CLARIFYING THE SPEECH PERCEPTION DEFICIT IN DYSLEXIC CHILDREN

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ABSTRACT

It has often been claimed that dyslexic children show deficits in various speech-perceptual tasks. In this study, dyslexic and chronological-age-matched control children were asked to identify words, and label monosyllables from a voiced/voiceless plosive continuum, in quiet and in noise. Correlations on these tasks with reading and reading-related skills were weak and about half of dyslexic children had categorization slopes within the normal range in quiet. Both reading groups performed similarly well for labeling in noise and when identifying words in noise. The identification of words in noise was found to be related neither to reading nor to the consistency of categorical labeling. This study confirms that only a subgroup of children with dyslexia appears to have speech-perceptual deficits.

Keywords: Dyslexia, Categorical labeling, Speech Perception, Noise.

1. INTRODUCTION

Dyslexia is defined as an unexpected difficulty in acquiring literacy despite average intelligence and appropriate learning opportunities. Given the large amount of evidence showing difficulties in processing phonological information [1], many investigators agree that poorly specified phonological representations are a key deficit in dyslexia [2].

Research on categorical perception has been conducted in dyslexic populations in order to determine if fine-grained speech perception abilities could be at the origin of the phonological deficit characterizing dyslexia. Various studies suggest that identification of items from an acoustic continuum representing a phonemic contrast (e.g. in voicing or place of articulation) differs between dyslexic and typically-developing listeners. Identification functions in dyslexic children were typically found to be shallower than those of chronological age controls [3, 4]; this indicates that phonemic categorization in dyslexic children is less consistent than average readers. Nevertheless, some studies failed to observe a systematic deficit in categorical labeling in dyslexic children [5, 6]. Adlard and Hazan [5] observed that despite significant group differences, only a subgroup of the dyslexic children were identifying the contrast less consistently than reading level matched controls controls.

The present study evaluated categorical labeling in dyslexic and average reading children matched in age. A sizeable enough group of well-characterized dyslexics was recruited in order to identify the proportion of dyslexics performing outside the average reader range. The first aim of the study was to determine if categorical labeling deficits are restricted to a subgroup of dyslexic children, consistent with the findings of Adlard and Hazan [5]. Most communication situations take place with background noise, but little data are available on speech perception abilities of dyslexic listeners in noise. Therefore, we assessed categorical labeling and identification of words with noise in the background. If dyslexic children have poorly defined phonemic categories, they may be more affected by noise than average readers.

2. METHOD

2.1. Population

53 monolingual English native speakers aged between 7.11 and 13.06 were recruited. In order to be included in the study, participants were required to score within a standard deviation of the standardized mean in of receptive grammar [7], verbal [8] and non-verbal IQ [9]. 33 of the participants received a formal diagnosis of dyslexia by an educational psychologist. The 20 remaining participants (the controls) never experienced reading difficulty nor showed any reading delay in the tests we applied.

Table 1: Mean scores (and standard deviations) for the dyslexic and average reading groups. Last column presents the results of ANOVAs with group as a between-subject factor for age and inclusion tests

	Dyslexic	A. Readers	F
Age month	125 (16)	125 (18)	<1
Non-V IQ	97 (9)	102 (9)	(1.52)=2.9
Verbal IQ	99 (8)	106 (8)	(1.52)=3
Grammar	106 (11)	112 (10)	(1.52)=8.8*

* Significant at 0.05

2.2. Material

Children were assessed in a quiet room in their school. Instructions and testing material were recorded by female native speakers of British English.

2.2.1. Reading

Reading delay/advance was calculated by measuring the discrepancy between the score on a pseudo-word reading test [10] and non-verbal IQ [9], both derived from standard norms (mean of 100 and standard deviation of 15). This gave a measure of the difference between their actual decoding skills relative to the decoding skills predicted by their non-verbal IQ.

2.2.2. Phonological awareness

The rhyme and spoonerism subtests of the PhAB [11] were used as a measure of phonological awareness. In the rhyme subtest, children were asked to choose the words that sound the same at the end (e.g: sail, boot, nail). The spoonerism subtest requires children to swap the initial sounds of two words (e.g: "daisy log" gives lazy dog).

2.2.3. Phonological short term memory

Short-term memory was assessed with a nonword repetition task [12]. Twenty nonwords of two to five syllables ("rubid", "underbrantuand") were presented and the participants were instructed to repeat them.

