Could Specific Braille Reading Difficulties Result from Developmental Dyslexia?

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Abstract: A proportion of children with visual impairments have specific reading difficulties that cannot be easily explained. This article reviews the data on problems with braille reading and interprets them from the framework of the temporal-processing deficit theory of developmental dyslexia.

Like many sighted children who struggle with learning to read, a proportion of children with visual impairments have specific difficulties related to reading braille that cannot be easily explained (Arter, 1998). Although some of these difficulties may stem from the complexity of the braille code, they should not be considered merely an unavoidable consequence of the use of such a complicated reading medium. Some researchers (Arter, 1998; Coppens & Barlow-Brown, 2006; Greaney & Reason, 1999) have proposed the possible existence of braille dyslexia. Both the World Health Organization (1993) and the British Psychological Society (1999) use a broad working definition of developmental dyslexia with no exclusionary criteria. The term may also be applied to individuals with sensory impairments, such as blindness. Research on dyslexia has shown that the major deficit that causes literacy problems in dyslexia lies in the phonological domain (Ramus et al., 2003). One of the leading theories postulates that the fundamental impairment that directly causes phonological trouble in dyslexia is a deficit in temporal information processing (Stein & Walsh, 1997). In this article, we interpret existing data on problems with learning to read braille from the framework of this theory.

Language and literacy development of children with visual impairments

The development of language and literacy in children with visual impairments is similar to that of children who are sighted (Brambring, 2007). Although children who are visually impaired show clear developmental delays in the production of syllables and the acquisition of their first word, these developmental divergences decline during the course of further development. Generally, no differences can be confirmed when 10- or 50-word vocabularies are compared (Bigelow, 2005; Brambring, 2007; Mulford, 1988). Children with visual impairments perform on a comparable level with sighted children on different language-related tasks, such as identifying mispronounced words and imitating speech by age 5 (Dodd, 1980; Lucas, 1984) and phonemic fluency by age 15 (Wakefield, Homewood, & Taylor, 2006).
Visual impairment seriously challenges a person who is in the process of learning a language and becoming literate. It has been argued that in the absence of vision, children may have more difficulty understanding concepts and the relationships between concepts as well as acquiring generalizations about language (Andersen, Dunlea, & Kekelis, 1993). It has also been hypothesized that speech perception may be more complicated without the redundant input from looking at mouth movements (Millar, 1997). Speech perception plays an important role in learning to read, since it supports the development of proper phonological representations of sounds that are present in language (Stein, 2000).

The same reciprocal interaction between phonological awareness and reading acquisition that has been reported in individuals who are sighted (Bentin & Leshem, 1993) appears to be evident in individuals with visual impairments (Gillon & Young, 2002). Some studies have reported poorer phonological awareness skills in children with visual impairments (Dodd & Conn, 2000), whereas others have found no difference in the performance of children who are blind and those who are sighted (Greaney & Reason, 1999).

In individuals with visual impairments, the sense of touch is substituted for the sense of vision as a reading medium. People who are learning to read braille must acquire the ability to extract spatial information from subtle tactile stimuli (Sadato, 2005). The acquisition of phoneme-grapheme correspondence while learning to read initially depends on solid tactile recognition of letters and words (Millar, 1997). Therefore, tactile sensitivity is essential to the reading process.

Aside from the tactile nature of braille, the partly logographic nature of braille orthography also adds to the complexity of learning to read (Millar, 1997). It has been demonstrated that the logographic nature of contracted braille interferes with the development of phonological awareness (Dodd & Conn, 2000). The use of contractions, it has been claimed, prevents the possibility of auditory analysis and consequently contributes to problems in syllabification (Lowenfeld, 1969).

