Phonological representations in poor readers

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Abstract

According to the ‘phonological deficit hypothesis’, problems in reading and spelling in dyslexic persons are due to poor representations of sounds in long term memory. As a result, the acquisition of the grapheme-phoneme correspondence and word decoding is assumed to be difficult. In this paper we describe a perception experiment to find evidence for poor phonological representations in 9-13 year old pupils who perform poorly in reading. The experiment is a two-alternative forced choice task in which subjects had to identify an intervocalic consonant in clean and noisy conditions. The results support the phonological deficit hypothesis but do not provide unique cues for the precise manifestation of this deficit. Between normal and poor readers, significant differences have been found with respect to reaction times, but not to accuracy.

Index Terms: speech, dyslexia, phonological representations, phonological deficit.

1. Introduction

Dyslexia is a specific language-based disorder characterized by difficulties in single word decoding. Difficulties in word decoding are often unexpected in relation to age and other cognitive and academic abilities. Dyslexia is manifested by a difficulty with acquiring proficiency in reading, writing and spelling [1].

The ‘phonological deficit hypothesis’ [2,3] attempts to explain the reading and spelling problems of dyslexic persons. According to the PDH, dyslexic persons do not have adequate representations for sounds in long term memory. The basic hypothesis is that dyslexia stems from a functional deficit in brain areas that are associated with speech processing. It is based on evidence that individuals with dyslexia tend to do poorly on tests which measure their ability to decode words using grapheme-phoneme conversion rules. A large body of research points to the phonological deficit as main cause for dyslexia [1,5,6,7]. It is assumed, for instance, that dyslexic persons have problems detecting rapid changes that are required for the acquisition of phonological representations [8]. It has also been shown that dyslexic subjects have difficulty discriminating phonemically similar word pairs (e.g., ba-da) as well as discriminating short words (e.g., ba-ep) [2,9]. Interestingly, there are no deficiencies in auditory tasks not involving speech sounds. This suggests that dyslexia is not based on a general auditory processing problem but rather on deficits in a higher-level phonological decoding process.

There have been several studies that deal with speech in noise to investigate the hypothesis of poor phonological representations in dyslexia [10,11]. In this paper we describe an experiment that fits in this tradition. If the phonological decoding system is more challenged in noisy conditions, it will facilitate the detection of deficits in the dyslexic group. An early study by Cornelissen et al. [5] investigated whether poorly developed phonological representations lead to poor discrimination performance. Ten dyslexic adults and normal adults classified nine CV stimuli (e.g., ‘pa’, ‘wa’ and ‘ja’) in four noise conditions (SNR 19, 0, -2 en -3 dB). It appeared that noise was the primary factor explaining the accuracy of the responses, and that dyslexic subjects behaved as accurate as the control subjects. However, dyslexic adults were significantly slower. Results of the study performed by Ramirez & Mann [12] revealed an increased effect of noise masking on the perception of isolated CV stimuli in dyslexic subjects relative to controls. Ziegler et al. [11] compared 10 children with SLI (Specific Language Impairment) with a control group on intervocalic consonant identification in three different noise conditions: no noise, stationary noise and non-stationary noise. The stimuli were CVC utterances and the response set consisted of 16 consonants. Children with SLI made significantly more identification errors than children without SLI, but behaved identically to control children of the same language age. In the noisy conditions, the difference between the SLI children and control children increased. It is concluded that SLI children have problems handling noise, with impaired phonological representations as a consequence.

Due to the differences in experimental setup and subject groups, the above studies are not exactly comparable. Nevertheless, it is clear that adverse conditions have an impact on the phonological representations in children with specific language impairment. For that reason, we pursue the direction of Ziegler’s research. We describe an experiment that aims at discovering phonological deficits that hamper the building and access of phonological representations.

We hypothesize that dyslexic children, as compared to controls, have more problems identifying consonants in noise and that this effect will be most evident in stimuli with close distracters. The problematic character is represented primarily in response time.

2. Method

Participants

A total of forty children participated, twenty in the experimental group (13 boys, 7 girls) and twenty in the control group (14 boys, 6 girls). The reading scores on the decoding test (One-Minute-Test) were significantly different [t(1,40)= -6.673; p<.001]. All children had nonverbal IQ percentile score > 60 (Raven SPM) [14], but groups differed on this cognitive ability test [t(1,40) = -2.313, p=.028]. All children had a 100% correct score on letter naming and letter discrimination [15]. Those who were recently tested on the WISC (n=5) and had IQ scores within the normal range (> 85), were not tested again on the Raven test (see Table 1).
Task and material

