The role of metrical stress in comprehension and production in Dutch children at-risk of dyslexia

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Abstract

The present study compared the role of metrical stress in comprehension and production of three-year-old children with a familial risk of dyslexia with that of normally developing children. A visual fixation task with stress (mis-)matches in bisyllabic words, as well as a non-word repetition task with bisyllabic targets were presented to the control and at-risk children. Results show that the at-risk group is less sensitive to stress mismatches in word recognition than the control group. Correct production of metrical stress patterns did not differ significantly between the groups, but the percentages of phonemes produced correctly were lower for the at-risk than the control group. The findings indicate that processing of metrical stress patterns is not impaired in at-risk children, but that the at-risk group cannot exploit metrical stress in word recognition.

Index Terms: metrical stress, speech, visual fixation, non-word repetition

1. Introduction

Acquisition of reading is a complex achievement that is partly determined by spoken language skills. Developmental dyslexia is a specific language-based disorder characterised by difficulties in reading and/or spelling that are unexpected in relation to cognitive abilities and age [1]. A widely accepted explanation of dyslexia is that it stems from an underlying phonological deficit [2]. The phonological deficit hypothesis holds that children and adults with dyslexia have difficulty with constructing, maintaining, and retrieving phonological representations. Phonological representations are the foundation for reading development, as they should enable orthographic development and phonological awareness skills. Consequently, if phonological representations are poor (‘holistic’, ‘fuzzy’, or ‘underspecified’), slow literacy and spelling development ensue.

Traces of this phonological deficit have not only been reported for dyslexic children, but also for those with a familial risk of dyslexia, that is, young children with at least one dyslexic parent [3, 4, 5]. These at-risk children have not yet received literacy instruction. Approximately 30-60% of at-risk children actually become diagnosed with dyslexia at school. It has been found, for instance, that these children show poorer phonological awareness, categorical perception, and speech production.

Skills related to metrical stress, patterns of strong (stressed) and weak (unstressed) syllables, have received little attention in dyslexia research. The notion of the phonological deficit, however, warrants investigation into this suprasegmental area. Sensitivity to metrical stress patterns is necessary for the identification of word boundaries in spoken language [6] and thus for the construction of detailed phonological representations. Vihman et al. [7] found that typically developing 11-month-old infants showed a delayed response on a head-turn paradigm task when the metrical stress pattern was reversed (e.g. báby presented as babý). These findings show that metrical patterns are used as a cue for constructing phonological representations in typical acquisition. The question arises whether this is also the case for children with (a risk of) dyslexia.

Research by Wood [8] has shown that four-to-seven-year-old (normally developing) children had difficulty identifying words which had their metrical stress pattern changed (e.g. sófa presented as sofá). Furthermore, there was an association between performance on this metrical stress task and results on phoneme awareness, literacy and spelling ability. On the basis of these findings, it can be anticipated that children at-risk of dyslexia will show poorer metrical sensitivity in word recognition.

A second question is whether the production of stress patterns is affected in at-risk children. Production data of young English and Dutch children, i.e. children learning a trochaic language (with strong-weak rhythm), show a trochaic bias [9, 10, 11]. In early stages, a trochaic foot is produced, omitting weak non-final syllables (e.g. ballóon realised as loon). It will be assessed here whether this trochaic bias is also present for at-risk children and whether it might be stronger for the at-risk than control group, possibly pointing towards a delay in phonological acquisition. Furthermore, it can be expected that the percentages of correctly produced phonemes will be lower in targets with a weak-strong as opposed to a strong-weak pattern.

In sum, this paper investigates the role of metrical stress in comprehension and production of metrical stress of three-year-old Dutch children at-risk of dyslexia. Assessment of phonological acquisition can thus be used to further qualify the phonological deficit hypothesis. The questions targeted were: 1) Is word recognition of young children at-risk of dyslexia affected more by metrical stress ‘mismatches’ than those of normally developing children? and 2) Does their production of metrical stress display (similar) difficulties? These questions were addressed through a visual fixation task and a non-word repetition task, reported as Experiment I and Experiment II.

2. Experiment I: Comprehension

The aim of this experiment was to establish whether stress mismatches affected word recognition of the at-risk group similarly as the control group.

2.1. Method

2.1.1. Participants

At-risk and control children were recruited through calls in newspapers and magazines. The at-risk children had to have at least one dyslexic parent. For more information on subject selection, see [3]. Relevant information on number of participants, age, non-verbal IQ, and vocabulary score measured through the Dutch MCD, the N-CDI,I is presented in Table 1. The number of at-risk participants exceeded that of control children, as only 30-60% of the at-risk group is assumed to become dyslexic.

