Cognition 168 (2017) 205–216

Contents lists available at ScienceDirect

Cognition

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

Original Articles

Developmental surface and phonological dyslexia in both Greek and English

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ARTICLE INFO

Article history:
Received 4 August 2015
Revised 20 June 2017
Accepted 21 June 2017
Available online 12 July 2017

Keywords:
Dyslexia in transparent orthographies
Reading speed in dyslexia
Surface dyslexia in Greek

ABSTRACT

The hallmark of developmental surface dyslexia in English and French is inaccurate reading of words with atypical spelling-sound correspondences. According to Douklias, Masterson and Hanley (2009), surface dyslexia can also be observed in Greek (a transparent orthography for reading that does not contain words of this kind). Their findings suggested that surface dyslexia in Greek can be characterized by slow reading of familiar words, and by inaccurate spelling of words with atypical sound-spelling correspondences (Greek is less transparent for spelling than for reading). In this study, we report seven adult cases whose slow reading and impaired spelling accuracy satisfied these criteria for Greek surface dyslexia. When asked to read words with atypical grapheme-phoneme correspondences in English (their second language), their accuracy was severely impaired. A co-occurrence was also observed between impaired spelling of words with atypical phoneme-grapheme correspondences in English and Greek. These co-occurrences provide strong evidence that surface dyslexia genuinely exists in Greek and that slow reading of real words in Greek reflects the same underlying impairment as that which produces inaccurate reading of atypical words in English. Two further individuals were observed with impaired reading and spelling of nonwords in both languages, consistent with developmental phonological dyslexia. Neither of the phonological dyslexics read words slowly. In terms of computational models of reading aloud, these findings suggest that slow reading by dyslexics in transparent orthographies is the consequence of a developmental impairment of the lexical (Coltheart, Rastle, Perry, Langdon, & Zeigler, 2001; Perry, Ziegler, & Zorzi, 2010) or semantic reading route (Plaut, McClelland, Seidenberg, & Patterson, 1996). This outcome provides evidence that the neurophysiological substrate(s) that support the lexical/semantic and the phonological pathways that are involved in reading and spelling are the same in both Greek and English.

1. Introduction

Children with developmental dyslexia in English-speaking countries generally experience difficulties with reading and spelling familiar words and unfamiliar word-like letter strings (nonwords). Nevertheless, two distinct patterns of selective impairment can be observed in some individuals. Cases of developmental *surface* dyslexia read and spell nonwords relatively well. However, these individuals have difficulties in learning to read and spell inconsistent or irregular words (e.g. Castles & Coltheart, 1996; Coltheart, Masterson, Byng, Prior, & Riddoch, 1983; Goulandris & Snowling, 1991; Hanley & Gard, 1995; Hanley, Hastie, & Kay, 1992; Romani, Ward, & Olson, 1999; Temple, 1985). Irregular words (e.g. *come*) contain one or more atypical correspondences between their spelling and their sound. Surface dyslexia is also associated with regularization errors (the inappropriate assignment of typical spelling-sound correspondences to irregular words during reading, and the inappropriate assignment of typical sound-spelling correspondences to irregular words during spelling). In contrast, individuals with developmental *phonological* dyslexia have a difficulty in reading and spelling nonwords despite relatively good reading and spelling of familiar words (e.g. Campbell & Butterworth, 1985; Funnell & Davison, 1989; Howard & Best, 1996; Snowling & Hulme, 1989; Temple & Marshall, 1983; Wang, Nickels, & Castles, 2015). Both surface (e.g. Di Betta & Romani, 2006; Romani, Di Betta, Tsouknida, & Olson, 2008) and phonological dyslexia (e.g. Howard & Best, 1996) have been shown to persist into adulthood.

Differences of this kind have also been observed amongst groups of people with dyslexia (Castles, Bates, & Coltheart, 2006; Castles & Coltheart, 1993). Castles and her colleagues administered tests of irregular word and nonword reading to a large number of

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http://dx.doi.org/10.1016/j.cognition.2017.06.024
0010-0277/

dyslexic children and compared their performance with normally developing readers with whom they were matched for chronological age (CA controls). Although the majority of dyslexic children were significantly impaired at both irregular word reading and nonword reading, substantial numbers of surface dyslexics (selectively impaired at irregular word reading) and phonological dyslexics (selectively impaired at nonword reading) were observed in both studies. The use of CA controls in studies of this kind was criticized by Snowling, Bryant, and Hulme (1996), and numbers of surface dyslexics are substantially reduced when reading-age (RA) matched controls are used instead (Manis, Seidenberg, Doi, McBride-Chang, & Petersen, 1996; Stanovich, Siegel, & Gottardo, 1997). Nevertheless, the use of RA controls in the identification of surface dyslexia is itself controversial (e.g. Douklias, Masterson, & Hanley, 2009; Jackson & Coltheart, 2001; McDougall, Borowsky, MacKinnon, & Hymel, 2005), and approximately equal numbers of surface and phonological dyslexics were observed when dyslexics and controls were more appropriately matched for reading ability (Wybrow & Hanley, 2015).

