CORTEX 46 (2010) 982–1004

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/cortex

Research report

Is the visual analyzer orthographic-specific? Reading words and numbers in letter position dyslexia

Naama Friedmann, Dror Dotan and Einav Rahamim*

Language and Brain Lab, School of Education, Tel Aviv University, Israel

ARTICLE INFO

Article history:
Received 7 July 2008
Reviewed 6 February 2009
Revised 9 August 2009
Accepted 13 August 2009
Action editor Sergio Della Sala
Published online 27 August 2009

Keywords:
Dyslexia
Letter position dyslexia
Developmental dyslexia
Numbers
Hebrew

ABSTRACT

Letter position dyslexia (LPD) is a deficit in the encoding of letter position within words. It is characterized by errors of letter migration within words, such as reading *trail* as *trial* and *form* as *from*. In order to examine whether LPD is domain-specific, and to assess the domain-specificity of the visual analysis system, this study explored whether LPD extends to number reading, by testing whether individuals who have letter migrations in word reading also show migrations while reading numbers. The reading of words and numbers of 12 Hebrew-speaking individuals with developmental LPD was assessed. Experiment 1 tested reading aloud of words and numbers, and Experiment 2 tested same–different decisions in words and numbers. The findings indicated that whereas the participants with developmental LPD showed a large number of migration errors in reading words, 10 of them read numbers well, without migration errors, and not differently from the control participants. A closer inspection of the pattern of errors in words and numbers of two individuals who had migrations in both numbers and words showed qualitative differences in the characteristics of migration errors in the two types of stimuli. In word reading, migration errors appeared predominantly in middle letters, whereas the errors in numbers occurred mainly in final (rightmost) digits. Migrations in numbers occurred almost exclusively in adjacent digits, but in words migrations occurred both in adjacent and in nonadjacent letters. The results thus indicate that words can be selectively impaired, without a parallel impairment in numbers, and that even when numbers are also impaired they show different error pattern. Thus, the visual analyzer is actually an orthographic visual analyzer, a module that is domain-specific for the analysis of words.

1. Introduction

Individuals with letter position dyslexia (LPD) typically make within-word transpositions such as reading *diary* instead of *dairy*, or *bread* instead of *beard* (Friedmann and Gvion, 2001, 2005; Friedmann and Rahamim, 2007). This dyslexia results from a deficit in the visual analysis system, which selectively impairs the ability to encode the relative position of letters in the word. The current research explored whether this deficit is domain-specific to orthographic-verbal material or whether it also extends to numbers. A selective deficit in words but not in numbers would indicate that a letter-position-encoding function exists that is specific to words, and that the early stage of visual analysis of words is actually

* *Corresponding author*. Language and Brain Lab, School of Education, Tel Aviv University, Tel Aviv 69978, Israel.
E-mail address: naamafr@post.tau.ac.il (N. Friedmann).
0010-9452/$ – see front matter © 2009 Elsevier Srl. All rights reserved.
doi:10.1016/j.cortex.2009.08.007

orthographic visual analysis, specific to orthographic-verbal input.

This early stage of word reading, visual analysis, is responsible for the encoding of abstract letter identities (Coltheart, 1981, 1987; Evett and Humphreys, 1981; Bigsby, 1988), for encoding the relative position of letters within words (Ellis et al., 1987; Humphreys et al., 1990; Ellis, 1993; Peressotti and Grainger, 1995), as well as for setting the attentional window that allows for the allocation of attention to a single word (Coltheart, 1981; Shallice, 1988; Ellis and Young, 1996). A deficit in each of these functions causes a different type of peripheral dyslexia, with different characteristics: deficits in letter identity result in letter substitutions or omissions (as in the case of visual dyslexia, Marshall and Newcombe, 1973; Lambon Ralph and Ellis, 1997; Cuetos and Ellis, 1999; Biran et al., 2003; and in visual letter agnosia, which some researchers term ''pure alexia'' – Déjerine, 1892; Goldstein and Gelb, 1918; Gainotti et al., 1974). A deficit in the encoding of the relative position of letters within words results in migration of letters within words (LPD, Friedmann and Gvion, 2001, 2005; Friedmann and Rahamim, 2007; Friedmann and Haddad-Hanna, in press). A deficit in letter-to-word binding results in migrations of letters between words (as is the case in attentional dyslexia, Shallice and Warrington, 1977; Saffran and Coslett, 1996; Hall et al., 2001; Davis and Coltheart, 2002; Friedmann et al., in press).

