Dyslexia, Fluency, and the Brain

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Chapter • 5

Is the Reading-Rate Problem of German Dyslexic Children Caused by Slow Visual Processes?

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German children with dyslexia are interesting for questions concerned with the causation of dyslexia because they suffer mainly from a massive reading fluency problem, but less from an accuracy problem (Klicpera and Schabmann 1993; Landerl, Wimmer, and Frith 1997; Wimmer 1993; Wimmer 1996). The high reading accuracy is not astonishing because German, in contrast to English, exhibits rather regular grapheme-phoneme relations (in particular for vowel graphemes) and teaching in first grade is focused on leading children to accurate word decoding via blending. A similar manifestation of developmental dyslexia is found in other more regular orthographies such as Spanish (Rodrigo and Jimenez 1999), Italian (Zoccolotti et al., 1999), Norwegian (Lundberg and Hoien 1990) and Dutch (Yap and van der Leij 1993).

A main cognitive associate of the reading fluency impairment of German dyslexic children has been found to be a rapid naming deficit (Wimmer 1993; Wimmer, Mayringer, and Landerl 1998). In their review of the role of rapid naming deficit in reading impairments, Wolf and Bowers (1999) consider the theoretical possibility that the empirical connection between rapid naming and reading fluency deficits is caused by impedements at a low visual perceptual level. In particular, they consider the argument that, due to a dysfunctional magnocellular visual system, the processing of lower spatial frequency components will be slowed, leading to slower visual feature detection and to slower letter identifications. This, in turn, would have the consequence that associations between letters that co-occur frequently in words would not be forged easily, and this then has the consequence that a full repertoire of orthographic patterns (which contributes to reading fluency) will not accrue.

Data from a recent investigation of cognitive deficits of German children with dyslexia allow us to examine this interesting hypothesis. Our investigation included phonological tasks (short-term memory, phoneme segmentation), rapid naming tasks, and—of importance for the present hypothesis—a set of visual processing tasks. This set included purely perceptual tasks: a visual choice reaction time task and a speeded (Greek) letter identity judgment task (involving strings of two and six letters). Further tasks involved more than perceptual processes: a speeded visual continuous performance task with letter-size configurations required additional attentional control processes and a visual memory task with time-limited presentation of sequences of Greek letters required short-term memory capacity. Because the children did not know Greek letters, no phonological contributions can be assumed for the visual short-term memory task and the letter identity judgment task. If the mentioned hypothesis is valid and the problem of children with dyslexia starts with slow visual processing then we would expect poor performance of our fluency-impaired children with dyslexia on the visual tasks. In examining this prediction we followed Lovett's (1987) distinction between rate-disabled and accuracy-disabled poor readers. The expectation was that particularly the rate-disabled subgroup may exhibit slow visual processing.

METHOD

Participants

The selection of the subgroups of reading-disabled children was a two-step process. The first step was based on a classroom reading test administered in the middle of grade 3 to a large sample of about 350 children. The classroom reading test consisted of several pages of sentence lists. The content of each sentence had to be

judged as being correct or not (half of the sentences were correct). An example of an incorrect sentence is "For singing you need a pocket calculator." After each sentence a yes/no response box had to be marked. The initial sentences were short and consisted of simple words, and then sentences with longer words were included. Semantic content of the sentences were kept as simple as possible so that judging the sentence as correct or incorrect should pose no difficulty. The time limit was 10 minutes and the resulting measure was correctly marked sentences within this time limit. As expected, very few errors occurred so that the score reflects solely reading rate. A practice page was used to clarify the task and the response requirements. Children were selected for further testing, when they scored below percentile 20 on the classroom reading test, but did not score below percentile 20 on a classroom arithmetics test and did not exhibit a nonverbal IQ of below 90 on Raven's Coloured Progressive Matrices. Twenty-three children fulfilled the mentioned criteria and participated in an extended assessment of reading and cognitive deficits in our department.

