15 Morphological and Semantic Processing in Developmental Dyslexia

S. Hélène Deacon, Xiuli Tong, and Catherine Mimeau

15.1 Introduction

This chapter examines the theoretical and empirical foundations of the roles of morphological and semantic skills in developmental dyslexia. Morphemes are the minimal units of meaning by which we create new words in any given language (e.g., "magic"+"ian" = "magician"). Semantics is the study of meaning, broadly speaking. In this chapter, we review data on children's access to meaning at the word and sentence level in tasks, primarily in the oral modality. This review is important because of two common assumptions. The first is of the dominant role of phonological skills in dyslexia, an assumption that has limited the scope of empirical exploration into other potentially implicated factors. The second is that people with dyslexia have a strength in morphology and semantics, a speculation with surprisingly little empirical foundation. We first review the theoretical background for these speculations. We then present the available research evidence, focusing specifically on children with dyslexia, for alphabetic, morphosyllabic, and abjad writing systems. We then review explanatory mechanisms, before turning to cross-linguistic dimensions. We conclude with a broad discussion of these theories and findings, including clinical implications.

15.2 Theoretical Background

15.2.1 Morphological Awareness and Semantic Deficits

Phonological awareness and decoding are viewed as foundational to reading acquisition. In sharp contrast, morphemes play a minimal role in most models of reading. When morphological awareness is included, it is typically described as late emerging and closely connected to orthographic skills (e.g., Ehri, 2005; Seymour, 1999). For instance, according to Ehri's phase model (1995), children first learn to read through phonological decoding. On this foundation,

children's reading strategies later extend beyond strict adherence to letter–sound correspondences to the use of rimes, syllables, and morphemes. According to this model, children experience difficulty in acquiring skill because of challenges with phonological awareness and phonological decoding, which in turn, cause difficulties in morphological awareness.

Semantics is also considered to be relatively neglected (Keenan & Betjemann, 2008) in models of reading. For instance, while Goodman (1967) postulated that semantic cues from the sentence are helpful in reading, others have suspected that this attention to semantics is to the detriment of that which should be paid to orthography (Ehri, 2005). At the word level, connectionist models of reading also state that semantic processing is involved in word reading (Plaut et al., 1996) and reading comprehension (Perfetti & Hart, 2002). Despite its inclusion in some prominent models, semantics has received limited empirical attention. As a striking example, Seidenberg and McClelland (1989) entirely omitted the semantic component from their original simulations in their triangle model of word reading (though see Harm & Seidenberg, 2004).

Following on the centrality of phonological awareness and phonological decoding in theoretical models of dyslexia (see, e.g., Vellutino & Fletcher, 2005, for a review), morphological awareness and semantic deficits in dyslexia are widely viewed as a consequence of more fundamental phonological deficits.

15.2.2 A Compensatory Perspective

Established phonological deficits in dyslexia have led to an alternative hypothesis: Morphological and semantic processing might in fact be a strength in dyslexia (Catts, Adlof, & Weismer, 2006; Elbro & Arnbak, 1996). In Stanovich's (1980) interactive-compensatory model, smaller units of words (e.g., letters) are processed to attain higher levels of information (such as meaning; e.g., LaBerge & Samuels, 1974), and higher levels of information support the processing of smaller units (e.g., Goodman, 1967). This simultaneous processing means that "a deficit in any particular process will result in a greater reliance on other knowledge sources, regardless of their level in the processing hierarchy" (Stanovich, 1980, p. 32). In relation to dyslexia, this model would thus predict that poor phonological skills could result in a greater reliance on semantic and morphological skills, thereby reducing cognitive resources available for reading comprehension (see also Perfetti, 1985).

Dual-route models of reading traditionally encompass a lexical and a non-lexical route for accessing pronunciation from print (Coltheart et al., 1993, 2001; Ellis & Young, 1988; from Grainger & Ziegler, 2011 article). These provide a framework for compensation. The lexical route involves direct access to whole-word orthographic representations in the lexicon. The non-lexical route applies letter–sound correspondences prior to accessing phonological and

semantic representations. According to this theoretical approach, dyslexics' impairments in phonological decoding lead to reliance on the lexical route. More recent conceptualizations of dual-route models suggest that the use of morphological information speeds lexical access, with both direct and indirect lexical access via letter co-occurrences, such as complex graphemes and morphemes (e.g., TH, CH and RE, ED, respectively; Grainger & Ziegler, 2011). This provides a theoretical context for the speculation that dyslexics might rely on a lexical route that includes morphemes.

