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Developmental dyslexia in a regular orthography: A single case study

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This study of an adult case examined in detail with eye movement measures the reading speed problem which is characteristic for developmental dyslexia in regular orthographies. A dramatic length effect was found for low frequency words and for pseudowords, but not for high frequency words. However, even for high frequency words it was found that reading times were substantially prolonged although number of fixations did not differ. A neurocognitive assessment revealed no visual deficits (parallel processing, precedence detection, coherent motion detection) but speed impairments for certain verbal and phonological processes. We propose that the reading difficulties are phonological in nature, but these difficulties become manifest as inefficiency and not as inability.

Introduction

The subject of our case report is Thomas, a German-speaking young man, who presented himself as suffering from embarrassingly slow reading and from poor spelling, and who had experienced reading and spelling difficulties throughout his school career. As there is no report of an adult case of developmental dyslexia in German, we explored in detail the reading difficulties of this case. For interpreting these difficulties, a closer look at German orthography may be useful. German shares several features with English, as is evident from similar words such as *Hand-hand*, *Haus-house* or *Schuh-shoe*, but exhibits higher grapheme-phoneme regularity and this is particularly the case for vowel graphemes. To illustrate, the /*a*/ in *Ball*, *Garten*, and *backen* receives the same pronunciation, but it does not in *ball*, *garden* and *bake*. As is the case for many alphabetic orthographies, the regularity of German is higher in the reading than in the writing direction. Therefore, when relying on systematic grapheme-phoneme coding in reading, there should be few misreadings, whereas when relying on phoneme-grapheme coding in writing, there should be many of misspellings.

The high regularity in the reading direction associated with instructional emphasis on phonological recoding may be responsible for the infrequent reading errors among young German readers. This difference from English was found in direct comparisons of normally advancing young German and English readers (e.g., Frith *et al*., 1998) and of German and English dyslexic children (Landerl *et al*., 1997; Ziegler *et al*., 2003). In regular orthographies the main dyslexic problem is to become fast and fluent (e.g., German: Wimmer, 1993; Spanish: Jimenez & Hernandez, 2000; French: Sprenger-Charolles *et al*., 2000; Italian: Tressoldi *et al*., 2001; Dutch: De Jong, 2003). The characteristic reading fluency deficit is not limited to existing words but was also found in aggravated form for pseudowords (e.g., Wimmer, 1996), which precludes a straightforward interpretation of the fluency deficit in terms of a failure to store or use visual orthographic recognition units. Therefore, the fluency deficit may reflect a slowed access to phonology ranging from whole-word phonology to small phonological segments. The term “phonological speed dyslexia” was introduced (Wimmer, 1993) to mark the difference to “phonological dyslexia” which, in the English context, refers to decoding errors for new words and pseudowords.

The present case study had two main goals. The first one was to examine in detail the massive and persistent reading speed problem of an adult case. We know of no single case study which studied this typical manifestation of developmental dyslexia in regular orthographies. For a detailed characterization of the speed problem the reading material was varied in length (short vs. long words) and in familiarity (high and low frequency words and pseudowords). If the speed problem is primarily due to reduced visual familiarity of existing words (due to missing visual-orthographic recognition units), then one would expect that the speed deficit should be reduced for pseudowords which must be unfamiliar not only for Thomas but also for normally reading controls. Alternatively, if the speed problem extends to pseudowords, then the efficiency of grapho-phonological recoding processes and of pronunciation assembly process are also affected. In this case one can reason that inefficient phonological reading

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may, in fact, constitute the developmental root of the reading speed problem by limiting the possibility of orthographic learning, that is, the storage of a visual-orthographic representation after successful phonological recoding (Share, 1995). In addition to the usual single item presentation with measurement of reading onset time, we used eye movement recording where the items were presented in several lines on the screen. The eye movement recording is of particular interest as here the speed problem may not only become manifest in the expected long fixation durations, but also in an increased number of fixations, which is a direct reflection of reliance on serial decoding.