Despite all the described difficulties, most children with visual impairments who study braille will learn the braille script. Because of the complexity and tactile nature of braille, children with visual impairments start reading later and are slower readers than are children who are sighted (Dodd & Conn, 2000). A proportion of children with visual impairments, however, fail to master the skill despite remedial efforts (Arter, 1998; Greaney & Reason, 1999). Within the sighted population, the term developmental dyslexia is most commonly used in relation to the failure to acquire age-appropriate reading skills (Coppins & Barlow-Brown, 2006). Both phonological awareness and tactile perception play an important role in the process of learning to read braille. Persons with visual impairments who find it difficult to read braille have been reported to have difficulties with both. Similar difficulties are also experienced by individuals with dyslexia. Therefore, by placing data on problematic braille reading within the context of the temporal processing-deficit theory of dyslexia, we may be able to gain a better understanding of the
direction in which research on this subject could be taken next.

Temporal processing–deficit theory of dyslexia

Developmental dyslexia is a specific inherited neurological disorder that affects about 5% to 10% of the population. It is characterized by severe reading and spelling difficulties that are resistant to the usual teaching methods and remedial efforts (Gersons-Wolfensberger & Ruijssenaars, 1997). The predominant current etiological view postulates that dyslexia is the result of a cognitive deficit that is specific to the representation and processing of speech sounds (Snowling, 2000). Research has provided ample evidence that persons with dyslexia have specific difficulties processing the phonological structure of language and that training in phonological skills improves the reading performance of poor readers (see, for example, Bradley & Bryant, 1983; for a review, see Rack, 1994).

It has been shown that persons with dyslexia are worse than individuals without dyslexia in processing short, rapidly presented and dynamic, changing acoustic stimuli (Talcott & Witton, 2002; Van Ingelghem et al., 2005). Persons with dyslexia also tend to have subtle speech-perception problems (McBride-Chang, 1995). It is hypothesized that the deficit in perceiving auditory temporal cues causes a problem in accurately detecting rapid acoustical changes in speech and consequently disrupts the development of adequate phonological representations (Talcott & Witton, 2002; Wright et al., 1997). It has been suggested that an analogous problem in the visual magnocellular sub-system interferes with the development of orthographic skills (Stein, 2001; Stein & Walsh, 1997). The auditory and visual research traditions converge in postulating that dyslexia results from a shortage in temporal information processing. As a consequence, the general temporal processing deficit theory suggests that this kind of deficit can be generalized to all modalities (Stein & Walsh, 1997). This assumption was further supported by the discovery of decreased tactile sensitivity in individuals with dyslexia (Grant, Zangaladze, Thiagarajah, & Sathian, 1999; Stoodley, Talcott, Carter, Witton, & Stein, 2000).

Anatomical support for the temporal processing deficit theory has come from the research of Livingstone, Rosen, Drislane, and Galaburda (1991), who conducted neuropathological studies on dyslexic brains postmortem. These researchers found that the neurons of the magnocellular layers of the lateral geniculate nucleus (the entity in the thalamus that processes visual transients) are, on average, 27% smaller in dyslexic brains. The magnocellular system is specialized for timing visual events and hence for detecting visual motion. It communicates this information rapidly to the visual cortex via the magnocellular layers of the lateral geniculate nucleus and to the superior colliculus for the reflex control of eye movements (Stein, 2003). Furthermore, Galaburda, Menard, and Rosen (1994) found that the distribution of neuronal sizes differed between the left dyslexic and left control medial geniculate nucleus (the auditory relay nucleus of the thalamus), with dyslexic brains having more small and fewer large neurons. The magnocellular divisions of all the
auditory relay nuclei have a particular responsibility for following changes in the frequency or amplitude of acoustic signals with time (Trussel, 1998).