These two dyslexic subtypes can be understood as a selective developmental impairment to one of two reading routes in computational models of reading aloud. In the DRC model (Coltheart, Rastle, Perry, Langdon, & Zeigler, 2001) and the CDP++ model (Perry, Ziegler, & Zorzi, 2010), the lexical route can accurately process familiar regular and irregular words, and the non-lexical route can accurately process nonwords and regular words irrespective of their level of familiarity. Phonological dyslexia is consistent with a selective impairment to the development of the nonlexical route, whereas surface dyslexia can be conceptualized as a selective impairment to the development of the lexical route. In the *Triangle* model (Harm & Seidenberg, 1999; Plaut, McClelland, Seidenberg, & Patterson, 1996; Woollams, 2014), there is a semantic reading route that can generate the correct pronunciations for both regular and irregular words by activating their meaning from their orthography. This pathway is particularly important for the accurate reading of irregular words of relatively low frequency that cannot be read correctly by the phonological route. Impaired development of this pathway is generally associated with surface dyslexia (e.g. Woollams, 2014). Nonwords, regular words and irregular words of high familiarity can be read on the basis of direct mappings between orthography and phonology (the phonological route). Phonological dyslexia in the triangle model is attributed to impaired development of the phonological units themselves (Harm & Seidenberg, 1999). This impairment will have particularly severe implications for the development of the phonological pathway and means that phonological dyslexics will rely disproportionately on the semantic pathway for reading (Woollams, 2014).

Surface dyslexia in English (e.g. Castles & Coltheart, 1993) and French (Ziegler et al., 2008) is identified by examining the accuracy of irregular word reading. An important issue is whether the distinction between surface and phonological dyslexia can also be applied to those who are learning to read more transparent alphabetic orthographies that contain relatively few words that have atypical spelling-sound correspondences. Following Wimmer (1993), it is now well established that dyslexia in transparent orthographies is more strongly associated with slow than with inaccurate reading (e.g., Greek: Porpodas, 1999; Italian: Zoccolotti et al., 1999; Dutch: Van den Bos, 1998; Yap & Van der Leij, 1993; Norwegian: Lundberg & Hoien, 1990; German: Wimmer, 1993; Spanish: Gonzalez & Valle, 2000). One possibility is that these longer reading times indicate an overreliance on the slower phonological/nonlexical route, and therefore reflect impaired development of the lexical or semantic route, consistent with surface dyslexia. Alternatively, Ziegler and Goswami (2005) suggested that slow reading in transparent orthographies might be the consequence of a phonological impairment. They argued that impaired development of the phonological/nonlexical reading route might allow accurate reading of words and nonwords in a transparent orthography because the consistent grapheme-phoneme correspondences are relatively easy to acquire. A phonological impairment might nevertheless produce slow reading of both words and nonwords in a transparent orthography if it prevented people with dyslexia from applying letter-sound correspondences as quickly as ordinary readers.

Many shallow orthographies, including German, are less transparent for writing than for reading and contain many words with atypical sound-spelling correspondences. Bergmann and Wimmer (2008) found that German-speaking dyslexics had particular problems in spelling irregular German words and argued that dyslexia in German is associated with a lexical rather than a phonological impairment. The assumption here is that the same orthographic units support both reading and spelling. Consequently, the deficit in dyslexia/dysgraphia is in those representations themselves (rather than in their input or output pathways, which might affect one task but not the other). Further evidence for a lexical rather than a phonological impairment emerged when the German-speaking dyslexics found it difficult to distinguish correctly spelled words from pseudohomophones on a written lexical decision task but were able to distinguish pseudohomophones from phonologically incorrect spellings. Bergmann and Wimmer concluded that dyslexia in German more closely resembles surface than phonological dyslexia.

Nevertheless, it might be also be possible to identify poor readers who experience a selective phonological impairment when learning to read a transparent orthography. In contrast to those with a selective lexical impairment, those with a selective phonological impairment might read real words relatively quickly and spell atypical words relatively accurately, but experience selective difficulties in reading and spelling nonwords. In order to address this issue, Douklias et al. (2009) investigated whether distinct types of dyslexia could be identified within groups of dyslexic children who were learning to read Greek. Greek is considered to be one of the most transparent of alphabetic orthographies for the purposes of reading (Seymour, Aro, & Erskine, 2003). However, like German, Greek is much less transparent when it comes to spelling. The spelling of three of the five vowels is not predictable from phonology alone. For instance, the phoneme "e" can be represented by five different graphemes: ι, η, υ, ει and οι, with the appropriate spelling being determined by principles of morphology and etymology (Chliounaki & Bryant, 2002; Porpodas, 1999). Douklias et al. referred to words that contained less frequent spellings of these vowels as being irregular. Because this terminology differs from how the term 'irregular' is generally used in English, we instead refer to these words as being *atypical*. Douklias et al. identified two Greek dyslexic children with accurate nonword reading and spelling who read words relatively slowly. Consistent with a lexical impairment, these slow readers also made a relatively large number of errors when spelling Greek words with atypical sound-spelling correspondences. Douklias et al. concluded that these children were suffering from a form of developmental surface dyslexia. Two additional children were identified who performed quickly and accurately when reading familiar words but made a relatively large number of errors when reading and spelling nonwords, consistent with developmental phonological dyslexia. Using the same criteria, Niolaki, Terzopoulos, and Masterson (2014) identified three Greek children with characteristics of phonological dyslexia and two Greek children with characteristics of surface dyslexia among a sample of nine dyslexic children.

It therefore appears that cases of both surface and phonological developmental dyslexia can be identified amongst individuals who are learning to read Greek. The present study examined whether individuals who suffer from surface and phonological dyslexia in