The second goal was to examine visual and verbal phonological deficits which may be at the root of the reading speed problem. Our initial hypothesis was that extremely slow reading may be due to a visual perceptual dysfunction. An assessment of such dysfunctions included simultaneous multi-element processing, precedence detection and coherent motion detection. A deficit in multi-element processing may have the effect that the letters of a string (independent of word frequency or lexical status of the string) have to be processed one by one as in acquired cases of letter-by-letter reading. For such acquired cases a deficit in simultaneous multi-element processing was indeed found (e.g., Behrmann *et al*., 2001). Furthermore, studies with dyslexic children found evidence for multi-element processing deficit in subgroups of dyslexic readers (Enns *et al*., 1995; Bosse & Valdois, 2003; Hawelka & Wimmer, 2005). Two further tasks examined even more basic visual perceptual deficits. On the visual precedence detection task one has to decide which of two elements had appeared first. This task revealed sluggish deployment of visual attention in a group of Finnish dyslexic adults (Hari *et al*., 2001). We also administered the visual coherent motion detection task which was introduced to measure a magnocellular deficit in dyslexic persons (reviewed by Stein, 2001). A magnocellular dysfunction may affect binocular fixation after saccades or may affect the encoding of letter position (Cornelissen *et al*., 1998).

To examine the alternative interpretation of the reading fluency problem of our case in terms of “phonological speed dyslexia” (Wimmer, 1993), we assessed the speed of verbal phonological processes. For assessing rapid “automatized” naming (RAN) we used tasks introduced by Denekla and Rudel (1976). For assessing the speed of purely phonological processes we used a word fluency task and contrasted fluency in response to a semantic and a phonemic cue. The speed of phonological manipulation processes was examined by measuring the time for phoneme deletion (“Say bread without /b/”).

Case report

At the time of the present assessment Thomas was 30 years old and introduced himself as suffering from impaired reading speed and poor spelling. While attending evening school to attain a degree for university entrance, he also attended university as an auditor of political science classes. Thomas worked as a freelancer in the IT sector. He reported a history of reading and spelling difficulties throughout his school career starting from first grade. Several teachers suggested dyslexia, but he received neither a formal diagnosis nor remediation. His school career included 10 years of obligatory schooling and 3 additional years in a preparatory school for lower positions in business administration. This was followed by job training as a business assistant followed by employment in the family business. He served in the military as a sailor on a sailing school ship.

Thomas’s reading performance was assessed on two different occasions with two parallel versions of a standardized reading speed test which is under development in our laboratory and for which norm data are in the process of being collected. This test presents a list of sentences for one minute with the instruction to mark each sentence as quickly as possible as correct or incorrect. The sentences are of simple content, and complex words of foreign origin are excluded. On the two assessments, Thomas did not commit a single error, but processed only 12 and 13 sentences, respectively, compared to a mean of 21.7 (SD = 5.1) of the standardization sample. This performance corresponds to percentiles below 3. On a standard spelling test (Jäger, 1968) his score corresponded to a percentile below 1.

Thomas was tested with the German version of the Wechsler Adult Intelligence Scale-Revised (WAIS-R) and obtained a full scale IQ of 116 (Verbal IQ: 101, Performance IQ: 124). Subtest scores were in the average range for Information (10), Vocabulary (12), Arithmetic (10), and Block design (12), and in the superior range for Comprehension (13), Similarities (13), Picture completion (17), Picture arrangement (16) and Object assembly (15). Below average performance was limited to Digit Symbol (7) and Digit Span (6). The low performance on the latter is suggestive of poor phonological short term memory. In face-to-face communication his spoken language appeared completely normal. Actually, Thomas is a communicative person and a fast and fluent speaker. Handedness was assessed by having Thomas demonstrate 9 activities (e.g., dice casting, teeth brushing), which all were performed with the right hand.

Control groups

The performance of Thomas on the reading assessing (both eye recording session and single item reading) was compared to that of an age-level control group of 13 participants (4 male and 9 female) with a mean age of 26.7 years (range 21 to 38) who all were university students with normal reading performance. Inspection of the scores gave no indication of a substantial female advantage. A second age-level control group of 10 non-impaired male readers (age range 25–35 years) was used for the extensive cognitive assessment. A reading-level control group was considered problematic and was not used. We estimated that the reading speed of our case for pseudowords (where Thomas has neither an vocabulary advantage nor an advantage of visual word familiarity) would correspond to the speed of 8-10-year-olds. It appeared uninformative to compare the performance of 8-10-year-old children on demanding visual and verbal tasks with that of an intelligent young adult.