Nonetheless, Betjemann and Keenan (2008) argued against the notion that semantic processing is a strength in dyslexia, an idea that can be applied equally to morphological processing. The authors explained that dyslexic children rely on semantic cues more than typical readers because they need to compensate for their poor phonological skills when trying to read, rather than because they have particularly strong semantic skills. Like Stanovich's (1980) interactive-compensatory model, Betjemann and Keenan (2008) incorporate the paradoxical hypotheses that dyslexics have impaired morphological and semantic processing, and yet rely greatly on these while reading. Together, these approaches provide theoretical justification for the possibility that dyslexics' established phonological deficits might be associated with relative strengths in morphological and/or semantic processing.

15.2.3 Insights from Chinese

These aforementioned models suggest that dyslexics may show a strength in morphological and/or semantic processing, but remain limited because these models focus almost exclusively on studies of alphabetic writing systems. Chinese provides a fascinating window into the role of morphological and semantic skills in dyslexia because of its unique morphosyllabic writing system, which emphasizes the role of semantics instead of phonology in word-recognition systems.

Unlike English and other alphabetic orthographies that emphasize letter–phoneme mappings, the Chinese character, the basic unit of Chinese writing, maps onto a syllable or a morpheme (DeFrancis, 1989). The majority of Chinese characters are semantic-phonetic compounds containing a semantic radical (a clue to meaning) and a phonetic radical (a clue to sound). As an example, the character 清/tsʰɪŋ1/ (*clean*) consists of a semantic radical inline indicating a *water*-related concept and a phonetic radical 青 with the pronunciation /tsʰɪŋ1/. Notably, the phonetic radical maps onto a whole syllable instead of the phoneme. Of the two radicals, the semantic radical is far more predictive; for semantic-phonetic compound characters, roughly 26 percent share the same sounds with their phonetic radicals, while more than 80 percent are semantically related to

their semantic radicals (Shu et al., 2003, 2006). As such, the Chinese writing system itself is more reliable in terms of its orthography–semantic links than its orthography–phonology links (Seidenberg, 2011). The centrality of the direct orthography–semantic links (i.e., semantic radicals) encourages the examination of the possibility that a semantic-related construct, such as morphological awareness but not phonological awareness, is a key construct of understanding Chinese developmental dyslexia (McBride-Chang et al., 2008; Shu et al., 2006; Tong & McBride-Chang, 2010).

Furthermore, Chinese has unique morphological properties, strikingly different from the derivational and inflectional morphology used in alphabetic orthographies, whose presence further supports the possibility that morphological awareness is key to understanding developmental dyslexia in Chinese. First, lexical compounding is the main vehicle of word formation in Chinese, with the majority of compound words semantically transparent (e.g., 電動車 / tin6 tʊŋ6 tsʰɛ1/ (*electric vehicle*) =電 /tin6/ (*electric*) + 動 /tʊŋ6/ (*motor*) + 車 / tsʰɛ1/ (*vehicle*)). The transparent nature of the component units of meaning may make Chinese readers attend more to semantics rather than phonology (Shu et al., 2003). Second, there are a large number of homophones in Chinese for which meaning is clarified in their writing or word context. For example, the tonal syllable /si6/ has at least six visually distinctive characters, 視 "see," 士 "solider," 示 "show," 是 "is," 事 "work," 侍 "serve," indicating six meanings, respectively. This large number of homophones, each with distinctive characters, makes sound information less reliable in reading Chinese words. This may promote access of exact meaning of each individual morpheme, strengthening the semantic representations of the individual words (Tong, McBride-Chang, & Wong, 2011).

Collectively, the unique characteristics of Chinese orthography, specifically, the predictability of the semantic radical, lexical-compounding morphology and the large number of homophones, are likely to make morphological awareness deficits much more evident than those in phonological awareness in Chinese developmental dyslexia.

15.2.4 Insights from Abjad Languages

Languages represented with abjads, such as Hebrew and other Semitic languages, are of interest in part because they have morphology at the core of their orthographic representation, albeit in a different manner than Chinese writing systems. As an example, in Hebrew each individual word is constructed from two basic morphemes: the root and word pattern (Berman, 1987; Ravid, 1996; Schiff & Ravid, 2007). The root contains the core meaning of all morphologically related forms and is represented in print by three or four consonants. The word pattern is a set of vowels intermingled between the consonants. For

example, the root *g-d-l* means grow, and it is contained within the set related words of *gadal* "grew," *gidel* "raised," and *gudal* "was raised" (examples from Schiff & Ravid, 2007). The centrality of morphology in the writing system and the rich and complex morphology might make it particularly difficult to learn to use morphological analysis in reading, and all the more so for students with dyslexia (Schiff & Ravid, 2007). In terms of models of word reading, these features of the orthography might cause morphological, rather than phonological awareness to be foundational in word-reading development. As such, a morphological deficit might underlie the emergence of reading difficulties in Arabic and Hebrew.