Table 1. Subject information

Group	N	Age (months)*	IQ	N-CDI percentile
Control	17	36.4 (2.9)	111.2 (15.7)	47.1 (27.1)
At-risk	36	38.7 (2.7)	112.0 (12.7)	43.4 (20.9)

*p<0.01

2.1.2. Stimuli

Test stimuli consisted of ten bisyllabic words, five with a strong-weak (SW) pattern: *áuto* (car), *pótlood* (pencil), *pínguïn* (penquin), *zébra* (zebra), *báby* (baby), and five with a weak-strong pattern (WS): *banáan* (banana), *tomáat* (tomato), *koníjn* (rabbit), *kadó* (present), *giráffe* (giraffe). Each item was presented twice in the experiment, once produced with the correct stress pattern, e.g., *banáán* and once with the incorrect stress pattern, e.g., *bánaan*. In addition, there were 10 bisyllabic filler words of which half had an SW and the other half a WS pattern. All filler words were presented once with the correct stress pattern. Each critical word appeared at the end of a sentence, e.g., *Waar is de banaan?* (Where is the banana?). All sentences were recorded by a trained female speaker of Dutch.

2.1.3. Procedure

Children's sensitivity to stress patterns during word recognition was assessed using a visual fixation task. Children were seated on their parent's lap at a distance of approximately 1.5 meters from two adjacent LCD screens. During each trial, two pictures were displayed (one on each screen) for 6.5 seconds. 2.5 seconds after picture onset a sentence was played over loudspeakers, in which one of the pictures was named (either with the correct stress pattern or the incorrect stress pattern). Children's faces were recorded on videotape during the entire experiment.

2.1.4. Analysis

Videotapes were digitized and coded off-line frame by frame by a trained coder who was blind to the pictures and sentences that were presented. For each video frame (40 ms interval) the coder determined whether the child looked at the left picture, the right picture, or somewhere else. For each item and subject the proportion of fixation to the target picture was calculated (see [12]) over a window of 2 seconds, which started 360 ms after the onset of the target word.

2.2. Results

Figure 1 displays the mean proportions of fixations to target pictures for the different conditions, plotted separately for the control and the at-risk children. A repeated measures analysis of variance (ANOVA) with Target stress pattern (SW or WS), Stress match (Match or Mismatch) and Group (Control or At-risk) as factors was conducted. The analysis revealed a main effect of Target stress pattern ($F(1,51) = 4.96$, $p = .030$), a main effect of Group ($F(1,51) = 5.73$, $p = .020$) and a significant interaction ($F(1,51) = 4.15$, $p = .047$), indicating that the at-risk children looked less to the targets when they heard a WS word than when they heard a SW word (irrespective of the realized stress pattern).

More interestingly, the outcomes showed a main effect of Stress match ($F(1,51) = 6.86$, $p = .012$) and a marginally significant interaction with Target stress pattern ($F(1,51) = 3.72$, $p = .059$). Children looked less to the target picture when the word was produced with a mismatch stress pattern than when it was produced with the correct stress pattern, but in particular when the word required an SW pattern. Separate ANOVAs for the two groups indicated that the stress-mispronunciation effect was highly significant for the controls ($F(1,16) = 21.49$, $p < .0001$) but not for the at-risk children. The at-risk children, however, showed a main effect of Target stress pattern ($F(1,35) = 15.74$, $p < .0001$).

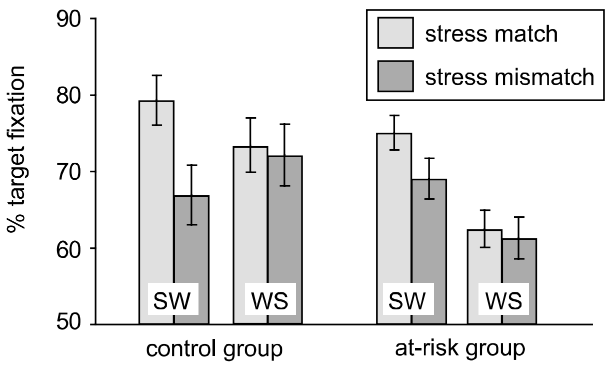

Figure 1: *Results of Experiment I, showing children's proportion of fixation to the target picture upon hearing a word with a matching or mismatching stress pattern. Error bars are standard errors.*

2.3. Discussion Experiment I

First of all, the findings of the comprehension experiment show a preference for looking at SW targets than WS targets. A similar pattern has been found for adults in a priming experiment, where SW patterns were encoded faster than WS targets [13]. This may be due to the fact that WS words are in conflict with the segmentation strategy, based on the frequency fact that in Dutch most bisyllabic words start with a strong syllable. Furthermore, the finding that a mismatching stress pattern affects the recognition of SW but not of WS words is probably also due to the segmentation strategy: a mismatching WS stress pattern for a SW word predicts an incorrect word boundary, while a mismatching SW pattern for a WS word actually favours the correct segmentation. Crucially, the effect of mismatching stress was only significant for the control children and not for the at-risk children, suggesting that the at-risk children have more difficulty using the segmentation cues than normally developing children. As mentioned earlier, the ability to segment words from continuous speech is a crucial first step for word learning. A problem with word segmentation may lead to less specified phonological representations and may therefore be one of the underlying problems of the phonological deficit.

