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Differential cognitive and perceptual correlates of print reading versus braille reading

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ABSTRACT

The relations between reading, auditory, speech, phonological and tactile spatial processing are investigated in a Dutch speaking sample of blind braille readers as compared to sighted print readers. Performance is assessed in blind and sighted children and adults. Regarding phonological ability, braille readers perform equally well compared to print readers on phonological awareness, better on verbal short-term memory and significantly worse on lexical retrieval. The groups do not differ on speech perception or auditory processing. Braille readers, however, have more sensitive fingers than print readers. Investigation of the relations between these cognitive and perceptual skills and reading performance indicates that in the group of braille readers auditory temporal processing has a longer lasting and stronger impact not only on phonological abilities, which have to satisfy the high processing demands of the strictly serial language input, but also directly on the reading ability itself. Print readers switch between grapho-phonological and lexical reading modes depending on the familiarity of the items. Furthermore, the auditory temporal processing and speech perception, which were substantially interrelated with phonological processing, had no direct associations with print reading measures.

1. Introduction

The braille writing system constitutes the primary means of literacy access for individuals who are blind (Pring, 1994). While the majority of children learning braille eventually read fluently and well (Coppins & Barlow-Brown, 2006), some blind children experience considerable difficulties learning braille and some of them never master the skill (Dodd & Conn, 2000; Greaney & Reason, 1999). Few studies have investigated the cognitive and perceptual processes involved in braille reading. Research on this topic, however, is essential to gain a deeper insight into the possible reasons for braille reading difficulties.

Braille is a tactile writing system, where all the characters of the alphabet are formed by the presence or absence of elevated dots arranged in a two by three matrix known as the braille 'cell' (Greaney & Reason, 1999). In alphabetic braille each character represents an individual letter. In contracted braille (logographic by nature) certain characters represent letter clusters, numbers and short words (Pring, 1984). Different types and number of contractions, aimed at saving space and speeding up the reading process, are used in different languages. While standard English braille uses 189 contractions and short-form words (Greaney & Reason, 1999), in Dutch braille only three contractions (oe-, ch-, sch-) are regularly used.

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Contrary to print reading, braille reading is sequential rather than simultaneous (braille cells are encountered one at a time) and exhaustive rather than selective (words are not skipped) (Hughes, 2011). Since reading fingers must unavoidably pass over all the characters on a line, braille reading is considered the most strictly serial mode of language input (Bertelson, Mousty, & Radeau, 1992). The sequential nature of braille implies that blind readers predominantly rely on the non-lexical grapho-phonological reading route, whereas sighted readers variably switch between a lexical and a grapho-phonological reading mode, depending on word characteristics (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Coltheart & Rastle, 1994). Consequently, it can be assumed that an effective engagement of phonological processing skills is required throughout the braille reading process (Veispak & Ghesquière, 2010).

Three interrelated but distinctive phonological aspects have been demonstrated to play a crucial role in the reading development of sighted readers and have been shown to be affected in individuals with dyslexia (Boets, De Smedt, Cleuren, Vandewalle, Wouters, & Ghesquière, 2010; Di Filippo et al., 2005; Rack, 1994; Snowling, 2000; Wolf & Bowers, 1999), i.e. phonological awareness (PA), verbal short-term memory (VSTM) and lexical retrieval of phonological codes (as assessed by rapid automatic naming tasks; RAN) (e.g., Wagner & Torgesen, 1987). While PA has primarily been related to reading accuracy and pseudoword reading, RAN has been associated with reading speed and orthographic pattern recognition (Boets et al., 2010; Savage & Frederickson, 2005; Verhagen, Aarnoutse, & van Leeuwe, 2008). The impact of PA on reading is considered to be more fundamental and longer lasting in languages with inconsistent orthographies like English (Share, 2008), while in transparent languages it is only pertinent during the first few months of starting formal reading instruction (Holopainen, Ahonen, & Lyytinen, 2001). RAN, conversely, is a more important predictor for reading in languages with a more transparent orthography, such as German, Italian, Spanish, Dutch and Finnish (e.g., Landerl & Wimmer, 2008).

