LETTER REVERSALS IN THE CONTEXT OF THE FUNCTIONAL COORDINATION DEFICIT MODEL

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Abstract

Reading disability is introduced as a deficit in the coordination of functions involved in reading (Lachmann, 2001). Reversal errors, typically found in reading disabled children and extensively described by Orton (1925) are explained within this mulicausal approach. Data collected from normal and disabled readers in grades two through four suggests that reversal errors in reading are the result of a failure in binding visual and phonological information because of an insufficient suppression of symmetry generalization.

The field of reading disability research was most influenced by Orton's (1925) concept of developmental dyslexia or strephosymbolia approximately until the seventies of the 20th century. He studied those children, who showed a high discrepancy between their intelligence level and reading performance and described three typical groups of symptoms of strephosymbolia:

(1) *static reversals*: a difficulty in differentiating letters which are horizontally or vertically symmetrical to each other or rotated (*p* and *q*; *b* and *d*; *p* and *d*);
(2) *kinetic reversals*: a tendency to confuse palindromes (*was* and *saw*; *not* and *ton*) and to ocasionally read from right to left resulting in a reverse of paired letters or even syllables within a word;
(3) a remarkable capability for *mirror reading and writing*, sometimes surpassing the performance in reading in normal orientation.

Orton (1925) assumed that reversal errors reflect a cardinal symptom of the faulty development of cerebral dominance and interhemispheric communication. From his point of view, reading disability is a variant in the development of the physiologic lead in the hemispheres. The hemispheres work in union "to produce a single conscious impression" (Orton, 1929) within the early levels of word processing (the *visual perceptive level* and the *visual recognitive level),* whereas the association with sound and abstract meaning is realized by the dominant hemisphere only, on the *associative* or *symbolic level*. Considering the symmetrical build of the hemispheres, Orton assumed the engrams of visual information to be symmetrical to each other as well, since they are represented in both hemispheres. An anomaly in the pattern of hemispheric dominance could produce confusion within the associative level. This would lead to a high number of reversal errors in reading and writing.

The influential studies of Liberman et al. (1971), Vellutino (1977) and Fisher, Liberman and Shankweiler (1978) initiated the "phonological turnaround" (Lachmann, 2001) in the field of reading disability research. Phonological segmentation, rhymes and other phenomena that stand for the ability to process language have been shown to be of great importance in the explanation of failures in reading development (Miles & Miles, 1999). As a result, till this days, most cognitive explanations of reading disability are based on the assumption of phonological deficits within the language processing system (Snowling, 2001). Reading is mostly seen as a primarily linguistic skill (Vellutino, 1987).

Orton's theory doesn't postulate a perceptual deficit, as is often claimed in reading disability literature (Vellutino, 1987). From his point of view, reversals are assumed to be caused by a failure to integrate visual and phonological information represented in memory (Orton, 1925; Corballis & Beale, 1993; Lachmann, 2001). Nevertheless it is evident that reversals cannot be described as the cardinal symptoms of reading failure within a monocausal model of reading disability (Liberman et al., 1971; Fisher, Liberman and Shankweiler; 1978). On the other hand, phonological deficit theories come short of explaining the contradictory findings in the literature about reading disabilities by postulating models that concentrate solely on phonological aspects of reading problems.

Reading is a complex cognitive technique which requires the coordination of a series of subfunctions which can be characterized as *visual functions*, such as configurational (feature) and orthographic (word form) analyses, and *verbal (language) functions*, such as phonological, semantic and syntactic coding and decoding, and *guiding* functions, such as memory, attention and motor skills. Thus, contradictory findings in reading disability research can be best explained by a multicausal model. Reading can be hindered by faulty mechanisms in any one or several of the functions involved or by a faulty coordination of otherwise intact functions. From our point of view, reading disability describes a functional coordination deficit (FCD, Lachmann, 2001).

Not all children with reading difficulties and otherwise normal intelligence will display the same symptoms. Reversals, however, are indeed often described as being typical errors of many reading disabled children (cf. Willows & Terepocki, 1993, for a review). Our research effort lies in explaining the occurrence of reversal errors as found by Orton (1925) within the multicausal framework of FCD.

