children in the two experimental sub-groups showed similar performance on the reading of regular and irregular words. The PW children however made around 20% more errors on average in their reading of nonwords.

Standardized tests of reading and non-verbal intelligence. The sub-groups did not differ in terms of their non-verbal intelligence. Comprehension scores on the Neale test for the PW sub-group were lower than the rest of the experimental group by 10 percentiles on average.

Speech discrimination tests. In Figure 1, mean scores are plotted separately for the PW sub-group and for the rest of the experimental (NP) group, and presented with the scores for the two control groups. For the cluster discrimination and VCV tests, the mean error rate for PW children was between 14 and 17%, whilst the mean error rates obtained by the NP experimental children and controls were negligible (below 2%). These children also obtained higher error rates in the minimal-pair test, although the increase in error rate was less marked. Scores obtained for the VCV test were examined in more detail to see whether the PW sub-group appeared to have specific difficulty with certain types of consonant contrasts (e.g. stops). Bar-charts showing the percentage of errors obtained for stop, fricative, nasal and glide contrasts are presented in Figure 2. High error rates relative to controls are seen for all categories and especially nasal contrasts.

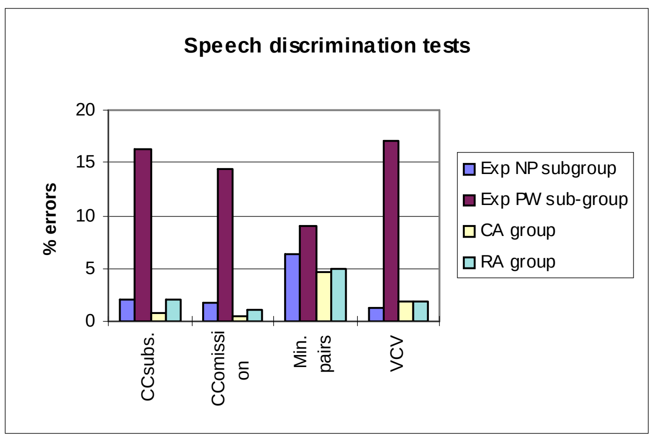

Figure 1: Error scores for the cluster substitution, cluster omission, minimal pair and VCV tests.

Speech pattern identification tests. For the DATE-GATE test, 2 out of 4 children labeled the contrast categorically in the combined-cue condition. In the "burst cue" condition, all four children were unable to label the endpoints of the continuum. In the "F2 transition" condition, two children labeled the contrast categorically or progressively. These four children also performed poorly on the SUE-ZOO contrast, and labeled the contrast at random when solely cued by changes in friction duration.

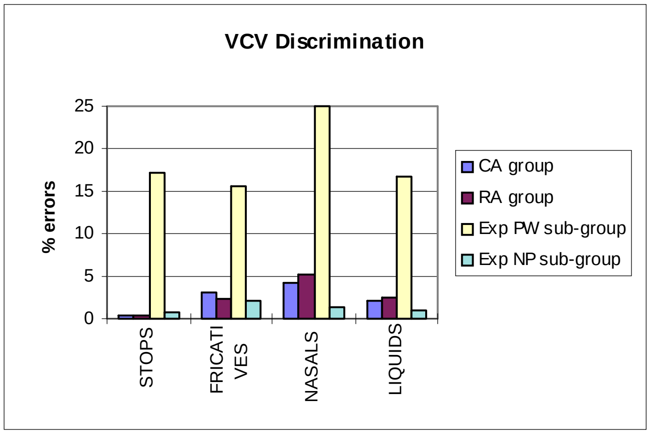

Figure 2: Error scores for VCV stimuli classified in terms of the consonant's manner of articulation.

Psychoacoustic tests. There was no evidence of systematically poorer performance on the psychoacoustic tests by children in the PW sub-group than by the remaining SRD children, or either control group.

4. CONCLUSIONS

A sub-group of SRD children (30% of our sample) are showing a weakness in perceptual processing which extends to a range of phonological contrasts and which is consistent over a set of discrimination and identification tests with real and nonsense words. All four children in this sub-group were right-handed girls. We use the term "weakness" because error rates for these children were relatively low; however, they were statistically significant and were obtained with high-quality material presented in better than usual listening conditions. These children did not appear to be performing significantly worse than other experimental or control children on psychoacoustic tests. It must be noted, however, that these tests may not have been sufficiently sensitive to detect small differences in performance. The PW children were also generally similar to the rest of the SRD group in terms of their standardized scores and their reading of regular and irregular words, although they performed worse on the reading of nonwords. This latter result concurs with the findings of Masterson, Hazan and Wijayatilake [8] that children with developmental dyslexia who were poor at phonemic discrimination were also poor at nonword reading. We can surmise that, for these children, a weakness in speech perceptual processing is at least a contributing factor to their failure to develop age-appropriate reading skills. An important point to note is that the rest of the children within the SRD group (70%) performed within chronological- and reading-age norms on speech discrimination tests.

The phonemic contrasts which seemed problematic were not merely phonetically similar (i.e. differing in a single feature) but also acoustically similar (i.e. differing in a feature which is not acoustically salient). We would also argue that problems in discrimination are not limited to contrasts which are marked by transient temporal cues, as suggested by Tallal's work, but that they can also be present for consonant contrasts which contain spectral cues which are not acoustically salient, such as certain fricative and nasal contrasts. The contrasts which these children found particularly difficult to discriminate are also the ones for which errors were also found for controls, and which are acquired late in the normal process of speech perception development. Degree of acoustic salience is not only related to the consonant contrast under investigation but also to the vocalic context in which the consonant appears, as this will determine the extent of formant transition present. For example, in the minimal pair test, high error rates were obtained for "met-net" but the error rates for "man-nan" were negligible. A similar effect of vocalic context, which gives further credence to the acoustic salience argument, was found in recent work by Tallal and her colleagues with language-impaired children [9] who report differences in performance levels for [βA–δA] and [βE–δE] identification tests.

5. ACKNOWLEDGMENTS

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