15.3 Research Evidence

We review here studies of the morphological and semantic skills of dyslexic children learning to read across a range of orthographies. We first do so for morphological awareness, the ability to manipulate morphemes in the oral language. We then turn to the role of morphemes in reading and in lexical organization, given the theoretical predictions on morphology as a compensatory reading strategy. We prioritize studies with a reading-level match design, contrasting performance of children with dyslexia to that of younger children with reading skill. If dyslexics perform poorer than reading-ability-matched controls, then the difference cannot be explained by reading skill (or experience with print). We think that this design is vital in evaluating evidence on morphological and semantic skills in dyslexics because of the clear evidence that children learn about both skills during their reading (e.g., Cunningham, 2005; Deacon, Benere, & Pasquarella, 2013; Kruk & Bergman, 2013). Uncovered differences can then be considered a potential causal factor in poor reading (e.g., Goswami & Bryant, 1989) or a consequence of a more primary deficit, such as phonological awareness (see, e.g., Casalis, Colé, & Sopo, 2004). In this design, we need to be wary of factors that are not matched, such as explicit instruction in the classroom, which could provide an alternative explanation of differences.

15.3.1 Morphological Awareness in Dyslexics

Alphabetic Orthographies. Across several studies, French and English children with dyslexia have been shown to perform similarly to or better than younger children of similar reading skill on a range of measures of morphological awareness (Egan & Pring, 2004; Egan & Tainturier, 2011; Robertson et al., 2013; Tsesmeli & Seymour, 2006). As an example, Egan and Tainturier contrasted 9-year-old children with two or more years of reading delay with 7-year-old children matched on reading level. Children judged whether there was a smaller word within a larger word that was related to the larger word

(e.g., *farmer*, which contains the related word *farm* versus *corner*, which contains the unrelated word *corn*). Children also completed morphological sentence analogies, and inflected nonsense words presented within sentence context. Across these diverse measures of morphological awareness, dyslexics performed similarly to reading-level-match controls. That said, we need to be aware that, in studies of English, French, and Bosnian, children with dyslexia have been shown to underperform their chronological-age-matched peers on morphological awareness (Berthiaume & Daigle, 2014; Carlisle, 1987; Duranovic, Tinjak, & Turbic-Hadzagic, 2014; Egan & Pring, 2004; Egan & Tainturier, 2011; Joanisse et al., 2000; Leong, 1999; Siegel, 2008; Tsesmeli & Seymour, 2006; Vogel, 1977; but see Robertson et al., 2013). As such, dyslexics may have a deficit in morphological awareness relative to their typically developing peers, but this level may be commensurate with their reading skill. One common interpretation of such findings is that parity in performance by dyslexics relative to reading-level matches suggests that morphological awareness is not a deficit causing the dyslexics' reading difficulties.

The use of morphemes in reading is a key test of whether dyslexics might use morphemes as a compensatory avenue to reading. A single study shows greater use of a morphemic strategy in word reading than reading-level controls. Elbro and Arnbak (1996) found that Danish dyslexic adolescents were significantly better in reading text parsed into morphemes than into syllables. In another paradigm, 15-year-old dyslexic Danish students were faster in reading words with than without a semantically transparent morphological structure (e.g., *sunburn* versus *window* as an example in English). Two other studies show use of a morphemic strategy across more word types by dyslexics than reading-level-matched controls. Burani et al. (2008) found that 11-year-old Italian dyslexics were faster in reading morphologically complex over simple words (e.g., *cassiere* versus *cammello*, translates as "cashier" versus "camel") for both real and nonwords. A similar pattern emerged for reading-level-matched controls for nonwords, but not for real words, with no differences between any word types for chronological-age controls (see also Suárez-Coalla & Cuetos, 2013; but see Deacon, Parrila, & Kirby, 2006; Lázaro, Camacho, & Burani, 2013). Burani et al. (2008) argued that children might rely on morphemes in their reading of words not yet automatized at the whole-word level; certainly, there might be more such words for dyslexics. Intriguingly, in Elbro and Arnbak's original study, the size of the difference in performance between the words with and without morphological structure was correlated with better reading comprehension, offering support for the possibility that use of morphemes in reading is a compensatory mechanism to support dyslexics' reading. Comparable studies clearly need to be conducted in more opaque languages, such as English and French, and in languages that do not use letter–sound mapping, such as Chinese.