Boder's (1968, cited in Boder, 1973) distinction between dyseidetics (10% of her sample) and dysphonetics (67% of her sample) has been most influential as a multicausal approach towards reading disability. A body of evidence for a visual subtype of dyslexia has been collected since than. Reversals, to our understanding, would fit the subgroup of dysphonetics, since considering Orton's theory, they reflect a problem of connecting phonological and visual representations.

Symmetry generalization in reading

Orton (1925) explained reversal errors as being an anomaly in the pattern of hemispheric dominance. On the associative level of "*visual word processing"* one hemisphere needs to "*take the lead"* in order to accomplish the right association between visual input and meaning. Confusion occurs when the two symmetric engrams stored in both hemispheres cannot be distinguished properly as in the case of unclear hemispheric dominance. Adapting Orton's neurological theory, Corballis and Beale (1993) describe the processes that leads to symmetric engrams as *mirror-image generalization*. They postulate that a function which automatically generates mirror-image replicas of incoming visual information in both hemispheres is part of perception. This function accounts for the recognition of objects perceived in spatial orientations that bare prior physical experience. That this generalization process is not confined to bilateral symmetry is part of the theory of *symmetry generalization* (Lachmann, 2001). Generalization takes also place for vertical, horizontal and diagonal symmetry and is a learned process due to the behavioral relevance.

Spatial information has tremendous importance in reading. A sufficient process to differentiate between the automatically generated symmetrical replicas is needed to guarantee letter and word decoding. The "original" information about letter orientation (bottom-up) is needed to differentiate e.g. between “b” and “d”. Otherwise it would be hard or sometimes impossible to perform proper semantic decoding as e.g. in the words “dear” and “bear”. Therefore, in learning to read we must also learn how to deal with symmetry generalization. Visual functions involved in reading must perform an efficient suppression of symmetry-generalized information. This might or might not, have something to do with hemispheric balance and interhemispheric communication as postulated by Orton (1925).

The relationship between symmetry generalization and reversal errors

Lachmann & Brendler (in preparation) describe the relationship between symmetry generalization and reversal errors analyzing data from normal and disabled readers in grades two, three and four (mean age of 9,5). The “disabled readers” group consisted of students attending special classes for reading disabled children in the German federal state of Saxony-Anhalt. The school boards of this region have strict criteria for placing a child in these special schooling programs. Therefore, these children have been tested with reading, writing, speech and motor development tests. All students showed a discrepancy between their level of intelligence and their reading achievement, but have been classified as being of at least “average” intelligence.

In order to investigate the role of symmetry generalization all children performed a *same-different* task with lexical and non-lexical material. We used lowercase letters as lexical and dot-patterns (as first used by Garner & Clement, 1963) as non-lexical material (see Fig. 1). The configurations were shown in differing orientations, including a rotation with a 180° angle and reflections on thevertical and horizontal axes. Thus, the two stimuli to be compared could either be the same in shape and orientation, the same in shape but not in orientation, or different in shape.

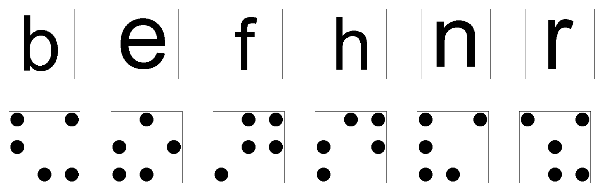

Figure 1. Lexical material (letters) and non-lexical material (dot-patterns).

The children attended two experimental sessions on differing days. In both sessions they performed the *same-different* task. The instruction, however, differed from session to session (counterbalanced between participants). The *physical instruction* ordered the participants to compare the two successively presented stimuli and to respond with the answer “same” when both stimuli were equal in shape and orientation. Thus, configurations which were reflected or rotated versions of each other as well as the ones differing in shape had to be judged as being “different”. Under the *categorical instruction* the participants were asked to differentiate the two stimuli according to their shape only. The response had to be “same” if the stimuli were equal in shape independently on their orientation. Feedback was given to improve speed and accuracy.