Reading

Both the list reading procedure used for eye movement recording and the single item reading task used for response latency measurement used the same reading material, that is, 40 high frequency words, 40 low frequency words, and 40 pseudowords and within each category half of the items were short (one-syllable, about 4 letters) and the other half were long (three-syllables, about 8 letters). For high frequency words, typical short items are *Brot* (bread), *gut* (good) and *Geld* (money), typical long items are *Politik* (politics), *Ergebnis* (result) and *zusammen* (together). For low frequency words, short items are *Aas* (carcass), *Psalm*, and *Milz* (spleen), long items are *Dekanat* (dean's office), *Novize* (novice), and *Kondensat* (condensate). The mean occurrence of the high frequency words was around 200, that of the low frequency words about 1 per million according to the CELEX database (Baayen *et al*., 1993). The short pseudowords were constructed by exchanging the consonantal onsets between the short words. Examples of resulting pseudowords are *Zot*, *Krut*, and *Nahl*. The long pseudowords were constructed by exchanging the syllables of the long words. Examples are *Verlibot*, *Powintik*, and *bebine*.

The silent reading task used for eye movement recording presented the 120 items on 6 screens (each consisting of 5–6 lines). The 4 screens with word items were presented separately from the 2 screens with pseudowords. Both reading tasks were introduced with a short familiarization trial, and the instruction was to read through the lines on the screen in a way similar to one's normal reading habit. The size of a single letter was 10 mm for upper case letters and 7 mm for lower case letters. From a viewing distance of 120 cm, this corresponds to a visual angle of maximally 0.5 degrees. The width was approximately 2 cm for the shortest and 6 cm for the longest items corresponding to 0.9 and 2.8 degrees of visual angle, respectively. Items were presented in yellow on black background on a Belinea 21 inch CRT-monitor connected to a Pentium II Windows computer. Eye movements were recorded every 20 ms from the left eye in a natural binocular viewing situation with an ISCAN (Model RK-464) video-based eye tracking system. The initial calibration of the system took about 5 minutes.

The reading aloud task presented each item separately on the screen and the latency of the response was measured by a voice key. The readings were recorded for later error analysis. For the reading aloud task, the order of all 120 items varied randomly and the instruction was to pronounce each item as quickly as possible but to avoid errors. The reading aloud task was administered about 3 months after the silent list reading task.

Reading errors

Corresponding to the errorless performance on the standardized sentence reading test, Thomas read the singly presented words rather accurately and the few errors may have resulted from responding too quickly. Only 2 of the 40 high frequency words (*Glas* for *Gas*, *verhalten* for *erhalten*) and 3 of the 40 low frequency words led to misreadings (*Kranz* for *Kauz*, *einzig* for *einzeilig* and *reflektiv* for *reflexiv*). All these errors were existing words. The reading of the 40 pseudowords was also quite accurate as only 7 misreadings occurred. Only two of these were lexicalisations (e.g., *Gurt* for *Grut*). All misreadings of the pseudowords were close to the target, and the majority resulted from adding a phoneme (e.g., *Angladers* for *Angaders*, *Powlintik* for *Powintik*) and obviously could not result from an error of grapheme-phoneme recoding but appeared to result from an error in assembling the pronunciation.

Eye movements and response latency

The first and the second section of Figure 1 show how item length within each familiarity category affected eye movements during silent list reading. The third section shows the effect of item length on response latency in the single item reading aloud task. Eye movement measures are number of fixations per item and total inspection time per item. In both measures the extremely infrequent refixations of an item were included. Total inspection time per item is derived by adding the durations of all fixations falling on an item. The final measure in Figure 1 is response latency per item obtained in the single item reading aloud task. For inspection time and reading onset time (but not for number of fixations) we excluded scores which were 2 SDs above or below the individual mean for the 20 items of each category. In no case did we have to exclude more than two items per category. Reading onset times for the few incorrectly read items were not excluded as the misreadings were close to target.

