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The effect of hand movements on braille reading accuracy

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A R T I C L E I N F O

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A B S T R A C T

This study investigated types of hand movements of 32 participants who were blind while they were reading braille texts. Hand movements were correlated with: a) errors in reading accuracy, b) content of texts, c) educational level of texts and d) braille reading patterns. The movement 'return to the line' was strongly related to omission of phrases and words, whereas "forward scanning" was linked to errors regarding letters or syllables. The text content did not affect the type of hand movements during braille reading, while it was observed that there was a difference between secondary-level texts and primary-level texts. The study concludes with interesting outcomes about preferred braille reading patterns with important, theoretical, developmental and methodological implications in instruction.

1. Introduction

The braille code is a tactile organized system of raised dots that enables individuals with visual impairments (VI) to access information through touch. Its fundamental element is the braille cell, which consists of six raised dots distributed into the scheme of two columns and three rows. The pattern of the raised dots creates a total of 63 distinct combinations indicating an alphabet letter, a numeral or a punctuation mark.

Braille reading constitutes a highly specific active tactile process, wherein fingers, hands, even elbows contribute to a reading outcome (Millar, 1997). Braille reading is related to the sense of touch as well as to the somatosensory system of the brain including the thalamus and the primary somatosensory cortex (Goldberg & Swan, 2011), while it activates the occipital and basal temporooccipital brain areas with particular importance of the primary visual cortex (Beisteiner et al., 2015). Moreover, when it comes to verbal exercises, a brain area, called the visual-word form area, seems to be activated in a similar way for sighted and congenitally blind braille readers (Reich, Szwed, Cohen, & Amedi, 2011). The establishment of such procedures is not consolidated ab initio but evolves over time (Millar, 1997).

Tactile reading is considered to be complicated because braille readers need to link spatial and language skills, which are controlled by the right and left hemisphere of the brain respectively (Lorimer, 2002). Braille readers decode each braille character individually using their fingertips with the assistance of specific neurons, such as the endings of the Merkel cells in the skin (Hughes, 2011). Afterwards, braille readers extract the meaning of the word and they ultimately link the hand movements with perceptual and linguistic processes of reading, in order to transform spatial into meaningful information (Glyn, Lim, Hamm, Mathur, & Hughes, 2015; Wei, Scheffer, & Hughes, 2014). For example, a braille reader decodes dots 1 and 5 through his/her fingertip(s). With the assistance of the perceptual and linguistic process of reading, dots 1 and 5 are transformed to the meaningful braille character 'e'. Nevertheless, the way hand movements interact with the perceptual and linguistic process of reading is unknown yet or at least "uncharted" (Hughes, 2011).

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In Greek language, word reading is based on graphophonemic correspondence, although there are some inconsistencies between phonemes and letters (Vakali & Evans, 2007). Additionally, the Greek language has a rich morphology system including derivational morphology, inflections and compounding. Nonetheless, at the end of the first grade, students are expected to be accurate readers (Rothou, Padeliadu, & Sideridis, 2013). Respectively, the Greek braille code is regarded uncontracted, because it mainly depends on a one-to-one correspondence between a print letter and a braille character. More specifically, the Greek braille code consists of sixty-three characters, out of which eight are called diphthongs and combine two vowels in one. Accent is not used in the Greek braille system, so it is not taken into account.

1.1. Braille reading patterns

Reading patterns affect the rate and the amount of successive tactile input, which loads short-term memory (Millar, 1997). Despite reader's individuality, the consistent and systematic use of a specific reading pattern determines the kinesthetic admission of information (Davidson, Wiles-Kettenmann, Haber, & Appelle, 1980). It has been reported that the main braille reading patterns are: a. reading with the right hand solely (first pattern) b. reading with the left hand only (second pattern), c. reading with simultaneous usage of both hands, in which the left index is flat, whereas the right index precedes (third pattern) and d. reading with both hands, when hands act independently (fourth pattern) (Papadopoulos, 2005).