Chinese. There is empirical evidence that Chinese developmental dyslexics have challenges in morphological awareness, at least in comparison to their peers of the same age (e.g., McBride-Chang et al., 2008, 2012; Shu et al., 2006). For example, Shu and colleagues (2006) found that Grade 5 and 6 Mandarin-speaking Chinese dyslexic children had poorer performance in both a morpheme production and a morpheme judgment tasks than their chronological-age controls. Moreover, the dyslexics and chronological-age control groups were most accurately separated by the morpheme production task. McBride-Chang and colleagues (2008) also showed that Cantonese-speaking preschool children at risk for dyslexia underperformed their chronological-age-matched peers in a lexical-compounding morphological awareness task. They therefore provided evidence that morphological awareness is a hallmark of reading disorders and identifies children at risk of dyslexia in Chinese.

To date, two studies compared the morphological awareness of a group of dyslexics with both a reading-level and chronological-age control group. In one study, Chung, Ho, Chan, Tsang, and Lee (2011) compared a group of Cantonese-speaking dyslexic middle-school students with these two normally achieving control groups in a morpheme discrimination task and a morpheme production task. In both tasks, the dyslexic group underperformed the chronological-age-matched group, but performed similarly to the reading-level-matched group. In a second study, Zhou and colleagues (2014) compared a group of 6-year-old Cantonese-speaking dyslexics with two control groups. In a morphological construction task tapping Chinese lexical compounding, the authors found that the dyslexic group outperformed their reading-level-matched peers, but had indistinguishable performance with their chronological-age-matched peers at the end of the two years.

Collectively, one convergent finding emerges from these studies with Chinese dyslexics. Across multiple morphological tasks, morphological awareness is a key factor distinguishing children with dyslexia from their chronological-age-matched normally achieving readers. However, there is lack of convincing evidence supporting that Chinese children with dyslexia underperformed reading-level-matched normal readers. This is especially critical given that many morphological awareness tasks in Chinese involve print (e.g., Chung et al., 2011). As such, it seems that the difficulties experienced by dyslexics with morphological awareness tasks is as one would expect based on their reading level and there is little evidence to date to support the conclusion that morphological awareness is a causal factor leading to developmental dyslexia for Chinese readers. Further, we were not able to identify any studies of the use of morphemes in reading by dyslexic child readers of Chinese. Thus, future longitudinal research with reading-level control groups is needed to examine the role that morphological awareness and morphological reading

strategies play in dyslexia. Additionally, future research might set out to provide a more comprehensive understanding of Chinese dyslexic children's deficits in the use of phonetic and semantic radicals by assessing Chinese dyslexic children's sensitivity to both phonetic and semantic radicals. Previous research with typically developing Chinese children has shown that school-aged Chinese readers are sensitive to the sound cuing function of phonetic radicals by showing the use of full or partial information of phonetic radicals in Chinese character recognition (Anderson et al., 2003; Ho & Bryant, 1997). However, no study to date has systematically evaluated Chinese dyslexic children's use of phonetic and semantic information of radicals in character reading. It would be worthwhile to examine this issue in future research.

Abjads. A very small set of studies of Hebrew- or Arabic-learning children with dyslexia attempted to include reading-level-matched controls; we focus first on data from these studies to provide the most stringent evaluation. A single study was able to include comparison groups that were well matched on the basis of reading level. Schiff, Schwartz-Nahshon, and Nagar (2011) contrasted the performance of 12-year-old children with dyslexia to reading-level-matched peers in Grade 3. Dyslexics performed similarly to these reading-level-matched children on a word-analogy task, and better than reading-level-matched peers on a sentence-completion task. Several other studies attempted to find reading-level matches to younger dyslexics, but did not succeed, with large remaining differences in word-level reading. These studies, in general showed poorer performance by dyslexics than younger children on several morphological tasks, including the ability to judge morphological relationships between written words (Abu-Rabia, Share, & Mansour, 2003; Ben-Dror, Bentin, & Frost, 1995; see also Leikin, 2002) and skill in generating morphologically related words (Abu-Rabia et al., 2003, but see Ben-Dror et al., 1995). As we noted at the outset, however, only one of these included a true reading-level match (Schiff et al., 2011) and this showed that dyslexics performed similarly to or better than reading-level matched controls. This evidence can be paired with findings that dyslexic Hebrew children underperformed their chronological-age peers on a wide range of tests of morphological awareness (Abu-Rabia, 2007; Abu-Rabia et al., 2003; Ben-Dror et al., 1995; Schiff & Ravid, 2004; references from Schiff et al., 2011, see Leikin & Zur Hagit, 2006; Schiff & Ravid, 2013, for similar patterns with adults with dyslexia). As such, it seems that dyslexics have difficulties in morphological awareness relative to typically developing children of the same age, but these difficulties appear to be as expected on the basis of their reading skill. Similarity in performance by dyslexics on morphological awareness tasks to reading-level matches suggests that morphological awareness is not a deficit causing the dyslexics' reading difficulties for readers of Hebrew and Arabic.