Length effect

From Figure 1 it is obvious that for low frequency words and pseudowords the increase of length had a dramatic effect for Thomas but not for controls. In contrast, for high frequency words the length effect was similar for Thomas and controls. The length effect was examined for each item category separately by an item-based ANOVA, that is, each item received a score for Thomas and for controls (i.e., the mean of the controls). Infrequently, an item did not receive a score for Thomas either because the item did not receive a fixation or no

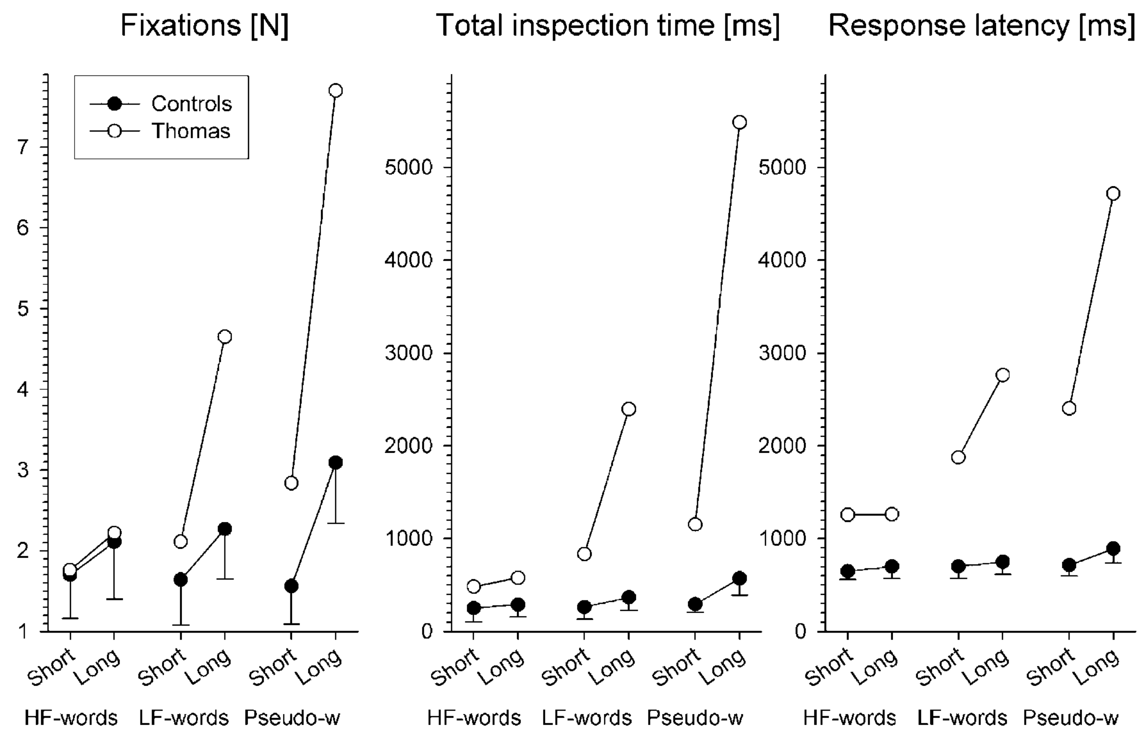

Fig. 1. Number of fixations, total inspection time and latency for short and long high frequency- (HF-), low frequency- (LF-) and pseudowords for controls (means and standard deviations) and for Thomas.

voice onset time was registered in the reading aloud task. Therefore, the degree of freedom in the error terms varied slightly. Both reading ability (Thomas vs. controls) and item length (short vs. long) were used as fixed factors. In none of the three ANOVAs for high frequency words was the length by ability interaction reliable, $Fs < 1$. The long high frequency words led to an increase in number of fixation, $F(1, 71) = 4.09$, $p < .05$, for both Thomas and controls. In contrast, they did not lead to prolonged inspection time or longer response latency, $Fs < 1$, either for Thomas or controls. Figure 1 further shows that for number of fixations there was no difference at all between Thomas and controls, $F < 1$, but there was a difference for the two other measures with Thomas exhibiting prolonged inspection time and prolonged response latency, $F(1, 71) = 13.94$ and $F(1, 73) = 19.01$, $ps < .001$, respectively. Figure 1 shows that for low frequency words—different from the findings for high frequency words—Thomas reading performance was more affected by increasing item length than that of the controls. The length by ability interaction was reliable for fixations and total inspection time, $Fs(1, 71) = 10.34$ and 5.86, $ps < .02$, and of borderline reliability for response latency, $F(1, 74) = 3.68$, $p = .06$. The difference between Thomas and controls was highly reliable for each measure, all $Fs > 18.63$, $p < .001$, but obviously resulted more from the long than the short items, particularly so in the case of the eye movement measures. Thomas also exhibited a dramatic length effect for pseudoword reading whereas controls exhibited a small effect. For all three pseudoword reading measures the length by ability interaction was reliable, $Fs(1, 73–75) > 9.96$, $ps < .002$.