A two-alternative forced choice task was used with an auditory input and a visual response mode. VCV utterances had to be identified by choosing between the corresponding target letter and distracter letter on the screen (button press). All VCV utterances (Dutch) contained long vowels (e.g., [apa]). 60 stimuli were created by a combination of four long vowels (/a,o,e,u/) and fifteen consonants (/b,p,v,f,z,s,d,t,k,m,n,l,r,j,w/). Stimuli were produced by a female professional speaker, and digitized using 16 kHz, 16 bits/sample. All stimuli were segmented with 300 ms silence fade-in and 300 ms silence fade-out [16]. Speech-shaped noise was added by software provided by Stuart Rosen (UCL, London). The speech-shaped noise was added with > 80 dB SNR (no noise), 0 dB SNR (low noise) and -3 dB SNR (high noise).

Design

The distracter letter was either a close or a distant phoneme. Close phonemes shared more than four phonological features with the target consonant (e.g., /b/-/d/). Distant phonemes had less than 4 shared features (e.g., /k/-/w/) [17]. Response letters were black on a gray background (Arial, size=40, Bold), presented in the middle of the screen, 5 cm apart. The experimental paradigm was built using the stimulus presentation software Eprime [18].

The experiment comprised three parts, two instructional phases and one test phase. During the instructional phases visual feedback was provided on the screen with respect to both accuracy (hit/false) and reaction time (response time in ms). In the first phase, 12 items were randomly chosen out of 24 items. Presentation was experimenter-paced. Consonants had to be identified by making a choice between the target letter and a distant distracter. A criterion of 80% correctness was required to go to the second instructional phase. During this second phase, 12 predetermined items were presented at random, divided into items with no noise, low noise and high noise. Again, only distant distracter letters were given as response alternatives. The criterion was 70% correct.

Table 1. Means for age, didactic age equivalence (DAE), single word reading (OMT), letter naming and discrimination, and nonverbal intelligence scores.

<table>
<thead>
<tr>
<th></th>
<th>Poor readers</th>
<th>Normal readers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>sd</td>
</tr>
<tr>
<td>Age</td>
<td>10.0</td>
<td>0.8</td>
</tr>
<tr>
<td>DAE</td>
<td>-23.7</td>
<td>6.4</td>
</tr>
<tr>
<td>OMT</td>
<td>41.5</td>
<td>10.6</td>
</tr>
<tr>
<td>Letter naming (%)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Raven (percentile)</td>
<td>71.6</td>
<td>16.4</td>
</tr>
<tr>
<td>WISC</td>
<td>100.4</td>
<td>9.4</td>
</tr>
</tbody>
</table>

During the second phase and the test phase the inter-trial-interval was: beep/400 ms silence/VCV stimulus instantly followed by response alternatives on the screen for 2000 ms/500 ms silence. During the test phase no feedback was provided. Items were grouped into three blocks of 60 items with a subject-paced pause after 30 items. They were presented at random within blocks. The noise levels (no noise, low noise, high noise) were counterbalanced across blocks. Presentation of the target letter at right or left was balanced with a maximum of four consecutive trials at one side. Response alternatives were either close or distant. If subject A was given the close alternative /b/ next to target /p/, then subject B was given the distant alternative /s/, and so forth. All subjects received as many close alternatives as distant alternatives, and an equal number of items without noise, with low noise, and with high noise.

Procedure

The participants were tested individually in a separate room at school using a laptop and closed headphones.

3. Results

First, outliers have been removed from the data by discarding extremely long and short response times. After deleting response times outside the μ±3σ interval, 99.01 percent was left for further analysis (56 tokens were deleted).

All analyses have been carried out using a Generalized Linear Model (GLM) with repeated measurements with ‘group’ as between-subject variable, and with ‘noise’ and ‘distance’ as within-subjects variables (α = 0.05). We will also describe the results of a correlation analysis between reading score and reaction time.

3.1 Reaction times

Figure 1 shows the average response times (RT) and standard deviations per group. The poor readers identify target consonants significantly slower than the normal readers [F(1,38)=7.369; p<.010], as expected.

As shown in figure 2, consonants are identified slower as a function of noise level [F(2,76)=89.594; p<.001]. As noise level increases, the identification times increase too. The no-noise condition (noise0) differs significantly from both the low noise condition (noise1, p<.001) and the high noise (noise2, p<.001).

There is no significant difference between noise1 and noise2. In each noise condition, the poor readers have longer identification times than the normal readers (see figure 2). However, the group difference is most obvious in the noise0 condition, followed by the noise1 and noise2 condition (mean differences between groups are 142 ms, 84 ms, and 78 ms, respectively). Thus, as noise level increases, the group difference decreases. This is not as expected.
Figure 2. Average response time and (sd) for the experimental and control group to stimuli presented without noise (noise0), with low noise (noise1) and with high noise (noise2).