Braille readers who read with one hand rarely change their reading pattern in the course of time. The tendency to read only with the left hand may be attributed to the fact that the brain treats braille dots as spatial objects, which are analyzed by the right hemisphere before or during the verbal encoding held by the left hemisphere (Hermelin & O'Connor, 1971).

The third reading pattern refers to braille readers who prefer simultaneous reading with both hands, where the reader keeps the left hand flat while the index of the right hand precedes. This pattern has two versions. According to the first version (called 'parallel reading'), both indices move along the braille line from right to left and then drop down to find the next line. The left index is adjacent to the right index or both indices are very close to each other having distance of one or two braille characters approximately (Bertelson, Mousty & D' Alimonte, 1985; Lorimer, 2002). The second version depicts the reading process of both indices collaborate almost until the end of the line. At that point the right hand continues to decode until the end of the line (verbal skills), while the left hand seeks the next line (spatial skills). In turn, indices are met at the beginning of the next line and keep on together. However, it is supported that the right index has the chief role in the process of decoding (Millar, 1997). The rest of the fingers swap roles in spotting the beginning and end of lines (Lorimer, 2002). Research studies have indicated that those who preferred the third braille reading pattern performed similarly well compared to those who read with the right hand only, even though reading with both hands joined together is likely to provide input from both hemispheres (Davidson, Appelle & Haber, 1992). In general terms, the third pattern is usually selected by novice and slow braille readers (Lorimer, 2002).

Braille readers who prefer reading with both hands that act independently are reported to be more efficient, because one hand receives verbal information while the other one at the same time deals with spatial attributes (Davidson et al., 1992; Millar, 1997; Mousty & Bertelson, 1992; Wormsley, 1996; Wright, Wormsley & Kamei-Hannan, 2009). The left index starts to read until it meets the right index approximately at the middle of the braille line. At that point, both indices go along for a while. Then the right index takes charge of decoding until the end of the line, while the left finds the beginning of the next line (Lorimer, 2002).

1.2. Hand movements during braille reading

The main hand movements in braille reading are: a. forward scanning, b. returns to the next line, and c. regressions to a place already explored (Bertelson et al., 1985). Additional movements are scrubbing, searching, pause and purposeless movements (Wormsley, 1979 in Wright et al., 2009).

Forward scanning of braille texts occurs in a continuous and fluent manner (Wright et al., 2009). The rate of the reading finger may change positively (acceleration) or negatively (deceleration) but never moves at a constant speed (Hughes, van Gemmert & Stelmach, 2011; Wei et al., 2014). Proficient braille readers move their hands horizontally from left to right and touch the paper gently with loose lateral (Millar, 1997) rhythmic movements (Lamb, 1996). Their fingers bent and fingertips focus on the top of the braille cells, where the majority of braille dots appear, but they also extend to the entire braille cell (Papadopoulos, 2005). Moreover, they are apt to replace their hands incessantly (Millar, 1997). In contrast, poor braille readers apply jagged vertical or circular movements (Davidson et al., 1980).

Regressions may range from one or two braille characters until a number of words (Papadopoulos, 2005) and they are performed with gentle movements at relatively high speeds (Hughes, 2011). One or two hands move backwards for a short time without fingers rising from the braille characters, in order to reread something that was not detected by the initial scanning (Hughes et al., 2011), to control or/and to regulate tactile reading (Mousty & Bertelson, 1992). Alternatively, it may be the second phase of forward scanning (Millar, 1997). Glyn et al. (2015) observed that braille readers returned to the first part of the sentence in order to find the source of the error only when there was a prospect to extract meaning from the sentence. The number of regressions may also reveal reading difficulties (Perea, Jimènez, Martín-Suesta, & Gómez, 2015), while the use of both hands for a regression may constitute an indicator of poor reading abilities (Lorimer, 2002). In case braille readers select reading patterns with both hands, regressions seem to benefit braille reading (Wright et al., 2009). In contrast, braille readers who prefer reading patterns with one hand inevitably perform regressions with that hand and stop forward scanning (Davidson et al., 1992).

Sometimes the reading finger occasionally stops at some braille characters performing awkward up and down rubbing movements, instead of moving smoothly along the line from left to right. This move which imposes increased pressure, and is exerted by