In line with the assumptions of the temporal–processing deficit theory, Boets, Wouters, van Wieringen, De Smedt, and Ghesquière (2008) investigated the interrelationships among preschool measures of dynamic sensory processing, speech perception, orthographic and phonological ability, and first-grade measures of reading and writing achievement using structural equation modeling. Using data from a longitudinal study with a group of children who were at a high family risk of dyslexia and a group of well-matched control children (Boets, Wouters, van Wieringen, & Ghesquière, 2006a; 2006b; Boets, Ghesquière, van Wieringen, & Wouters, 2007), Boets et al. (2008) constructed and tested a path model for reading development. In this model, phonological awareness was determined by speech perception, which, in turn, was determined by dynamic auditory processing. Likewise, dynamic visual processing was related to orthographic ability.

The model fit was best when the direct influence of dynamic auditory processing on phonological awareness was allowed. Similarly, speech perception had a direct influence on reading development. Subsequently, phonological awareness and orthographic ability—together with verbal short-term memory—were shown to be the unique predictors of literacy development. These preschool data are in accordance with those of previous studies of adults and school-aged children that demonstrated that dynamic auditory sensitivity is uniquely related to phonological skills, whereas visual sensitivity is related to orthographic skills (Talcott & Witton, 2002). In individuals with visual impairments, we assume that tactile sensitivity has a similar relationship to orthographic skills as visual sensitivity has to orthographic skills in people who are sighted.

The role of auditory perception and speech perception

The temporal–processing deficit theory of dyslexia hypothesizes that the basic deficit in perceiving auditory temporal cues causes a problem for the accurate detection of rapid acoustical changes in speech and consequently disrupts the development of adequate phonological representations and later reading and spelling skills (Talcott & Witton, 2002; Wright et al., 1997). Auditory temporal processing seems to be crucial in the development of adequate phonological representations. The cues that distinguish the different letter sounds are changes in the frequency and amplitude of speech sounds. The difference, for example, between /d/ and /b/ is that in /d/, the second and third formants rise in frequency in the first 40 milliseconds, while in /b/, they go down. Thus, phonological analysis draws heavily on the ability of the auditory system to track changes in frequency and amplitude accurately (Stein, 2000).

It has been shown that dyslexia is less sensitive to particular rates of auditory frequency modulation (2 Hz and 40 Hz) (Witton et al., 1998). Van Ingelghem et al. (2001) showed that 70% of children with dyslexia had higher thresholds than did persons without dyslexia for auditory temporal processing. Temporal processing measures were significantly related to word and nonword reading skills. Furthermore, Boets et al. (2008) showed
that the sensory problems observed in dyslexia precede the literacy delay. Thus, high auditory frequency modulation sensitivity seems to enable children to develop strong phonological skills, whereas poor auditory frequency modulation sensitivity prevents them from doing so (Stein, 2000).

No data on the auditory frequency modulation sensitivity of children or adults who are blind were found. Adults with visual impairments have been shown to have enhanced performance of auditory perception (Röder & Rösler, 2003), attention (Röder, Rösler, & Neville, 1999), pitch and temporal order discrimination (Gougoux et al., 2004), and speech perception (Röder, Rösler, & Neville, 2000). Relevant data on children who are visually impaired is virtually nonexistent. The question of whether children with visual impairments who struggle with learning to read braille also have problems with auditory temporal processing and speech perception remains to be elucidated.

The role of phonological awareness

Auditory temporal processing determines the development of adequate representations of speech sounds. If these sounds are poorly represented, stored, or retrieved, learning grapheme-phoneme correspondences—the foundation of reading an alphabetic system—will be affected accordingly (Snowling, 1981). Children who have dyslexia perform particularly poorly on tasks that require phonological awareness—that is, the conscious manipulation of speech sounds (Johnston & Morrison, 2007; Snowling, 1991).

Although only limited data on braille reading difficulties are available, the reciprocal nature of the interaction between phonological awareness and reading acquisition that has been reported for sighted children (Bentin & Leshem, 1993) also appears to be evident for children who are visually impaired in relation to reading braille. Gillon and Young (2002), who studied the phonological awareness skills of children who read braille, found a strong relationship between phonological awareness and braille reading accuracy and comprehension. Children who were reading below their age levels were also delayed in their ability to understand the sound structure of spoken language at the phonemic level and to use phonological knowledge in the reading process. Good braille readers, however, had standard scores within or above the average range for their ages on complex phonological tasks when compared to children who are sighted (Gillon & Young, 2002).

