The phonological representations hypothesis of dyslexia: consequences for the formation of associations

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6. Epilogue

Review of the experimental studies

In the study described in Chapter 2 it was examined whether dyslexic children had problems with the formation of associations between words and pictures and between nonwords and pictures as compared to age-matched and younger normal readers. Dyslexic children were found to have more difficulty with the learning of phonologically unfamiliar words than the age-matched normal readers. In addition, dyslexic children were found to have more difficulty with the learning of familiar words. On both verbal learning tasks dyslexic children performed similar to younger normal readers.

The lower performance of the dyslexic children on the nonword learning task could be explained by their general problems with the processing of novel phonological material. The analysis of the errors made in the responses of the children during the acquisition of new phonological representations revealed that these representations were less well specified. Dyslexic children were found to make a similar amount of errors at the global word level as age-matched and younger normal readers, but they made more single phoneme errors than their normal reading peers. The distribution of error types in nonword learning of the dyslexic children did not differ from younger normal readers, which indicates that the specification of dyslexic children’s phonological representations is related to their reading level.

More speculatively, underspecified phonological representations might also underlie dyslexic children’s observed learning problems for known words. The finding that dyslexic children made somewhat more phonological errors than the normal readers tends to support this hypothesis.

In Chapter 3, we aimed to replicate the findings on word and nonword learning reported in Chapter 2. As an extension, it was investigated whether dyslexic children’s paired associate learning problems were confined to verbal learning or also included nonverbal learning. The paired associate learning performance of dyslexic children was compared to the performance of age-matched and younger normal readers. The findings of both word and nonword learning problems in dyslexic children were replicated. Dyslexic children performed worse as compared to age-matched normal readers, but similar to younger-normal readers on both learning tasks. Nonverbal learning, however, was not impaired in dyslexic children. They performed similar to their normal reading peers, and outperformed the younger normal readers on this learning task.

The existence of this exclusive verbal learning problem in dyslexic children could indicate that their problems arise from an underlying phonological deficit. The disappearance of the performance difference between dyslexics and age-matched normal readers on both word and nonword learning when phonological awareness was taken into account supported this view. Though the dyslexic children made more errors than their normal reading peers in the verbal
learning task, the percentage of phonological errors made was similar to that made by the normal readers. In contrast to the previous study, these findings support the idea that dyslexic children have more difficulty with the acquisition of phonological representations of new words, but that this process is not qualitatively different from normal readers.

As another extension, compared to the study in Chapter 2, in this study the long-term retention of the learned associations was considered. For verbal learning (both words and nonwords), dyslexic children were found to have problems with the acquisition of the correct associations, but not with the long-term retention of the verbal labels as compared to age-matched and younger normal readers.

In Chapter 4 three experiments were reported that aimed to test the phonological representations hypothesis in the context of visual-verbal learning. Phonological representations of words in the mental lexicon of dyslexic children are assumed to be either less distinct (e.g., Elbro, 1996) or to be less segmentalized (Fowler, 1991; Metsala & Walley, 1998). The implication of both hypotheses is that underspecified (i.e., less distinct or less segmentalized) phonological representations of words in the mental lexicon are more similar than fully specified phonological representations. Accordingly, it follows that for dyslexic children, having less segmentalized representations, words from the same neighborhood (i.e., words that differ on one phoneme) are relatively more similar than for normal readers. From this assumption, it was hypothesized that for dyslexic children the visual-verbal paired associate learning of a set of words with many neighbors would be more difficult than the learning of a set of words that are phonologically distinct. Normal readers, however, were expected to be less affected by the phonological distinctness of the set of words to be learned. As expected, indistinct word sets were more difficult to learn than distinct word sets. However, dyslexic children were not hampered more by the phonological similarity across a set of words than their normal reading peers.

In addition to the effect of phonological distinctness on visual-verbal paired associate learning, distinctness of the visual stimuli was also considered. As expected, normal and dyslexic readers were found to be equally affected by the visual distinctness of the pictures used. Both normal and dyslexic readers performed more poorly on the set of visual indistinct pictures than on the set of visual distinct pictures.

As in the studies reported in Chapters 2 and 3, dyslexic children performed worse than the age-matched normal readers on nearly all learning tasks. The differences in word learning between normal and dyslexic children could, to a large extent, be accounted for by their differences in phonological processing. This finding supports the hypothesis that dyslexic children’s verbal learning problems are manifestations of a single underlying phonological deficit.