Unfortunately, to our knowledge, there are no studies on the use of morphemes in reading by dyslexic child readers of Hebrew and Arabic; as such, we cannot evaluate whether they have a strength in reading strategies based on morphemes, as is suggested by evidence with dyslexic readers of alphabets (e.g., Elbro & Arnbak, 1996). Given this paucity of evidence with children, we expand our purview to a handful of studies of university students with dyslexia.

One study suggests potentially greater reliance on morphemes by dyslexics in reading, as revealed by a masked priming paradigm prior to lexical decision. There was greater priming following a morphologically than orthographically related prime for university students with than without dyslexia (e.g., 200 ms versus 30 ms priming effect); they also showed poorer performance on morphological awareness tasks (Leikin & Zur Hagit, 2006). Of course, as with any written task, it is not clear what effect dyslexics' slower reading time had on results. That said, these findings support the possibility of increased reliance on morphemes in reading, despite non-exceptional morphological awareness skills.

In contrast, university students with dyslexia showed marked insensitivity to either morphological or repetition priming in another study that contrasted visual and auditory prime presentation. In a long-term unmasked priming paradigm, adults with dyslexia showed no priming when the prime was visual, either repetition or morphological; there was both types of priming for the adults without dyslexia as well as for the reading-level matches. In sharp contrast, when the prime was presented in the auditory domain, adults with dyslexia showed similar morphological priming to chronological-age-matched peers (Raveh & Schiff, 2008). These results are compelling in that they reveal a pattern of stability in morphological representations in the auditory lexicon, with impairments in orthographic representations in general in dyslexics, not just specific to morphology (see Schiff & Raveh, 2007, for similar results in a fragment completion paradigm).

To date, the findings then are conflicting as to whether Hebrew and Arabic university students with dyslexia, who have likely compensated to some extent for their reading difficulties, use morphemes in their word recognition. Further studies need to be done specifically with children with dyslexia.

15.3.2 Semantic Skills in Dyslexics

Although research on semantic skills in dyslexics is far more limited than that on morphology, a range of studies in speakers of various languages suggest that dyslexic children also suffer from semantic impairment. Indeed, some studies comparing dyslexic children with same-age typical readers have found evidence of deficits in early semantic skills (Liu et al., 2010; Lyytinen et al., 2001; Torppa et al., 2010). For instance, a comprehensive study examined the early language skills of Finnish-speaking children

identified as dyslexic at 9 years of age. At 2, 3, and 5 years of age, the children who went on to become dyslexic recognized and produced fewer words in vocabulary and naming tasks (Torppa et al., 2010). Furthermore, dyslexic children's semantic skills seem to remain impaired through the elementary school years, at least in comparison with age-matched controls (Ben-Dror et al., 1995; Chik et al., 2012; Schulz et al., 2008; Vellutino, Scanlon, & Spearing, 1995). As an example, Ben-Dror et al. (1995) showed that 10- to 12-year-old Hebrew-speaking dyslexics performed worse than age-matched controls in producing and classifying words from different semantic categories. These semantic impairments could have a neural basis. Indeed, studies conducted in Polish (Jednoróg et al., 2010), Finnish (Helenius et al., 1999), and German (Schulz et al., 2008) have consistently indicated that dyslexics, in comparison with normal readers, showed delayed and weaker cerebral activations during the completion of tasks assessing semantic skills.

However, it remains unclear whether the behavioral and neural deficits in semantics observed in dyslexics (e.g., Ben-Dror et al., 1995; Jednoróg et al., 2010) are an underlying cause of their reading difficulties because the empirical evidence to date is contradictory. Whereas some studies have shown that dyslexic children had poorer semantic skills than reading-level-matched controls, others have shown no differences between the two groups. For instance, in a masked priming study, Betjemann and Keenan (2008) compared 11- to 13-year-old English-speaking dyslexic children with a reading-level-matched control group. The authors asked the children to indicate whether written stimuli were words. Both groups showed facilitation effects when the stimuli were preceded by a semantically related prime, but the size of the priming effect was significantly smaller for the dyslexic group compared with the control group. These findings suggest that dyslexics' processing of semantic information was poorer than that of typical readers of the same level of reading ability. Likewise, when 7- to 11-year-old Chinese-speaking children were asked to complete a synonym judgment task, the dyslexic group underperformed the reading-level-matched control group (Xiao & Ho, 2014). In contrast, Tsesmeli and Seymour (2006) showed that English-speaking 13- to 15-old dyslexics were better than their reading-level-matched controls at formulating definitions of words. Similarly, in a study conducted with 9-year-old Chinese-speaking children, the dyslexics were found to be as accurate as their reading-level-matched controls at using target words in sentences and at identifying synonyms (Chik et al., 2012). This mixed evidence from studies on both English and Chinese makes it difficult to postulate whether semantics has a causal role to play in dyslexia.