Frequency effect

Combined over short and long items, the difference between Thomas and controls was larger for low frequency words than for high frequency words as evident from reliable frequency by ability interactions for all three measures, $Fs(1, 145–147) > 10.88$, $ps < .001$. For example, for low frequency words Thomas exhibited 3.4 fixations and controls exhibited only 2.0. In contrast, for high frequency words the means were close to identical with 2.0 and 1.9, respectively. As evident from Figure 1, the stronger word frequency effect for Thomas than controls was carried more by the long items than by the short items within each frequency category.

Lexicality effect

Figure 1 also shows that Thomas's reading difficulty was not limited to existing words. Actually, the opposite is the case. The difference between Thomas and controls was larger for pseudowords than for high frequency words or for low frequency words. For a conservative evaluation of a differential lexicality effect we contrasted pseudowords with low frequency words and found the lexicality by ability interaction to be reliable for each measure, $Fs(1, 147–149) > 6.54$, *ps* < .05. Evidently, the lexicality by ability interaction was carried more by the long than by the short items.

Cognitive assessment

Visual Processing

The stimuli for the three visual tasks were presented on a 17 inch CRT-Monitor (refresh rate: 100 Hz) in a dimly lit room. Participants sat at a distance of 75 cm in front of the monitor. A detailed description of the multi-element processing task and the precedence detection task is given in Hawelka and Wimmer (2005) and may be obtained from the last author. For a detailed description of the coherent motion detection task see Hansen *et al*. (2001).

Multi-element processing

This task examined a perceptual deficit in the simultaneous processing of multiple visual forms as presented by the letters of a word. Arrays consisting of digits were briefly presented and participants had to report one of the digits in response to a position cue. The cue appeared immediately after array presentation to rule out a memory problem. As the cue was presented together with a mask, processing of an iconic representation after array presentation was precluded. Digits instead of letters were chosen to avoid the possibility that an impaired performance by Thomas may simply reflect less experience with the stimulus material. The arrays consisted of 2, 4, and 6 digits and were presented block-wise in this order. The first array of each length was presented for 200 ms. Presentation time was reduced by 30 ms during the first 5 trials (and by 10 ms thereafter) after a correct response and increased by 10 ms after an incorrect response. The presentation time threshold for each length level was based on trials which led to a change in the direction of presentation time. After 12 such reversal points the geometric mean of the presentation times of the final 8 reversal points was taken as threshold for a length level.

Precedence detection

Here the task was simply to register which of two horizontal bars had appeared first on the screen. It was introduced by Hari *et al*. (2001) to examine sluggish visual attention in dyslexic readers. A trial started with a 1000 ms fixation cross, followed by two white bars (1.5 degree in width, 0.3 degree in height) on dark background. The bars appeared horizontally to the left and to the right of the fixation cross. Randomly, one of the bars appeared first. Participants had to respond with the left or right forefinger. For determining the threshold of the inter-stimulus interval, the same adaptive staircase procedure as in the string processing task was used.

Coherent motion detection

This task developed by Hansen *et al*. (2001) presents two panels of 300 randomly arranged white dots on a black background. On each trial (2300 ms duration) the dots of one panel moved randomly, whereas on the other panel a certain proportion of the dots moved in the same direction. Participants had to point to the panel with the coherently moving dots. The presentation started with 75% of the dots moving coherently and this percentage was reduced or increased depending on correctness of the response. A run of this task ended after 10 reversals and the threshold was calculated as the geometric mean of the coherence levels of the final eight reversals. The thresholds of two runs of the task were averaged.

Rapid naming of sequences of visual stimuli

Two rapid naming tasks—corresponding to the original RAN tasks of Denckla and Rudel (1976)—presented 50 visual stimuli (5 pictured animals, presented in different order on each of the 10 lines of a single page). In one task the words consisted of one syllable (Pferd, Hund, Kuh, Fisch, Frosch—horse, dog, cow, fish, frog) and in the other of three syllables (Schildkröte, Papagei, Elefant, Schmetterling, Krokodil—turtle, parrot, elephant, butterfly, crocodile). Each task was preceded by a practice trial with three lines on the page. In addition, two number reading tasks were used for rapid naming. Here each page presented 18 three-digit numbers. One task presented only hundreds and tens, for which the digit order corresponds to the naming order (e.g., 240 → zweihundertvierzig—two hundred forty). The other presented units in addition to hundreds and tens (e.g., 241 → zweihunderteinundvierzig—direct translation: two hundred one and forty). In the latter, the order of naming differs from the order of the digits.