3. Experiment II: Production

This experiment aimed to assess whether the production of SW and WS metrical patterns were more difficult for at-risk than control children.

3.1. Method

3.1.1. Participants

Participants were the same as those in Experiment I, see Table 1 for details.

3.1.2. Stimuli

Ten non-word targets were presented to the children, five with an SW pattern (*bóla* /ˈbola/, *kákot* /kakɔt/, *kóbaat* /kobat/, *tágont* /’taχɔnt/, *tánei* /tanɛɪ/, and five with a WS pattern (*bokáat* /bɔˈkat/, *kadónt* /kaˈdɔnt/, *katéi* /kaˈtɛɪ/, *sotá* /soˈta/, and *watóp* /ʊaˈtɔp/. Non-words rather than words were chosen, as previous research suggested that a ceiling effect might be obtained for realisation of familiar targets [14].

3.1.3. Procedure

Children were presented with a picture of a fantasy animal, heard its name over a Fostex 6301B loudspeaker and had to repeat it. Children's realisations were recorded on DAT (Tascam DA-P1) with a highly sensitive microphone (Crown PZM-185).

3.1.4. Analysis

Recordings, converted to sound files, were independently transcribed by two trained transcribers, who were blind to the group membership of the children (at-risk or control). Differences (4% of the data) were resolved between the two transcribers. It was scored whether the metrical stress pattern was realised correctly. Additionally, the percentages of phonemes realised correctly was calculated.

3.2. Results

Children's realisations of the metrical stress patterns are plotted in Figure 2. The at-risk group showed lower percentages correct of both SW and WS patterns than the control group. However, a repeated measures ANOVA with Stress pattern (SW or WS) as within-subjects factor and Group (Control or At-Risk) as between-subjects did not lead to an effect of Group, or an interaction between Group and Stress pattern. There was an effect of Stress pattern ($F(1,51) = 7.99$, $p = .007$) in the expected direction; SW targets rendered higher scores than WS targets.

A repeated measures ANOVA on the percentage phonemes correct (control children: 78.7% (14.5); at-risk children: 69.6% (17.2) showed a main effect of Group ($F(1,49) = 4.05$, $p = .05$), indicating that the at-risk children made more segmental errors when repeating non-words than the control children.

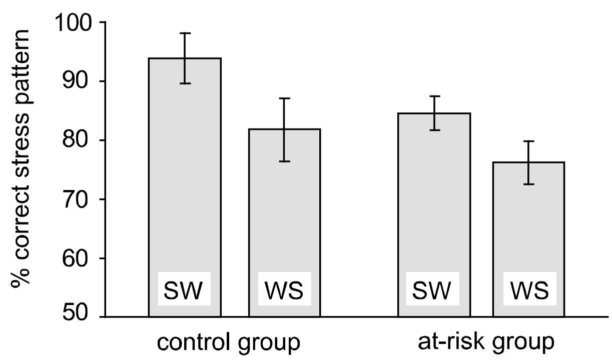

Figure 2: *Results of Experiment II, showing children's proportion of correctly produced stress pattern. Error bars are standard errors.*

3.3. Discussion Experiment II

Production of non-words with SW and WS metrical stress targets did not lead to significant differences between the control and at-risk group on the measure of correct stress patterns, even though the at-risk group always performed slightly lower. This finding suggests that perception, representation, and reproduction of the metrical stress patterns are not deviant for the at-risk group (as a whole). In terms of percentages phonemes correct, however, the at-risk group obtained a significantly lower percentage of correctly produced phonemes than that of the control group, suggesting they might show delayed construction of detailed representations.

4. Discussion and Conclusion

The present study explored the phonological skills of three-year-old children at-risk of dyslexia. Specifically, the role of metrical stress in word recognition and production was assessed. Whereas correct production of an SW or WS target in a non-word repetition task did not lead to significant differences between the groups, there were significant differences between the groups on the comprehension task. Specifically, the effect of stress mismatch was weaker for the at-risk children than for the control children. These findings suggest that processing of metrical stress patterns is not delayed in the at-risk group, but that the at-risk group does not exploit the metrical stress cues for speech segmentation, impacting on subsequent access to the mental lexicon. This could have a detrimental effect on the construction of detailed phonological representations. The non-word repetition task also showed that the at-risk group produced fewer correct phonemes, endorsing this interpretation.

It will be interesting to assess whether the patterns of performance on the comprehension and production task are related to the children's future literacy abilities. The findings of this study thus confirm a delay in phonological acquisition of at-risk children and demonstrate the importance of including suprasegmental skills in this type of research.

Specifically, on the basis of these findings we hypothesize that the reduced ability to use metrical stress cues to identify word boundaries is related to the phonological problems that dyslexic children encounter in both perception and production.

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