Regarding the use of semantic information while reading, dyslexics were found to rely more on semantic context than typical readers, as seems to be the

case for morphemes (Burani et al., 2008; Elbro & Arnbak, 1996; Suárez-Coalla & Cuetos, 2013). As an example, in a study conducted in English, Nation and Snowling (1998) asked a group of dyslexic 11-year-olds and a group of reading-level-matched 8-year-olds to read words either presented in isolation or preceded by a sentence. The authors observed a contextual facilitation effect that was greater for the dyslexics than for the typical readers. Likewise, in a study of English-speaking adults diagnosed with dyslexia in childhood (Bruck, 1990), the participants read words embedded in either sentences providing no clue to meaning or in a meaningful passage. The dyslexics showed a greater contextual facilitation effect than reading-level-matched sixth graders. Notably, however, the author did not take into account baseline differences in word reading between the groups, as did Nation and Snowling (1998).

In sum, studies on dyslexics' semantic skills suggest that this population is impaired in comparison with age-matched controls, but it remains very much unclear whether these semantic deficits are the basis for their reading difficulties (e.g., Chik et al., 2012; Xiao & Ho, 2014). Further, there is reasonably consistent evidence that, despite impaired semantic skills, dyslexics tend to rely on semantic context more than typical readers of the same level of reading ability to help them read words (e.g., Nation & Snowling, 1998).

15.4 Explanatory Mechanisms

Our review of empirical evidence to date highlights findings that need to be explained within any theoretical paradigm. To summarize, there is a pattern in which dyslexic readers in a wide range of writing systems have levels of morphological awareness that are concomitant with their reading level. Second, at least for dyslexic readers of alphabets, the use of morphemes in reading might be better than expected on the basis of their reading level. Finally, the evidence to date does not allow the identification of a straightforward pattern for semantics. In this section, we review mechanisms that might explain these general findings.

15.4.1 Morphological Awareness Equals with Reading-Level Matches

Turning to the first pattern, there is abundant evidence that children with dyslexia, regardless of the language in which they are learning to read, perform similarly to reading-level match controls on morphological awareness (e.g., Egan & Pring, 2004; Schiff et al., 2011; Zhou et al., 2014). This general pattern emerges across all the languages in which it has been tested, although notably few studies in Chinese have included this control group. This pattern suggests that morphological awareness is unlikely to be a causal factor leading to these children's reading difficulties; instead, it is likely that some third factor,

such as phonological awareness, leads to their challenges both in morphological awareness and word reading.

One explanation of this set of findings is based on the idea, articulated in multiple models of reading (e.g., Ehri, 2005), that phonological awareness is the primary cause of dyslexic children's reading difficulties. Weaknesses in phonological awareness, in turn, cause both morphological and reading problems (e.g., Shankweiler et al., 1995). Several researchers have noted that the phonological quality of morphemes likely makes them more difficult to access and manipulate in oral language tasks (e.g., Egan & Pring, 2004; Joanisse et al., 2000). This explanation is further supported by the abundant evidence of the role of phonological skill in typical reading development (e.g., Bradley & Bryant, 1983; National Reading Panel, 2000). This mechanistic interpretation gained plausibility from a comprehensive evaluation of the morphological awareness skills of French dyslexics. Casalis and her colleagues (2004) found that French children with dyslexia performed similarly to reading-level-matched controls on two tasks evaluating the ability to produce real derived forms, one after having been provided with a sentence context and another following a definition. In contrast, dyslexic children performed more poorly than reading-level-matched peers on two morphological awareness tasks resembling a standard phonological awareness task: blending together or removing a base and suffix (see Berthiaume & Daigle, 2014, for a similar pattern of results, and see also Bryant, Nunes, & Bindman, 1998). Overall, the pattern of results provides support for the possibility that deficits in phonological awareness underlie dyslexics' poorer performance on morphological awareness tasks in comparison to reading-level matches.

It is noteworthy that, even in Hebrew, a language in which morphemes are argued to be a primary means of lexical access, Abu-Rabia et al. (2003) noted that the dyslexic children were "virtually at floor" (p. 434) on the phonological awareness task, while the reading-level controls were virtually at ceiling. As such, even in Hebrew, there is evidence that phonological awareness plays a substantive role in reading difficulties.