The results for lexical material show that under the *physical instruction* the disabled readers made significantly more errors than normal readers when two letters with equal shape but different orientation (e.g. “b” and “d”) had to be judged as being different stimuli (column row 1 in Fig. 2 a). They also made more errors when two different shapes (e.g. “b” and “h”) had to be compared (column row 2 in Fig. 2a). On the other hand, it was shown that the performance of normal and disabled readers did not differ under the categorical instruction (see column rows 3 and 4 in Fig. 2a). Consequently, the effect can be explained by the type of instruction only.

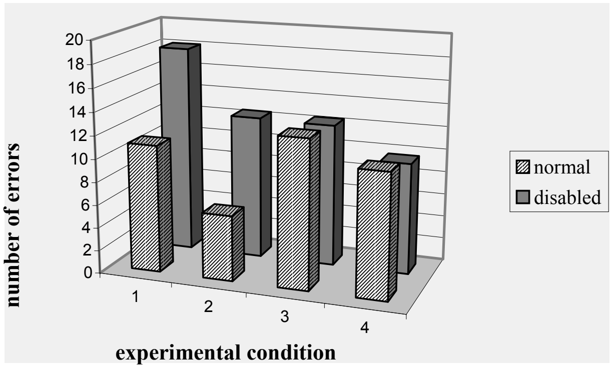

Figure 2a. Number of errors made in the same-different task for lexical material for normal and disabled readers (1 = symmetrically transformed letters under physical instruction, 2 = different letters under physical instruction, 3 = symmetrically transformed letters under categorical instruction, 4 = different letters under categorical instruction) .

It can be concluded that reading disabled children have more problems with the differentiation of lexical stimuli that are connected to each other through symmetric transformation than normal readers. This can be interpreted as an indication for an inadequate ability of reading disabled children to suppress symmetry generalization.

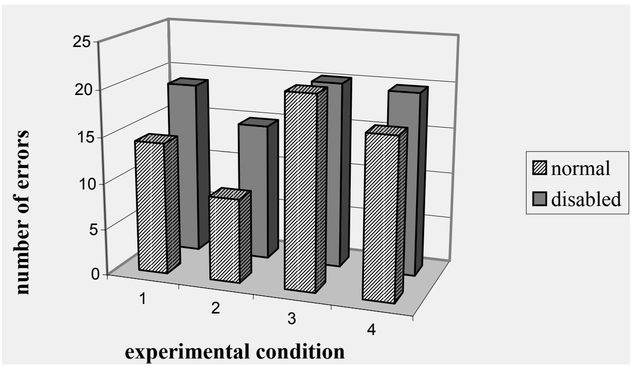

Figure 2b. Number of errors made in the same-different comparison task for non-lexical material (1, 2, 3 and 4 = see Fig. 2a).

It is of high interest, whether or not this effect is restricted to lexical material. Even though the task does not require phonological coding, it was often argued that letters are processed faster because of the use of visual and phonological codes (Lachmann, 2000). A tendency of the effect was also found for non-lexical material (see figure 3 b), however, the differences between the groups were not significant.

The Zürcher Lesetest (Linder & Grissemann, 1996) was administered to all children to evaluate reading performance and the occurrence of reversals and other mistakes in reading. Through the qualitative analysis of reading mistakes we found a higher occurrence of "b-d" reversals in reading disabled children than in normal reading children (see Tab. 1). All other types of static reversals play only a minor role in word reading and because of their rare occurrence they cannot be analyzed by statistical measures.

Table 1. Examples of the numbers of reversal errors found with the Zürcher reading test.

reversals	disabled readers	normal readers
all reversals	334	98
b-d	76	14
d-p	3	0
ei-ie	44	9
other kinetic	52	7

Moreover, the data shows that those children which made more than the average amount of "b-d" reversals in word reading also made significantly more errors in the same-different task when differentiating two letters of the same shape but of different orientation under physical instruction. Interestingly, these children had greater difficulties to differentiate between different orientations of the letter "h" than of the letter "b". We interpret this finding as an indication for learning mechanisms. As displayed in Fig. 3, those children which have a very high percentage of "b-d" reversals in word reading made more errors in differentiating symmetrically transformed single letters. However, only two thirds of the children with a higher than 20% "b-d" reversal rate in word reading can be classified as being "disabled readers".