The subtyping into a rate-disabled and an accuracy-disabled group was based on their reading-aloud performance on the word and non-word reading subtests (two each) of an individually administered reading test (Salzburg Reading and Spelling Test, Landerl, Wimmer, and Moser 1997). We selected as rate-disabled, 10 children (9 boys) from the 23 slow readers (identified by the classroom reading test), who exhibited the slowest reading times on the individual word reading subtests, but exhibited non-word reading accuracy in the normal range (percentile 30 and higher). Their mean reading rate for words (combined for the two subtests) corresponded to a percentile rank of 12. As accuracy-disabled, we selected 10 children (8 boys) from the slow reader group (classroom test based), who exhibited the lowest accuracy scores for non-word reading among the children of the slow reader group (i.e, error rates of 22% and higher). Errors for non-words were used as criterion, because very few errors occurred for word reading. In correspondence with their slow reading on the classroom reading test, the accuracy-disabled children also showed slow reading on the individual word reading subtest, although not as slow as the rate-disabled group. Their mean reading rate for words corresponded to a percentile rank of 20 (compared to a percentile of 12 for the rate-disabled group). Because of the slow reading of the accuracy-disabled children (both on the classroom test and also on the individual word reading subtests) we refer to them as rate-accuracy-disabled in the following. Both the rate-disabled and the rate-accuracy-disabled children were poor orthographic spellers, but the large majority of the orthographically wrong spellings were phonetically acceptable. An example of such a orthographically wrong, but phonetically acceptable spelling is Medchen instead of Mädchen. The means for orthographically correct spellings corresponded to percentiles of 24 and 14 for the rate-disabled and the rate-accuracy-disabled subgroup, respectively. The 26 control children (12 boys) scored above percentile 30 on the classroom reading test and often were class-mates of one of the reading-disabled children. Their reading rate for individual word reading corresponded to a percentile of 62 and their orthographic spelling performance to a percentile of 50.

Tasks

Visual Choice Reaction Time Children had to press, as quickly as possible, the left or right button of a response box (operated with the left and right index fingers), after a left or right pointed black arrow (about 5 cm long) appeared on the computer screen. The arrow stayed on the screen until the child had responded. One second after the response, the next stimulus was presented. Children were introduced to the task by seven training trials and encouraged to respond quickly and accurately. Then 20 test trials (half right, half left oriented arrows in unpredictable sequence) followed. Correctness of response and time between onset of the visual stimulus and response were recorded automatically. The slowest reaction times (higher than 1510 milliseconds, 1% of all reaction times) were excluded to avoid distortions of individual means. Despite these exclusions, each child had reaction times for at least 80% of the trials. For each child and each hand an average reaction time was computed for correct responses. Errors were very infrequent.

Letter Identity Judgments On this task children had to judge the identity of Greek letters that appeared in sequences of two or six letters on the screen. The size of the letters was 2 cm. For both lengths there were six identical and six non-identical sequences. In the non-identical six letter sequences, only one letter differed from the rest, and this deviating one never appeared in initial or final position. The child was instructed to press the left button (marked with =) of the response box for identical letters and the right button (marked with ≠) for non-identical sequences. Correctness of response and time between stimulus onset and response were automatically recorded. Response errors were infrequent. Separate for the two- and the six-letter sequences, the highest response times (1%) were excluded.

Continuous Visual Performance This was a paper-and-pencil task designed to measure attentional performance in addition to visual perception. Children were presented a page with nine lines, each line consisting of 47 Smiley and Frowney faces. The faces were circles of only 3 mm (!) diameter with two dots as eyes and with a mouth that either was upward bent for the Smiley or downward for the Frowney. The child's task was to cross out quickly the Smileys with two additional marks. The two marks could be a double quotation mark above or below the Smiley or two single quotation marks (one above, one below the Smiley). The distractors most similar to the targets were Smileys with only one mark and Frowneys with two marks. On each of the nine lines (47 faces), the child worked for 20 seconds. Because errors were less than 4% for each group, we used an item per minute score.