The interaction noise level x group is marginally significant [F(1,38)=2.904; p=.061]. Further inspection of the data using a t-test reveals that group differences are largest at noise0 (p<.001), followed by noise1 (p<.01) and noise2 (p<.05).

In general, reaction times to target consonants are longer if the distracter letter is a phonologically close consonant [F(1,38)=16.013; p<.001] (cf. figure 3). Both groups react slower to stimuli in the close condition than in the distant condition.

Figure 3. Average response time and (sd) for the experimental and control group to targets with phonologically close or distant distracters.

Again, in the noise0 condition poor readers differ most from the normal readers: in this condition, the difference in consonant identification time among close vs. distant distracters is larger for poor readers than for normal readers. The interaction effect group x distance in noise0 is significant [F(1,38)=4.154; p=.05].

Table 2. Average response time (ms) to target stimuli with close/distant distracters for poor and normal readers in noise0.

<table>
<thead>
<tr>
<th></th>
<th>Poor readers</th>
<th>Normal readers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close</td>
<td>759</td>
<td>612</td>
</tr>
<tr>
<td>Distant</td>
<td>782</td>
<td>676</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>64</td>
</tr>
</tbody>
</table>

3.2. Accuracy

Accuracy has been measured for each token. The poor readers do not significantly differ from the normal readers [F(1,38)=1.453; p=.236]. Both groups are equally accurate in identifying the consonant stimuli (0.77 poor readers vs. 0.80 normal readers). Accuracy decreases with increasing noise level, however [F(2,76)=259.834; p<.001]. All noise levels differ significantly from each other at p<.001. Figure 4 shows the average accuracy per group per noise condition.

Figure 4. The average accuracy (proportion) for the experimental and control group to stimuli without noise (noise0), with low noise (noise1), and with high noise (noise2).

The poor readers made more errors than the normal readers in stimuli presented in noise1 and noise2 (but not in noise0). There is no interaction, however [F(1,38)=1.988; =.144]. This is surprising because it was expected that the poor readers would produce significantly more errors in noisy conditions as compared to the normal readers.

Figure 5 shows that subjects are less accurate in case of close distracters. Distance is a main effect [F(1,38) = 17.964; p<.001]. There is no significant interaction distance x group, nor is there a significant interaction noise x distance x group.

Figure 5. Average accuracy score (proportion) for the experimental and control group to targets with phonologically close or distant distracters.

There is, however, a significant (overall) interaction noise x distance [F(2,37)=8.344; p=.001]. As noise increases, the
difference between identification times of targets with close vs. distant distracters increases too.

3.3. Correlation

Correlations (Pearson r) between reading scores and reaction times were calculated for all noise conditions (table 3). Moderate negative correlations at p<.01 were found between reading scores and reaction times in the noise0 condition. Identification times of consonants decreases as reading proficiency increases. The correlation coefficient is largest for stimuli with phonologically close response alternatives. No significant effects have been found for stimuli presented in noise.

Table 3. Correlation between reading score (OMT) and reaction times to target stimuli with close/distant distracters in the different noise conditions.

<table>
<thead>
<tr>
<th></th>
<th>noise0</th>
<th>noise1</th>
<th>noise2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close</td>
<td>-.55*</td>
<td>-.23</td>
<td>-.19</td>
</tr>
<tr>
<td>Distant</td>
<td>-.44*</td>
<td>-.32</td>
<td>-.25</td>
</tr>
</tbody>
</table>

*p<.01

4. Discussion and conclusion

The results clearly point to a phonological deficit for children with reading difficulties. However, they are not unambiguous with respect to the degree of phonological deficiency. There are significant differences between poor and normal readers with respect to reaction time, but not with respect to accuracy. It is assumed that access to phonological representation (and not phonological build-up) is impaired in poor readers as compared to normal readers.

Poor readers react slower than normal readers both in clean (no noise) and adverse conditions. However, the group difference is most obvious in the clean condition, which does not confirm our hypothesis. It corresponds to the findings by Cornelissen [5], but not to those by Ziegler et al. [11] (although their participants were children with SLI). Thus, in the present study it is in the clean condition where poor readers need more time to identify consonants and where the effect of distance in phonological representations (longer RT for close items as compared to distant items) is most obvious. The fact that reading proficiency is related to phonological access can also be observed in the negative correlations between reading scores and identification times in this clean condition. The results show that poor reading is related to problems in phonological access, but the way this problem is manifested across noise levels is not uniquely determined. The results suggest that noisy conditions do not necessarily have a negative effect on phonological access in poor readers.

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5. References