In Chapter 5 a study was reported which aimed to investigate the consequences of impaired phonological representations for the acquisition of orthographic knowledge. From the assumption that dyslexic children have underspecified phonological representations, it was hypothesized that learning to read words in a context of orthographically and phonologically similar words would be more difficult than learning to read words in an orthographically and
phonologically dissimilar context. This hypothesis is denoted as the Similarity Hypothesis, which states that for dyslexic children learning to read new words, the mapping of phonology to orthography is more difficult in a context of similar words than in a context of orthographically dissimilar words because the lower quality phonological representations of words overlap with one another to a great extent, especially in an indistinct condition. As a consequence, dyslexic children need more time to retrieve the correct pronunciation of the written word from memory.

The repeated reading of lists of nonwords in a distinct (kwog with kwes, snar, and skal) and in an indistinct context (kwog with kwos, knos, and knog) revealed that the dyslexic children were affected by the context in which the words were read. They read nonwords read in an indistinct context more slowly than nonwords read in a distinct context. Both age-matched and younger normal readers were not affected by orthographic context.

For reading accuracy, however, the results were different. Dyslexic children were found to read the nonwords read in a distinct context less accurate than the nonwords read in an indistinct context. Both normal reader groups, however, were not affected by orthographic context. The finding of the dyslexic children’s higher accuracy rates for words read in an indistinct context is in disagreement with the Similarity Hypothesis. The accuracy findings can be explained by the Minimal Difference Hypothesis. This hypothesis states that the minimal differences among the words read in an indistinct context encourage a focus on each individual letter in a word. Accordingly, the acquisition of fully specified phonological representations is supported and this increase in orthographic knowledge will be observed in an increase in reading accuracy.

Reading new nonwords that were orthographically similar to the nonwords read in the training (i.e., transfer nonwords) was found to be more difficult for dyslexic and younger normal readers. Both reader groups read the transfer nonwords slower than the previously trained nonwords. Although reading-age controls were affected more by transfer than the dyslexic children, the younger normal readers had most difficulty reading the transfer nonwords that differed in the onset cluster of the word. This finding, combined with the finding that dyslexic children read the transfer nonwords that differed on the last grapheme less accurate but at similar speed as trained and first letter transfer nonwords, suggests that dyslexic readers are less receptive to the subtle differences between the nonwords than the younger normal readers.

In all, the results of this study suggest that the availability of detailed phonological representations becomes critical when connections have to be formed in a context of learning to read similar words.
Chapter 6

Limitations of the studies

Some limitations of the studies reported in this thesis need to be addressed. These limitations mainly concern the materials and manipulations used in the various studies. For the studies reporting on the visual-verbal paired associate learning performance of dyslexic and normal readers abstract and concrete visual stimuli were used. The manipulations in these materials were based upon the manner in which neighboring words differ from one another. Due to the characteristics of the stimuli the manipulations were analogue but not equal. This might have affected the learning performance of the children differently. Though we did not report these findings, the results of Study 3 in Chapter 4 did indicate that the paired associate learning of words paired to abstract pictures was easier than the learning of words to concrete pictures. However, it needs to be pointed out that the stimuli in this study were indistinct, whereas the stimuli in the sets used in Study 1 of Chapter 4 were distinct. The finding in the latter study that words were more easily paired to concrete pictures then to abstract pictures can easily be explained by the namebility of the concrete pictures. However, in a learning task with sets of indistinct visual stimuli, the similarities and differences across the sets of abstract stimuli might have been more obvious then across the concrete stimuli enhancing the learning performance of the children.

With regard to the study reported in Chapter 5 investigating the consequences of underspecified phonological representations for the acquisition of orthographic knowledge, the following points need to be addressed. First, as the number of nonwords per orthographic context (indistinct, distinct, and unique) differed across the training and posttests, a selection of nonwords had to be made for the analyses. To ensure that the results would be unambiguous, the analyses only included nonwords that were read in both the posttests and the training. This selection of nonwords, however, implied that only two nonwords were available in each orthographic context, decreasing the power of the analyses.