Visual Short-Term Memory For the assessment of visual short-term memory, children watched the sequential build-up of a horizontal sequence of Greek letters in a presentation box in the upper section of the computer screen and had then to reproduce the sequence from memory by touching the letters in the response box in the lower section of the screen. This response mode was realized using a touch-screen. The letters of a sequence appeared from left to right, the first letter was presented for one second before the second letter was added and so on. After the letters had disappeared from the presentation box, they re-appeared simultaneously in changed order vertically arranged in the response box. The instruction to the child was to move the letters from the response box to the stimulus box by touching them in correct order. The letter touched first appeared in the first position of the stimulus box and so on. After the child has filled all positions of the stimulus box, the correct sequence appeared above the box to give feedback. Children were introduced to the task by four practice trials. Then sequences (5 items each) consisting of three, four, and five different letters were presented. Percentage of correctly reproduced sequences was used as measure.

Rapid Naming Here we used the standard digit naming task with randomized sequences of five digits repeated ten times on a page. The two other naming tasks were of the same format, one used five one-syllable animal words (*Hund*-dog , *Fisch*-fish, *Frosch*-frog, *Pferd*-horse, *Kuh*-cow), the other used five three-syllable animal names (*Schmetterling*-butterfly, *Papagei*-parrot, *Schildkröte*-tortoise, *Krokodil*, *Elefant*). Each of the two animal naming tasks was preceded by two introductory trials. On the first trial we made sure that each child knew the names of the depicted animals, and on the second trial, consisting of three lines with three animals each, children were familiarized with the rapid naming demand. Because naming errors rarely occurred, words per minute was used as measure.

Phonological Short-Term Memory For this assessment children had to repeat sequences of mono-syllabic pseudowords. The length of the sequences ranged from two pseudowords to four pseudowords (e.g., /rip/, /ʃo:f/, /kut/). For each length level eight items were presented. The pseudowords were pronounced by a male speaker and digitalized using sound software. Presentation was done through high-quality head-phones. All items were composed of 20 different pseudowords (all of CVC structure). The individual pseudowords were initially singly presented to check for perception or articulation problems. Afterwards items were presented blockwise with increasing sequence length. Each block was preceded by a familiarization trial. As measure for the present analysis we used the number of correctly repeated sequences combined over the three sequence lengths.

Phoneme Segmentation Children were presented nine complex 2-syllable non-words, which started and ended with a consonant cluster (e.g., *blowisk, flamont*). Children were required to first repeat each word—to guarantee correct perception—and then had to name each of the phonemes. The instruction stressed naming of sounds instead of naming letters, but letter names were also accepted as correct responses. Because the clusters were the most difficult parts to segment, only segmentation of the onset clusters and the offset clusters (9 each) were evaluated. Two practice items familiarized the children with the task.

Results and Discussion

Table 1 shows the cognitive profiles of the two reading-disability subgroups in relation to the non-disabled control children. The indexes above the means refer to the results of test comparisons between groups. For example, the indexes 2 and 3 above the mean digit naming score of the non-disabled group (in the first data column) indicates that the mean of the rate-disabled group (referred to with 2 because of being located in the second data column) and of the rate-accuracy-disabled group (referred to with 3) are reliably lower than that of the non-disabled group. For testing the differences between the non-disabled readers and each disability subgroup we used one-sided 5% Alpha levels, because there is no theoretical reason or previous empirical result to suggest that a disability group should perform better (!) than the non-disabled group. However, for testing the differences between the two disability groups two-sided 5% Alpha levels were used.

Table 1 Cognitive Profiles of Rate-Disabled and Rate-Accuracy-Disabled Children

Measure	Non-disabled $n = 26$ M (SD)	Rate-disabled $n = 10$ M (SD)	Rate-accuracy-disabled $n = 10$ M (SD)
Visual deficits			
Choice reaction (ms)	507 (102)	487 (79)	510 (69)
Letter (Greek) identity (ms)			
2 identical	887 (182)	902 (217)	926 (154)
2 non-identical	951 (155)	963 (119)	985 (154)
6 identical	899 (161)	920 (172)	924 (105)
6 non-identical	994 (197)	1027 (152)	994 (135)
Continuous performance (items/min)	53 (7)	54 (11)	56 (8)
Visual memory (% correct)	53 (19)	50 (13)	48 (16)
Rapid naming (words/min)			
Digits	127 (16)^{2,3}	96 (18)	97 (23)
Animals (1-syllable words)	63 (13)^{2}	53 (8)	58 (14)
Animals (3-syllable words)	51 (9)^{2}	43 (7)	45 (13)
Phonological deficits			
Short-term memory (% correct)	58 (14)^{3}	55 (12)	45 (17)
Segmentation (% correct)			
Onset clusters	89 (15)	94 (6)	80 (30)
Offset clusters	83 (14)^{3}	88 (14)^{3}	63 (22)

^{2}Significant difference ($p < .05$) of rate-disabled children.
^{3}Significant difference ($p < .05$) of rate-accuracy-disabled children.