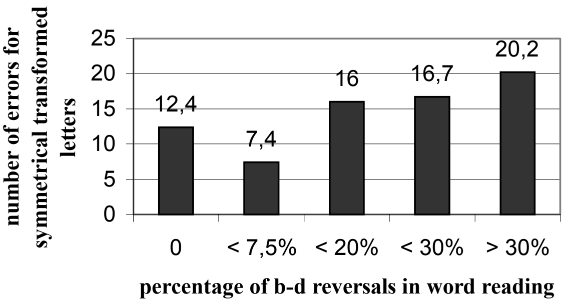

Figure 3. Relationship between "b-d" reversals in word reading and errors in the same-different task with physical instruction and lexical material.

Conclusion

We conclude that reversals made in word reading are related to the confusion of symmetrically transformed single letters. This conclusion contradicts the assumption of Liberman et al. (1971), that single letter reversals are not related to reversals made in word reading. Moreover we claim that reversals are not solely caused by phonological deficits but are related to an inadequate suppression of symmetry generalized information. Those suppression processes could be influenced by training. Not all reading disabled children show a faulty suppression of symmetry generalized information and therefore inadequate suppression mechanisms cannot be seen as the only cause of reading disabilities. Further research must show which mechanisms are involved in learning the suppression of symmetry generalization.

References

Boder, E. (1973). Developmental Dyslexia: a Diagnostic Approach Based on Three Atypical Reading-Spelling Patterns. *Develop. Med. Child. Neurol., 15,* 663-687.

Corballis, M. C. & Beale I. L. (1993). Orton Revisited: Dyslexia, Laterality, and Left- Right Confusion. In D. Willows, R. S. Kruk & E. Corcos (Eds.), *Visual processes in reading and reading disabilities*. pp. 57-73. Hillsdale, NJ.: Lawrence Erlbaum Associates.

Fisher, F. W., Liberman, I. Y., & Shankweiler, D. (1978). Reading Reversals and Developmental Dyslexia: A Further Study. *Cortex, 14,* 496-510.

Garner, W. R., & Clement, D. E. (1963). Goodness of pattern and pattern uncertainty. *Journal of Verbal Learning and Verbal Behavior, 2,* 446 - 452.

Lachmann, T. (2001). Reading disability as a deficit in functional coordination and information integration. In E. Witruk, A. D. Friederici, & T. Lachmann. Basic functions of reading and reading disability. In press. Dordrecht, NL: Kluwer.

Lachmann, T. (2000). Recognition and comparison of visual structure. Psychologia Universalis, Nr. 22 (edited by V. Sarris, M. Amelang, N. Birbaumer, F. Strack, & F. Wilkening). Lengerich, Berlin: Pabst.

Liberman, I. Y., Shankweiler, D., Orlando, C., Harris, K. S., & Berti, F. B. (1971). Letter Confusion and Reversals of Sequence in the Beginning Reader: Implications for Orton's Theory of Developmental Dyslexia. *Cortex, 7*, 127-142.

Linder M. & Grissemann H. (1996). *Zürcher Lesetest.* Göttingen, Bern: Hogrefe.

Miles, T. R. & Miles, E. (1999). *Dyslexia: a hundred years on.* Buckingham: Open University Press.

Orton, S. T. (1925). "Word-Blindness" in School Children. *Archives of Neurology and Psychiatry, 14, 5,* 581-615.

Orton, S. T. (1929). The three levels of cortical elaboration to certain psychiatric symptoms. *American Journal of Psychiatry, 8,* 647-659.

Snowling, M. (2001). From language to reading and dyslexia. *Dyslexia, 7,* 37-46.

Vellutino, F. R. (1977). Alternative conceptualizations of dyslexia: Evidence in support of a verbal-deficit hypotheses. *Harvard Educational Review, 47,* 334-354.

Vellutino, F. R. (1987). Dyslexia. *Scientific American, 256*, 20-27.

Willows, D. M. & Terepocki, M. (1993) The Relation of Reversal Errors to Reading Disabilities. In D. Willows, R. S. Kruk & E. Corcos (Eds.), *Visual processes in reading and reading disabilities*. (pp. 31- 56). Hillsdale, NJ: Erlbaum.