Second, only the correctly read nonwords were included in the accuracy and reading speed analyses. For several analyses, the amount of incorrectly read nonwords decreased the participants in the reader groups to less than 16, endangering the solidity of the data. Replacement of the missing values with estimations ensured the validity of the analyses. A replication of the study would ensure a more reliable representation of the findings.

General discussion

The studies presented in this thesis aimed to explore the consequences of the assumed underspecified or lower quality phonological representations of words in the mental lexicons of dyslexic children. The question whether dyslexic children have problems with the formation of visual-verbal associations and whether these problems are manifestations of the phonological deficit characteristic for dyslexia was addressed.
Furthermore, conditions were investigated in which dyslexic children’s problems with the formation of associations between the spoken and written forms of words (i.e., in reading acquisition) are aggravated.

In the sections below, several central themes and findings across the studies reported in this thesis are discussed.

**Manifestations of a phonological deficit**

The results of the various studies reported in this thesis suggest that manifestations of a phonological deficit mainly concern the verbal domain and not the non-verbal domain. Visual-visual paired associate learning was found to be unimpaired in dyslexic children (see also Liberman, Mann, Shankweiler, & Werfman, 1982; Nelson & Warrington, 1980; Rapala & Brady, 1990; Vellutino, Steger, & Pruzek, 1973). In addition, dyslexic children and normal reading peers were similarly affected by the visual distinctness of the stimuli in a visual-verbal paired associate learning task. This last finding is also in accordance with other studies on this matter (Mauer & Kamhi, 1996; Palmer, 2000).

However, within the verbal domain, manifestations of a phonological deficit were found. Each study reported in this thesis included the assessment of phonological processing skills. Dyslexic children were found to perform lower on all phonological processing tasks (phoneme deletion, rapid automatic naming, word completion, nonword repetition, spoonerisms, and phoneme recognition) as compared to age-matched normal readers. The only exception was a nonword span task, which did not differentiate between the dyslexic children and their normal reading peers.

In addition, the studies documented problems of dyslexic children in the acquisition of phonological representations of new words. Dyslexic children needed more time to learn the associations between the nonwords and pictures as compared to age-matched normal readers (also see Mayringer & Wimmer, 2000; Vellutino et al., 1975, 1995; Vellutino & Scanlon, 1989; Windfuhr & Snowling, 2000). Dyslexic children were also found to have problems with the paired associate learning of familiar words. Interestingly, when phonological awareness was taken into account, the differences between dyslexics and age-matched normal readers on both word and nonword learning disappeared. This result suggests that phonological awareness and visual-verbal learning largely reflect the same underlying ability.

The robust finding that dyslexic children have impairments on a wide range of phonological processing tasks is in accordance with the results of many previous studies (see for example Vellutino, et al., 2004). These impairments are generally believed to be the consequence of one, single underlying phonological deficit (Stanovich, 1986).
**Implications of impaired phonological representations**

Evidence that all phonological processing problems of dyslexic children might be attributed to a single underlying phonological deficit, does not clarify the particular nature of this deficit. According to the Phonological Representations Hypothesis, this phonological deficit can be characterized as a deficit in the quality of the phonological representations of words in the mental lexicons of dyslexic children (e.g., Snowling, 2000). In the studies presented in the Chapters 4 and 5 specific consequences of this interpretation of a phonological deficit were examined.

From the assumption that dyslexic children have impairments in the phonological representations of words, it was hypothesized that they would also have problems in the acquisition of novel representations. Indeed, nonword learning was found to be more difficult for dyslexic children than for their normal reading peers. However, the hypothesis that the acquired representations would be less segmentalized (Metsala & Walley, 1998), especially at the phoneme level, could not be supported. The errors made by dyslexic children in the pronunciation of the novel words to be learned, concerned errors at levels of the word, ranging form the complete word, to the syllable, to errors at the level of the phoneme. Furthermore, the distribution of errors over these levels was comparable to the distribution in normal readers. Although the errors of dyslexic children were not specifically tied to the phoneme level, their larger overall amount of errors suggests that the acquisition of novel representations was more difficult, and, that these representations were, at least during acquisition, less well specified than in normal reading children.