2.2.4. Words In Noise

Children were instructed to repeat highly familiar monosyllabic words (e.g: "girl", "blade") presented in multi-talker babble. The signal to noise ratio (SNR) was adaptively varied on a trial-by-trial basis in order to determine the level needed for 50% correct responses. Thus, lower SNRs indicate better performance.

2.2.5. Identification of a [pi-bi] continuum

Identification of a [pi-bi] synthetic continuum was assessed in quiet and in noise. Stimuli were generated by copy synthesis of a natural [bi] token recorded from a female native British English speaker, using the cascade branch of the Klatt synthesizer [13]. For the first 4 ms, aspiration and friction amplitude were respectively set at 74 and 70 dB to produce a burst. F1, F2, F3 and F4 were respectively set at 365, 2000, 2600 and 4252 Hz and reached respectively 167, 2745, 3283 and 4119 Hz at the end of the syllable, which lasted 460 ms.. The continuum was generated by delaying the onset of the voicing while concurrently increasing the aspiration duration, to obtain stimuli differing in Voice Onset Time (VOT) ranging from 0 ms for the [bi] end to 60 ms at the [pi] end of the continuum. In the noise condition, multi-talker babble was played simultaneously with the synthetic syllables at an SNR of +6 dB. The duration of the stimuli was 1000 ms with the noise starting about 315 ms before the beginning of the syllable. All other aspects of the procedure and stimuli were the same in quiet and in noise.

Children identified the presented stimulus by clicking on a picture of a "pea" or a "bee". Stimuli were presented using an interleaved adaptive procedure as described in [14].

3. RESULTS

As expected, groups differed significantly with regard to reading delay/advance ($F(1,52)=62.27$ $p< .01$), phonological awareness (Rhyme: $F(1,52)=16.33$ $p<.01$, Spoonerism: $F(1,52)=27.89$ $p<.01$) and phonological short-term memory ($F(1,52)=9.84$ $p< .05$).

For the identification tests, the phoneme boundary and the slope of the identification function were calculated for each participant using logistic regression. The phoneme boundary is the point at which listeners give 50% of response [pi] (or [bi]) and shows the point in the continuum where listeners switch their perception from predominantly /bi/ to predominantly /pi/. Two dyslexic listeners were excluded from the analysis of the identification in noise because their slopes were not different from 0, indicating they identified the continuum randomly. The phoneme boundary in quiet for both groups (Table 2) was similar to that reported in previous work conducted on English listeners [15]. The slope gives a measure of the steepness of the identification function and is an index of response consistency. Slope values were log transformed for statistical tests because of their skewed distribution. Figures 1 and 2 show boxplots of the values obtained for the two groups.

Table 2: Mean (and standard deviation) of: reading delay (standard score); phonological awareness (raw scores /21); short term memory span (raw scores /40); slope (logistic units/ms VOT) and boundary (ms VOT) of the identification of the [pi-bi] continuum in quiet and in noise; threshold for the identification of words in noise (signal to noise ratio) for the dyslexic and average reader groups.

Task		Dyslexic	A. Readers
Reading Delay		-11.93(13.2)	15.9 (11.05)
Phon Awareness	Rhyme	16.09(3.3)	19.2 (1.19)
	Spooner	10.36(3.27)	15.35 (3.42)
Short Term Memory		34.15(4.37)	36.35(2.54)
ID in Quiet	Slope	0.24 (0.20)	0.43 (0.28)
	Boundary	25.18(5.63)	22.38 (4.48)
ID in Noise	Slope	0.18 (0.14)	0.22 (0.22)
	Boundary	36.75 (11.20)	33.65 (8.14)
W in Noise	Mean SNR	-4.46 (1.53)	-4.47 (1.37)

Repeated-measures analyses were used to determine whether the two groups of children differed on either of the two parameters extracted from the identification functions, and whether performance was different in quiet and noise. ANOVAs were run on the log slopes and phoneme boundaries, with test condition (quiet vs. noise) as a within-subject factor and group as a between-subject factor. For the phoneme boundaries, only the effect of test condition was significant [p<0.001] with no evidence of an interaction between group and noise [p>0.8] nor a main effect of group [p>0.1]. Thus the phoneme boundary does not differ between dyslexics and average readers, but occurs at a significantly longer VOT in noise than in quiet, perhaps attributable to masking the aspiration before voicing onset.

For the slopes, the effect of test condition was again highly significant [p<0.001] with groups also performing significantly differently [p<0.03]. The interaction of noise and group just missed statistical significance [p=0.076] but independent samples t-tests show significantly shallower slopes for the dyslexics in quiet [p<0.006] but not in noise [p>0.35]. Thus, as a group, the dyslexics show poorer identification performance than the average readers, perhaps more so in quiet than in noise. Unsurprisingly, phonetic categorization is more difficult in noise than in quiet.