Verbal phonological processing speed

Phonemic vs. semantic word retrieval fluency

In the phonemic condition words beginning with /m/ had to be generated, whereas in the semantic version names of animals had to be generated. The score was the number of correct words within one minute.

Phoneme deletion

This task (5 practice-, 18 test-items) required the deletion of a specified phoneme from the beginning, the middle or the end of the word. The test format was “Say blood without /b/” and the time between the end of item presentation and the end of the response was measured.

Results

Table 1 presents first the mean and standard deviation of the controls, followed by Thomas scores. In the final column, Thomas’s performance is converted into standard scores which are pooled in such a way that a negative value indicates poorer performance.

The results in Table 1 show a simple pattern. On all visual measures there was no deviation from the controls. On the rapid naming tasks the deficit differed. Thomas performed below average but within the range of the controls on the two animal picture naming tasks. In contrast, he was substantially impaired on the two number reading tasks. On the fluency task he produced fewer words than controls in response to the phonemic, but not to the semantic cue. On the speeded phoneme deletion task he was correct on the large majority of the 18 items, but he was extremely slow as evident from a response latency of about 5 seconds per item.

Discussion

Reading impairments

The reading problem of the present adult case corresponds to the pattern—few misreadings, impaired reading speed—which was described in the Introduction as characteristic of dyslexic children in regular orthographies. Actually, the reading speed problem of the present case appeared dramatic compared to the data from dyslexic children. The detailed examination of the reading speed deficit of our case provided several findings. The first one was the longer inspection time for high frequency words in the eye movement assessment and, correspondingly, the delayed response onset in the single item reading aloud assessment. These speed deficits are particularly remarkable for high frequency words, Thomas, similar to controls, exhibited no length effect on inspection time and reading latency, and he did not differ from controls in the number of fixations. The absence of a length effect and the absence of a difference in fixations suggests that for high frequency words Thomas, similar to controls, relied on direct access to whole-word phonology. Nevertheless, this access was speed impaired as evident from the prolonged inspection times for silent reading and the prolonged latencies for reading aloud single items. Consistent with this interpretation of speed impaired access to whole word phonology is Thomas's poor performance on the rapid naming of sequences of digits representing number words. Of importance is the finding that the speed deficit for high frequency words was not limited to response onset time but was also present in the silent reading task used in the eye movement assessment. This finding

Table 1. Means, standard deviations and z-scores for rapid naming and for phonological and visual measures.

	Control group[a]		Thomas	
	M	*SD*	*M*	*z-score*
Visual measures				
Multi-element processing threshold [ms]				
2-digit arrays	20	8	17	0.4
4-digit arrays	52	42	28	0.6
6-digit arrays	109	92	78	0.3
Precedence detection thresholds [ms]				
Right hemifield	19	14	23	-0.3
Left hemifield	21	14	17	0.3
Coherent motion detection threshold [%]	9.6	4.4	7.8	0.4
Rapid automatized Naming				
Object naming [items/min.]				
1-syllable	108	15	88	-1.3
3-syllables	82	15	71	-0.7
Number naming [items/min.]				
Consistent	93	7.7	54	-5.1
Inconsistent	72	6.4	43	-4.5
Phonological measures				
Verbal fluency [words in 1 min.]				
Semantic cue	31.1	5.7	33	0.3
Phonemic cue	21.3	4.0	12	-2.3
Phoneme deletion				
Errors [*N*]	0.2	0.4	4	-9.5
Time per item [sec.]	1.1	0.2	5.6	-22.0

Note. [a]$n = 10$.

argues against slow articulation and, therefore, strengthens the interpretation that Thomas suffered from slow access to whole-word phonology.