Greaney and Reason (1999) described two examples of children who were blind, having tested them with the Phonological Assessment Battery. One child, Hailey (aged 9 years, 1 month), was behind chronological age expectations in word recognition, prose reading, reading accuracy, and comprehension. Hailey showed marked phonological difficulties and had severe problems with most elementary phonological skills. On the testing battery, her results on five of seven subtests [alliteration, rhyme, spoonerism, nonword reading, fluency (alliteration, rhyme), and nonphonological fluency] were two standard deviations below the mean. According to Greaney and Reason (1999), Hailey can be considered dyslexic, particularly because she demonstrates marked weaknesses in the “phonological core variable.”

In another case study, Young and Gillon (1998, cited in Gillon & Young, 2002),
demonstrated that an adapted version of a phonological awareness program, which had been successful in enhancing the word recognition skills of poor readers who were sighted, was also beneficial for D.R., an 11-year-old child with a visual impairment. Implementation of the training (Phonological Awareness Training for the Blind Instruction Manual; Young & Gillon, 2001) coincided with a rapid improvement of D.R.’s phonological-processing ability and braille reading.

**The role of verbal short-term memory**

Another variable that is hypothesized to act on literacy development is verbal short-term memory. Explanations of individual differences in memory span are most often couched in terms of the working memory model proposed by Baddeley and Hitch (1974). Baddeley and Hitch suggested a tripartite system of a visuospatial sketch pad, a central executive, and a phonological loop. The phonological loop is a limited-capacity system in which decaying traces may be refreshed by subvocal rehearsal (McDougall, Hulme, Ellis, & Monk, 1994). The most common tasks that are used to test verbal short-term memory are digit span, the recall of words, and the repetition of nonwords ( Gathercole, 1999). Individuals with dyslexia whose short-term memory has been shown to be affected perform particularly poorly on the aforementioned tasks (Snowling, 2000).

The short-term memory of adults and children with visual impairments has been shown to be better than that of their peers. Hull and Mason (1995) tested a large sample of children with visual impairments and found that gender, first language, and educational setting had no effect on the children’s scores and that the children who were congenitally blind scored higher than did the children who were sighted. The precise reason for their better memory span is not known. It is thought that preschool children who are blind who structure the world without the aid of vision have a greater need for verbal memory and thus become more skilled in this area (Hull & Mason, 1995). None of the studies that focused on braille reading difficulties has specifically measured verbal short-term memory or analyzed its relationship to the reading skill of children in braille below the age-expected level. Verbal short-term memory has been shown to be one of the unique predictors of literacy development (Boets et al., 2008). Therefore, the relationship between verbal short-term memory and other predictors of literacy development should be studied thoroughly in individuals who are visually impaired.

**The role of tactile processing**

Tactile processing substitutes for visual processing in reading in individuals with visual impairments. Several studies have demonstrated that adults who are blind perform better on different tactile tasks than do those who are sighted ( Grant, Thiagarajah, & Sathian, 2000; Van Boven et al., 2000). The superior performance, however, has been shown to reflect their braille reading experience (Van Boven et al., 2000). That is, reading braille improves the tactile sensitivity of the reading finger by expanding the processing area on the somatosensory cortex (Van Boven et al., 2000). Furthermore, people who are sighted can reach the
tactile performance of persons who are blind through training (Grant et al., 2000).