The language for which this conclusion is perhaps most contentious is Chinese, for which it has been argued that morphological awareness is a central factor in dyslexia; that said, our review revealed a lack of conclusive empirical evidence to support this. We concur that there is evidence that morphological awareness tasks are able to distinguish dyslexic from non-dyslexic children (McBride-Chang et al., 2012). However, many of the morphological awareness tasks in research to date involve access to the written form of Chinese characters, such as homograph identification (McBride-Chang et al., 2012) and morpheme discrimination (Chung et al., 2011). This raises the question of whether Chinese dyslexic children's deficits in morphological awareness are partly a consequence of their poor orthographic representation.

Further, one of the most commonly used Chinese morphological awareness tasks, morphological construction, may highly depend on children's analogical reasoning abilities. As such, there are confounds with both reading and other cognitive skills. Studies with oral morphological awareness tasks that include reading-level controls are critical in Chinese. Also, as noted earlier, the Chinese reading system itself emphasizes an orthography–semantics connection. It is highly likely that morphological awareness deficits observed in Chinese dyslexics are the consequence of a weak ability to establish orthography–semantic links rather than the cause. Thus, it would be worthwhile to consider separating orthographic knowledge (the written form of words) from the assessment of morphological awareness in Chinese dyslexics.

An alternative explanation is that children develop difficulties with both reading and morphology due to an underlying language deficit, at least for some children with dyslexia. Some support for this possibility came from a study by Joanisse et al. (2000) of third-grade children with poor reading skills. Children with both poor reading and language skills performed significantly worse on a morphological awareness task that involved producing novel inflected forms (e.g., Berko, 1958) than did reading-level controls; no such difference emerged for poor readers as a group. These findings suggest that children with only reading difficulties do not have challenges in morphological awareness beyond what one would expect based on their reading skill, and that deficits in morphological awareness might reflect underlying language impairments for a subset of children. This explanation is supported by the fact that morphology is considered to be a sensitive indicator of language ability (see, e.g., Leonard et al., 1997). This finding demonstrates the need, beyond this single study, to consider morphological awareness along with broader oral language skills in order to pinpoint the sources of deficits.

To summarize the mechanistic interpretation of findings on morphological awareness, the vast majority of current positions regard weaknesses in morphological awareness, as demonstrated in comparison to chronological-age controls, as secondary to primary deficits in some other domain (e.g., general language skills or phonological processing).

15.4.2 More Reliance on Morpho-Semantics in Alphabetic Languages

The second pattern is that dyslexic children learning to read in alphabetic languages demonstrate greater reliance on morphemes and semantic context in reading than one would expect based on their reading level (e.g., Burani et al., 2008; Nation & Snowling, 1998). The use of morphemes and context in reading has not, to our knowledge, been tested for dyslexic children learning to read in either Chinese or abjads, with limited and conflicting evidence from adult Hebrew dyslexics.

There are two postulated mechanisms for findings of greater reliance on morphemes in dyslexics' reading (Quémart & Casalis, 2013; Suárez-Coalla & Cuetos, 2013). Burani et al. (2008; see also Marcolini et al., 2011; Traficante et al., 2011) suggest that children rely on morphemic units when reading long and infrequent words because morphemes are often large phonological units represented with multiple letters. In contrast, Elbro and Arnbak (1996; see also Casalis et al., 2004) argue that it is the semantic quality of morphemes that makes them more accessible units, rather than their phonological and orthographic qualities. To our knowledge, only one study has evaluated these mechanisms.

In a masked priming paradigm administered to French dyslexics, Quémart and Casalis (2013) found that dyslexics showed significant priming in morphological conditions (e.g., *tablette–TABLE*, "little table–TABLE"), and not in the orthographic conditions, regardless of whether this had the appearance of morphological structure or not (e.g., pseudo-derived, e.g., *baguette–BAGUE*, "French stick–ring" and orthographic control *abricot–ABRI*, "apricot–shelter"). In contrast, the reading-level and chronological-age-matched children showed significant priming in both the morphological and pseudo-derived conditions, suggesting a role for orthographic overlap with the appearance of morphological structure. A similar pattern of results emerged in a second experiment that varied the degree of orthographic overlap. These results support the possibility that dyslexics' reliance on morphemes in their processing of written words is due to the semantic rather than orthographic features of morphemes, consistent with their greater use of semantic context during reading (e.g., Nation & Snowling, 1998). However, this pattern needs to be replicated, particularly in dyslexic readers of other orthographies.