The second main finding was that Thomas exhibited a truly dramatic effect of item length on the eye movement measures and on response latency when confronted with low frequency words and pseudowords. This dramatic length effect indicates slow serial grapheme-phoneme recoding and slow pronunciation assembly. For interpretation of the length effect for low frequency words it is of importance that Thomas exhibited no length effect for high frequency words. Apparently for low frequency words, different from high frequency words and different from nonimpaired readers, Thomas may have lacked visual orthographic word recognition units. Furthermore, it cannot be ruled out that some of the low frequency words were absent from his spoken word lexicon. However, we note that on the vocabulary subtest of the WAIS-R he scored above average. A length effect similar to that for low frequency words was also observed for pseudowords. For pseudowords the length effect cannot be attributed to missing visual-orthographic word recognition units. Therefore, the difference from nonimpaired readers may lie in an extremely inefficient phonological reading route. One may reason that Thomas was limited to serial grapheme-phoneme conversion when controls converted several graphemes in parallel. Another possibility is a failure of on-line activation of larger phonological segments, in particular, of syllables. Frost (1998) discusses various aspects of phonological inefficiency. A limitation to slow serial decoding was also observed by Ziegler *et al*. (2003) for 11-year-old dyslexic children. These children exhibited an increase of reading latency of about 300 ms per additional letter for monosyllabic words and for pseudowords whereas nonimpaired controls exhibited nearly no increase in latency. Eye movement studies with Italian and German dyslexic children similarly documented the length effect on number of fixations (DeLuca *et al*., 1999, Hutzler & Wimmer, 2004).

The present adult developmental dyslexia case—similar to group data from dyslexic children in regular orthographies—produced few misreadings of low frequency words and of pseudowords. This differs from reports on acquired dyslexia in other regular orthographies. For example, the Spanish case reported by Cuetos, Valle-Arroyo, and Suárez (1996) misread the majority of pseudowords, with most of the errors being pseudowords. As this case knew all relevant grapheme-phoneme relations, Cuetos and colleagues (1996) concluded that the phonological route impairment was located in the assembly process. One could reason that there is a continuum of difficulties with the assembly process. Our developmental case (a young adult) was able to accomplish assembly by an enormous time investment. This may not have been possible for the elderly Spanish man after a cardiovascular accident. Also of interest is that our case only seldom produced a word when confronted with a pseudoword. Such misreadings were aptly termed “lexical capture” by Funnell and Daivons (1989) and were frequent for an Italian acquired case (Bisiacchi *et al*., 1989) and a Japanese case (Sasanuma *et al*., 1996).

Neurocognitive dysfunctions

The hypothesis that Thomas’s slow reading may to some extent be due to visual dysfunctions found no support. As mentioned in the Introduction, such visual deficits were found in group studies with dyslexic children or dyslexic adults and obviously, when present, may lead or contribute to reading speed problems. Of immediate importance is that Thomas exhibited no deficit on the simultaneous multi-element processing task. This rules out that the serial letter processing in the case of the low frequency words and the pseudowords is due to a general problem with the simultaneous processing of several visual objects. Thomas also did not differ from controls on the precedence detection task which measures sluggish visual attention. Furthermore, no magnocellular deficit was found for coherent motion detection. Such a deficit may affect binocular fixation after saccades or the encoding of letter position. These negative findings suggest that in the present case the reading speed problem does not result from visual dysfunctions affecting the processing of the letter string.

Consistent with the phonological deficit explanation of dyslexia (e.g., Snowling, 2000) and specifically consistent with “phonological speed dyslexia” (Wimmer, 1993), Thomas performed slowly on verbal phonological tasks. His performance was markedly impaired on the digit versions of the rapid “automatized” naming test, but less so on the object pictures versions of this test and among the latter the difference from controls was more substantial for the picture sequences with one-syllable words than for sequences with three-syllable words. Apparently, the rapid naming deficit became larger for those rapid naming tests which allowed faster performance. A further deficit became apparent on the verbal fluency test, but here only when words had to be quickly retrieved in response to a phonemic cue. In contrast, in response to the semantic cue Thomas performed similarly to controls. This latter finding corresponds to the above average score on the vocabulary subtest of the WAIS-R and indicates that Thomas has command over a well developed verbal lexicon. Apparently, this lexicon was not accessible at normal speed in response to a phonemic cue. This finding is consistent with the interpretation of the massive length effect for low frequency and pseudowords in terms of deficient on-line access to phonological structures from phonemic information. The most dramatic speed deficit was observed on the phoneme deletion task. Thomas produced only few erroneous responses. However, he required about 5 sec on average to produce a response. Apparently, to identify the phoneme in the word and to assemble a new pronunciation without the specified phoneme was an extremely taxing task.

In conclusion, the present adult case could be seen as representing an extreme manifestation of the reading speed problem which was found in studies with dyslexic children in regular orthographies, and apparently the problem is phonological in nature.

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