Two individuals with a selective acquired deficit of letter position within words, without letter identity errors and without letter migrations between words, were reported by Friedmann and Gvion (2001). In a variety of tasks, their main errors were letter transpositions, namely, migrations of letters within words. The transpositions occurred almost exclusively in middle letters, whereas first and final letters remained in their original positions. Errors tended to occur mainly in ''migratable'' words, i.e., words in which transposition of middle letters can create another existing word. Friedmann and Rahamim (2007) reported 11 individuals with developmental form of LPD who showed a very similar pattern of reading, of migrations of middle letters within words; Friedmann and Haddad-Hanna (in press) reported a similar pattern in 3 readers of Arabic with developmental LPD and one with acquired LPD.

These studies presented cases of pure letter-position encoding deficit without other errors types. Errors of letter order were also reported in the reading of several individuals with various types of acquired dyslexia who made transpositions in addition to other types of reading errors, and whose deficit was not selective to letter position encoding. These individuals, when asked to name a letter in a sequence, occasionally named another letter that was located in a different position in the sequence, or made transpositions within words and letter sequences. This was reported for an individual with deep dyslexia (Marshall and Newcombe, 1973); for individuals with positional dyslexia and attentional dyslexia (Shallice and Warrington, 1977; Katz and Sevush, 1989; Price and Humphreys, 1993; Hall et al., 2001; Humphreys and Mayall, 2001) and for an individual with visual dyslexia (Biran et al., 2003). McCloskey and Rapp (2000a, 2000b) reported a woman who frequently misperceived the orientation and ordering of objects, letters and words. In reading single words she incorrectly perceived the location of letters when she read words or named letters. She had letter transposition errors but this was not the main type of error she made in reading, and she also had a general visual-localization deficit. Skilled readers also show letter transpositions in reading, and misperceive migratable nonwords as their transposed counterpart (Andrews, 1996; Perea and Lupker, 2004), findings that led to the development of models that accommodate encoding of letter position within strings (the SERIOL model, Whitney, 2001; Whitney and Cornelissen, 2005; Bayesian Reader theory, Norris et al., 2006; the overlap model, Gomez et al., 2008).

None of these studies directly compared transposition errors in reading whole words and numbers. One exception, which did not reach conclusive results, is the study by Friedmann and Gvion (2001). This study tested the reading of numbers by two individuals with acquired LPD and found that the participants' performance in the same–different decision task was significantly better in numbers than in words. The participants did make, however, errors in reading numbers aloud, which were not digit migrations, but rather doublings of digits. It is hard to determine whether these doublings resulted from migrations of a digit without deletion of the digit from its original position, or from digit substitution, and therefore the two case studies cannot be taken as a clear-cut evidence for a dissociation between letter position encoding in words and numbers.

Many case studies of other types of dyslexia report that the difficulties in reading words are accompanied by a similar impairment in the reading of Arabic numerals.[1] One study reported an association in peripheral dyslexia: Katz and Sevush (1989) described an individual with what they termed ''positional dyslexia'', who had difficulties in reading the first symbol in a sequence – be it a letter or a digit. Other studies described an association between number and word-reading impairments in central dyslexias. Cohen et al. (1994) described a case of deep dyslexia which affected numbers as well as words. Denes and Signorini (2001) reported an individual with phonological dyslexia who could read words but had impaired reading of nonwords and numbers (a finding that might be explained by the assumption that numbers are read, like nonwords, via a sublexical route).

However, impaired reading of words is not always associated with impaired number reading. In fact, the very first reported case of visual letter agnosia (''pure alexia''), described by Déjerine (1892), had spared reading of digits, and this dissociation was found in later studies as well (Cohen and Dehaene, 1995; Starrfelt, 2007). Friedmann and Nachman-Katz (2004) described a Hebrew-reading child with a severe neglect dyslexia who could still read Arabic numbers normally, and Nachman-Katz and Friedmann (2007) reported 18 additional children with this pattern. Ablinger et al. (2006) treated an aphasic patient (PK) who had difficulties in reading numbers aloud. The patient also had difficulties in word reading (she had deep dyslexia), but it seems that her number reading was

[1] The term ''Arabic numeral'' or ''Arabic number'' relates to the number symbols 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, which were brought to Europe by the Italian mathematician Fibonacci from the Hindu-Arabic system. Interestingly, the number symbols that are currently used in Arabic are different.