Although information about the role of phonological processing in braille reading is hardly available, a relation between PA and braille reading accuracy and comprehension has been reported (Arter, 1998; Gillon & Young, 2002; Greaney & Reason, 1999). In an Estonian sample (a highly transparent language with 100% isomorphism between phonemes and graphemes) it has also recently been shown that PA measures are significantly associated with the accuracy and speed of reading words and pseudowords in a group of braille readers, whereas in print readers they are not. Alphanumeric RAN was found to significantly relate to reading speed of short items in print readers, and to all the reading speed measures in braille readers. Additionally, VSTM, which did not show any relation to print reading measures, was significantly correlated with braille reading accuracy (Veispak, Boets, Männamaa, & Ghesquière, 2012). These results suggest that the serial versus parallel nature of the language input (i.e. braille versus print reading, respectively) determines the extent and the intensity of the recruitment of phonological processing skills in support of reading rather than the transparency of the language's orthography alone.

Even though braille reading relies on continuous serial decoding, braille readers have been demonstrated to read words faster than the letters comprising them (Krueger, 1982), to read words more accurately and faster than pseudowords, and to read coherent text faster than rows of unrelated words (Mousty & Bertelson, 1985; Simon & Huertas, 1998; Veispak, Boets, & Ghesquière, 2012). Hence, there is reason to believe that, similar to print readers, braille readers also benefit from semantic information (Millar, 1997). For print readers the benefit for reading words and coherent text compared to pseudowords has been suggested to result from top-down processing, simultaneous orthographic processing and low-level associative processes within the mental dictionary itself (Treiman, 2001). For example it has been demonstrated that words which are predictable from context are fixated for shorter periods of time and are skipped more often than words that are less predictable (Rayner & Pollatsek, 1989). Therefore, it is important to investigate how the semantic and contextual cues interact with the phonological processing demands in support of braille reading performance. For instance, it remains to be elucidated whether the relations between phonological processing and story reading may differ from the relations with word and pseudoword reading in groups of braille and print readers.

Within the context of print reading research, it has been suggested that auditory temporal processing has an essential impact on the development of adequate phonological representations (e.g., Richardson, Thomson, Scott, & Goswami, 2004; Tallal, 1980). The performance on tasks measuring the processing of short and rapidly presented acoustic stimuli (e.g., Farmer & Klein, 1995; McArthur & Bishop, 2001), as well as the processing of slowly varying amplitude and frequency modulated signals (e.g., Goswami et al., 2002; Talcott & Witton, 2002) has been associated with reading acquisition in both typically developing and dyslexic readers. Problems in the processing of these low-level auditory signals have been hypothesized to impact the precise detection of acoustical changes in speech, disrupt the normal development of the phonological system and consequently result in problems learning to read and spell (Boets, Vandermosten, Poelmans, Luts, Wouters, & Ghesquière, 2011). A number of studies indeed confirmed that the association between speech perception and word reading is mediated by PA, both in children (Boets, Wouters, van Wieringen, & Ghesquière, 2006; Boets, Wouters, van Wieringen, De Smedt, & Ghesquière, 2008, 2010; McBride-Chang, 1996) and in adults (Watson & Miller, 1993).

Blind individuals typically show superior performance on many auditory processing tasks as compared to their sighted peers (Gougoux, Lepore, Lassonde, Voss, Zatorre, & Belin, 2004; Papadopoulos, Argyropoulos, & Kouroupetroglou, 2008; Röder, Rösler, & Neville, 2000; Starlinger & Niemeyer, 1981), which has been hypothesized to result from their superior rapid auditory processing skills (Neville & Bavelier, 2001). The results of our previous study, where Estonian braille readers did not outperform sighted print readers on frequency modulation detection and speech perception, do not confirm these assumptions. However, the results did reveal a clear relation between speech perception and reading performance, both in braille and in print readers. Frequency modulation sensitivity, though, was not related to reading, phonological processing or speech perception in either group (Veispak, Boets, Männamaa, et al., 2012).