Figure 1: Boxplot of the slopes of the identification functions in quiet and in noise for average readers and dyslexic children.

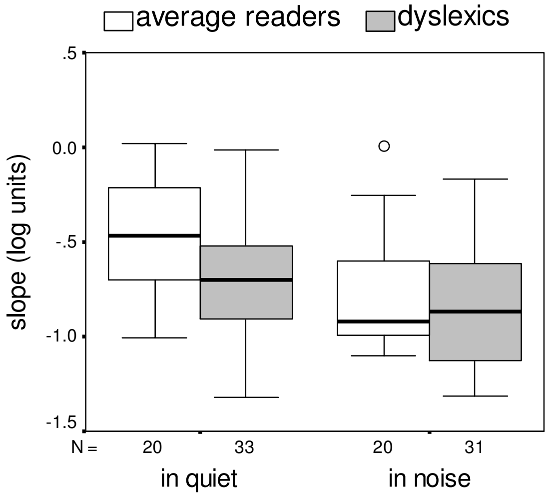
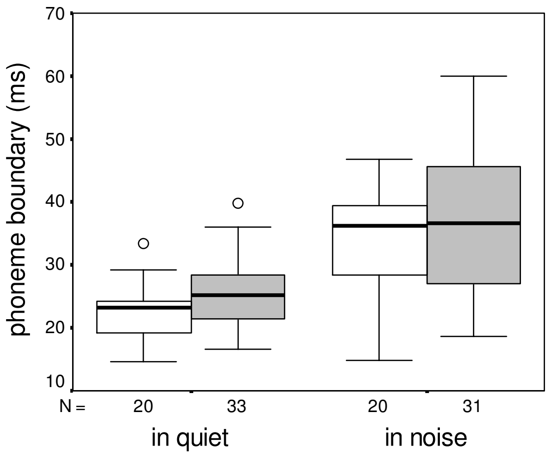


Figure 2: Boxplot of the boundary locations of the identification function for average readers and dyslexic children in quiet and in noise.



The mean signal to noise ratio achieved in the words in noise task was nearly identical in dyslexic and in average reading groups [p>0.9].

It is crucial to note that even for the slope measure, in which dyslexic children appear to be performing more poorly than average readers, the deficit is far from uniform. For performance in noise, 10/31 dyslexics (32%) had slopes shallower than 1 standard deviation (s.d.) below the mean, as did 2/20 average readers (10%). In quiet, 16/33 dyslexics (49%) had slopes shallower than 1 s.d. below the mean, as did 3/20 average readers (15%). Defining 'normal' performance as better than 1 s.d. below the mean on both tasks, nearly

40% of the dyslexics (12/31) performed 'normally' as did 80% of the average readers.

Over the two groups, the slope of the identification function in quiet was significantly correlated with the reading delay measure [r=0.41, p<0.005] and the rhyme subtest [r=0.27, p<0.05], while the slope in noise correlated with the spoonerism subtest [r=0.31, p<0.03]. Slopes in quiet and noise also correlated together [r=0.35 p<0.02] but none did so with identification of words in noise. In fact, performance in the words in noise task did not correlate with any other task presented.

Within groups, none of these correlations was robust, except that for the dyslexics, the slopes in noise and quiet were still correlated [r=0.39, p<0.03].

4. DISCUSSION

The dyslexic participants made more errors than controls in rhyme judgments, spoonerisms and phonological short term memory, replicating the typical difficulties in phonological processing classically reported [1, 2].

Speech perception abilities were considered for groups and individual variability within groups was also examined. Identification function slopes of the dyslexic group were significantly shallower than controls (especially in quiet), which indicates that the dyslexic group's response is, on average, less consistent for this VOT continuum. Nevertheless, nearly 40% of the children in the dyslexic group had slopes within norms, confirming previous findings that only a subgroup of children with dyslexia shows deficits in categorical labeling.

The categorization consistency in noise was similar between groups but the presence of noise affected the performances of average readers to a greater extent than dyslexic children. Additionally, noise did not appear to affect dyslexic children more than average readers when identifying words in noise and the task was not correlated with categorization in quiet.

Slopes of the identification functions in quiet and in noise were only weakly correlated to reading and phonological awareness tasks over the whole group, and none were significant within groups [16].

5. CONCLUSION

We observed that speech perception difficulties in dyslexic children were restricted only to a subgroup and conclude that reading deficit can therefore not be explained by a deficit in speech perception.

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