Problems in the acquisition of novel representations do not necessarily imply that existing representations are impaired. It remains possible that these representations are well specified, but that dyslexic children only needed more exposures. As said, the Phonological Representations Hypothesis states that representations of existing words are also impaired. Several researchers have shown that the performance of dyslexic children on phonological processing tasks is related to the quality of phonological representations of familiar words (Elbro, Borstrøm, & Petersen, 1998; Foy & Mann, 2001; Griffith & Snowling, 2002; Swan & Goswami, 1997a). However, the results of the current studies do not fully support impairments in the phonological representation of existing words. First, as in previous studies (Vellutino, Bentley, & Phillips, 1978; Vellutino, Scanlon, & Bentley, 1983; compare Vellutino & Scanlon, 1989; Vellutino et al. 1995), differences between dyslexic and normal readers in visual-verbal paired associate learning with words were not consistently found. Dyslexic children performed worse than normal reading peers on the paired associate learning tasks using names as verbal stimuli (see studies in Chapters 2 and 3), whereas they performed similar to age-matched normal readers when high frequency words had to be associated with pictures (see Studies 2 and 3 in Chapter 4). Perhaps not all names were as familiar for the children as assumed and hence might have acted as nonwords. Secondly, the number of phonological errors of dyslexic children in word learning was negligible, suggesting that the representation of words with a relatively simple phonological form, is not impaired.
More importantly, a larger effect of the phonological distinctness of the sets of words on the learning performance of dyslexic children was not found. The paired associate learning performance of the dyslexic children and their normal reading peers was similarly affected by the phonological distinctness of the sets of words to be learned (see Studies 2 and 3 in Chapter 4). This finding is problematic for the idea that phonological representations are qualitatively less well specified in dyslexic children. Rather, it seems that the phonological representations of known words were of a quality that was sufficient to perform at a similar level as normal readers in this particular task.

However, some support for the Phonological Representations Hypothesis was found in the study reported in Chapter 5. That is, the results of this study suggest that the quality of the phonological representations of words might become critical in the specific context of reading. During reading acquisition associations have to be formed between phonological representations and written words. The specific context here is that, unlike the associations that had to be made in the other studies, the written and spoken forms of the words are systematically related. The written forms of words contain embedded phonological information, because the graphemes of written words are systematically connected to the sounds in spoken words. In the studies on visual-verbal paired associate learning, relationships between the visual and verbal stimuli did not exist. Perhaps of even greater importance might be the ability to make use if this enclosed phonological information in the written forms of words. As McNeil & Johnston (2004) reported, if processing of phonological information is obligatory, dyslexic children tend to perform worse than when they can rely on visual information alone.

Reading words that were orthographically and phonologically similar, that is, when the connections between the spoken and written words were most critical, appeared to be relatively problematic for dyslexic readers. Compared to normal readers, dyslexic children read the words in an indistinct context slower but more accurate than words read in a distinct context. Age-matched and younger normal readers were not affected by the orthographic context in which the words were read. However, it should be acknowledged that these findings were based on nonword reading. Learning to read nonwords not only required the formation of new phonological representations of these words, but simultaneously the formation of associations between the written and spoken forms of these words. In learning to read nonwords, the set up of the fine-grained correspondences between the graphemes in the written form of the word and the sounds in the spoken form of the word is critically dependent on the quality of the phonological representations of the new words (see also Ehri, 1998). It is possible that different results would be obtained if the children had to read known words in a context of orthographically similar or dissimilar words (i.e., words from dense and sparse neighborhoods).
Chapter 6

Conclusion

The studies reported in this thesis considered the Phonological Representations Hypothesis of dyslexia and the consequences for the formation of associations. The Phonological Representations Hypothesis concerns the quality of representations of words in the mental lexicons of children. For dyslexic children, these representations are assumed to be poorly specified. The studies presented in the previous Chapters did not unequivocally support this hypothesis. The performance of the dyslexic children on the word learning tasks and their reaction to the phonological manipulations within the sets of words to be learned, supported the phonological deficit explanation of dyslexia, rather than the more specific hypothesis that dyslexic children’s phonological representations of known words are underspecified. The hypothesis is not rejected though. Rather, the hypothesis should be reevaluated and adjusted. From the results obtained in the present studies, the visual-verbal paired associate learning difficulties of dyslexic children cannot be attributed to poorly specified phonological representations of the words. However, in a specific context, the context of learning to read new words, the quality of the phonological representations can explain the difficulties encountered in reading words in an indistinct context.