From the means in table 1, a rather simple pattern of results is evident. The first main finding is that performance on the full set of visual processing task was essentially unimpaired for both subgroups. This is particularly remarkable for the rate-disabled subgroup. For the visual choice reaction task and for the four conditions of the letter identity task, the mean latencies of the rate-disabled group were maximally 33 milliseconds longer (in the case of six non-identical letter strings) than the means of the non-disabled group. These small non-reliable group differences have to be evaluated in relation to the large *SDs* for each group. There also were no deficits of the reading-disability subgroups, when attentional demands (continuous performance) or when short-term memory demands (visual memory) were added to visual perceptual processes. Actually, on the continuous performance task the two reading-disability subgroups tended to perform faster than the non-disabled group.

The uniformly good performance of the two reading disability subgroups on the visual processing tasks stands in contrast to the performance on the rapid naming tasks. The rate-disabled group on all three tasks performed reliably lower than the non-disabled group and the rate-accuracy-disabled group did so on the digit-naming task. On the digit-naming task, which to a higher extent than the other two tasks assesses *automatized* naming, the deficit of the two reading-disability subgroups was large. For example, the mean of the rate-disabled group was about two SDs below the mean of the non-disabled group. On the phonological processing tasks, the pattern of deficits was quite different from that of the rapid naming tasks. Phonological short-term memory and segmentation of offset clusters (at the end of two-syllable pseudowords) was impaired only for the rate-accuracy-disabled subgroup, but not at all for the rate-disabled subgroup. Actually, the latter subgroup tended to show better segmentation performance than the non-disabled group.

In summary, the results on the rapid naming and the phonological tasks are in correspondence with our previous findings that German children with dyslexia, as a group, show a marked rapid naming deficit, but a minor difficulty with phoneme segmentation (Wimmer 1993; Wimmer et al. 1998). The subgrouping here showed that the phonological segmentation problem was limited to the rate-accuracy-disabled group, whereas the rapid-naming problem was characteristic for both subgroups. The main new finding was that both subgroups exhibited unimpaired performance on the visual processing tasks. This is particularly astonishing for the children of the rate-disabled subgroup, who exhibited very good phonological segmentation skills. For this subgroup a visual processing speed impairment would have been the perfect candidate to explain both the reading fluency problem and the rapid naming problem. More generally, the present findings speak against the possibility that a reading fluency impairment can be traced back (via poor orthographic lexicon, impaired formation of inter-letter associations, and slow letter identification) to a dysfunctional magnocellular visual system.

Our own theorizing assumes that poor visual orthographic memory build-up (underlying the fluency impairment of German children with dyslexia) is due to impaired association formation

between segments of phonological word form and letters of the written word. For this associative process to occur, the phonological word representations must be segmented so that individual letters can be associated with their corresponding phonemes. This may not be a problem for our rate-disabled subgroup with close to perfect recoding accuracy. Another critical condition is that there is time overlap between activation of the phonological word representation (and the embedded phonemes) and activation of the letter recognition units. If phonological word representations are accessed too slowly from the brain areas responsible for visual letter string processing, then the visual areas may no longer be active and little association formation may occur. This speed impairment in getting from visual representations to phonological representation may be tapped by rapid naming tests. A further problem may be the long-term stability of neural visual-phonological associations underlying orthographic word representations. If such associations are only short-lived or may need many more learning-trials to become stable, then the orthographic lexicon must be impoverished. In other words, the build-up of visual-orthographic word representations may be impaired because of impaired association formation between visual and phonological representations and not because of purely visual processing impairments.

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