Grant et al. (1999) used gratings of alternating ridges and grooves to investigate tactile perception in dyslexia. Compared to individuals in the control group, persons with dyslexia were significantly impaired on the discrimination of grating orientation, with mean thresholds that were nearly twice as high as normal. Further support for previous findings came from Stoodley et al. (2000), who examined the domain of somatosensory perception in adults with a prior history of dyslexia compared to similarly aged adults in a control group. The detection thresholds for three frequencies of vibration (3 Hz, 30 Hz, and 100 Hz) were obtained. Individuals with dyslexia were significantly less sensitive to vibration at 3 Hz, which suggests the impairment of the slow-adapting I (SAI) fiber system beginning with Merkel-cell mechanoreceptors in the glabrous skin. The same SAI fibers with Merkel receptors are responsible for the recognition and processing of braille characters (Phillips, Johansson, & Johnson, 1990).

Arter (1998) studied children with visual impairments who were struggling to learn to read braille and found that 10 of the 12 experienced problems with tactile perception. Hailey (from the case study presented in Greaney & Reason, 1999) also seemed to have difficulties with tactile perception.

Conclusion

The literacy development of children who are visually impaired is highly dependent on the children’s caretakers and teachers who are responsible for compensating for the absence of spontaneous interaction with written language. A child with many interesting and stimulating experiences of books and reading is likely to be more motivated to acquire a complicated reading medium, such as braille, than is a child who does not even know that oral language can be written down (Erickson & Hatton, 2007).

Studies that have compared individuals who are sighted to those who are blind have shown that the latter are slower readers than are skilled sighted persons who read print. This difference, however, is due more to the tactile process of reading braille than to any major differences in orthographic or phonological processing (Barlow-Brown & Connelly, 2002). The main information-processing tasks in reading are essentially the same irrespective of whether the input stimulus is visual or tactile (Pring, 1984).

As in the sighted population, a proportion of individuals with visual impairments are unable to master the skill of reading despite remedial efforts (Arter, 1998). Limited data on problematic braille reading have shown that persons with visual impairments who struggle with reading also have difficulties with phonological awareness (Gillon & Young, 2002) and tactile perception (Arter, 1998; Greaney & Reason, 1999).

The temporal-processing deficit theory of dyslexia assumes that there are deficits in both these domains. The theory hypothesizes that the deficit in perceiving auditory temporal cues causes a problem for the accurate detection of rapid acoustical changes in speech and consequently disrupts the development of adequate phonological representations (Talcott & Witton, 2002). It has been demonstrated that children with dyslexia have higher
thresholds than do those without dyslexia for auditory temporal processing (Boets et al., 2008; Van Ingelghem et al., 2001). Furthermore, temporal-processing measures are significantly related to word and nonword reading in children both with and without dyslexia (Van Ingelghem et al., 2001). The temporal-processing deficit has also been shown to affect visual (Stein & Walsh, 1997) and tactile sensitivity (Stoodley et al., 2000) in persons with dyslexia. The decreased tactile sensitivity to vibration at 3 Hz of persons with dyslexia suggests an impairment of the SAI fiber system beginning with Merkel-cell mechanoreceptors in the glabrous skin. The same SAI fibers with Merkel receptors are responsible for the recognition and processing of braille characters (Phillips et al., 1990). In individuals who are visually impaired, the sense of touch has taken over the function of vision in the reading process. Therefore, a relationship similar to that seen in sighted individuals can be assumed between tactile sensitivity and orthographic skills in persons who read braille.

The limited amount of data from studies of children who have problems with braille reading seems to be compatible with observations that have been made in research on dyslexia. It could be the case that the neural deficit that is observed in dyslexia prevents a proportion of children with visual impairments from developing the tactile sensitivity that is necessary to decode braille and the auditory acuity that is needed to detect frequency modulation in speech, which underlie phonological awareness abilities and are necessary to tackle the partly logographic nature of braille orthography.

Therefore, there is a need for extensive research on the relationships among different subskills of reading braille. Research on phonological awareness and orthographic measures could be extended to looking at psychophysical underpinnings (low-level auditory and tactile processing), which would give the field a new dimension in the consideration of the existence of braille dyslexia.

References


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