15.4.3 Disparate Findings on Semantics in Dyslexics

The third broad set of findings that we need to consider comes from evidence on dyslexics' semantics skills; we need to exert caution in doing so as the pattern of results to date remains unclear regarding the question of causality. Whereas some studies suggest that poor semantic skills are partly responsible for dyslexics' reading difficulty (Betjemann & Keenan, 2008; Xiao & Ho, 2014), others have failed to make that demonstration (Chik et al., 2012; Tsesmeli & Seymour, 2006). The disparate findings on dyslexics' impairment at the semantic level are hard to interpret given the limited number of studies. On the one hand, as vocabulary is gained partly through reading (Cunningham, 2005), dyslexics' semantic deficits might result from their reading difficulty rather than the opposite. On the other hand, in two studies (Betjemann & Keenan, 2008; Xiao & Ho, 2014) dyslexic children do not perform as well as their reading-level-matched controls on some semantic

tasks; impaired semantic skills could cause reading difficulty, as suggested in some models (e.g., Goodman, 1967; Perfetti & Hart, 2002; Plaut et al., 1996). As meaning is automatically activated when reading a word (Forster & Hector, 2002), semantic information might be helpful to typical readers in word recognition. Given that dyslexics have difficulty retrieving the meaning of words, their word recognition might be diminished partly by this factor. Clearly we need studies designed to elucidate both the general pattern of results and its mechanistic interpretation.

15.5 Cross-Language Issues

We begin by highlighting possible universals across languages, reminding ourselves that not all of these have been demonstrated empirically to date. The overarching empirical pattern to date lies in dyslexics' comparability to reading-level matches on morphological awareness tasks; multiple theoretical positions would argue that the origins of their reading lie in other domains. The other pattern lies in dyslexics' greater use of morphemes in reading in comparison to reading-level matches, possibly originating in a relative semantic strength. These two patterns may be universals, with more empirical evidence on the former. It seems that morphological awareness may not be a source of dyslexics' reading difficulties, even for those learning to read in orthographies relying heavily on morphological principles. Moving forward, we note that these overarching patterns in the data to date exist alongside very clear gaps in the empirical tests of these patterns in specific orthographies. We highlight these here, with the intention of demonstrating the importance of providing empirical tests.

First, we note that rigorous reading-level match controls were included in studies of dyslexics' morphological awareness most prominently in studies of children learning alphabets. It has proven difficult in studies of children learning to read in Arabic or Hebrew, with large remaining differences in reading skill for groups attempted to be matched on reading level (e.g., Abu-Rabia et al., 2003). As such, a stringent reading-level control group has only been included in a single study in Hebrew (Schiff et al., 2011) and a single study in Chinese (Zhou et al., 2014). As such, we have little basis for confidence that the pattern that emerged from studies of children learning to read alphabets is the same or different for children learning to read other orthographies. From a theoretical and linguistic point of view, it is vital that we empirically test morphological awareness of dyslexic children.

As for semantics, two studies in English (Betjemann & Keenan, 2008; Tsesmeli & Seymour, 2006) and two studies in Chinese (Chik et al., 2012; Xiao & Ho, 2014) included reading-level-matched control groups. However, for these languages, the studies obtained opposite patterns. Along with the lack

of studies on other languages such as Hebrew and Arabic, these conflicting findings highlight the importance of studying dyslexics' semantic skills in both alphabetic and non-alphabetic languages.

Similarly, from a mechanistic point of view, these studies need to contrast the performance of children with deficits in either or both phonological awareness and oral language (following on Casalis et al., 2004; Joanisse et al., 2000). Such fine-grained investigations will determine the underlying factors influencing morphological awareness and semantic processing.

Finally, all of the evidence that morphemes and semantics might offer a compensatory route to reading for dyslexics comes from studies of alphabetic scripts. Even within alphabets, there is no evidence on use of morphemes in word reading by children learning to read in the most phonologically opaque languages of English and French. Most critically, use of morphemes in reading has not, to our knowledge, been tested for dyslexic children learning to read in either Chinese or abjads. These gaps limit the generalizability of any conclusions.

15.6 Discussion and Conclusion

To summarize, we found, overall, that morphological awareness levels of children with dyslexia are as one would expect on the basis of their reading level. This pattern has been taken to suggest that the cause of dyslexics' reading difficulties lies in domains other than morphology, most likely in phonology, especially for alphabetic orthographies. Intriguingly, we also found that dyslexics appear to rely on morphemes and semantic context in their reading to a greater extent than their reading-level-matched peers. This second set of results provides some support for the captivating possibility that morphology offers a compensatory mechanism. We encourage some remaining skepticism: this pattern is discrepant with performance on morphological awareness tasks, has not been assessed in the majority of the world's orthographies, and exists despite the fact that dyslexics in these studies have ongoing struggles with reading. Also, due to the diversities and complexities of morphology in different writing systems, there is a great variation in the use of different types of morphological awareness tasks to assess different aspects of morphological awareness. This leaves us with a fundamental question about whether the nature of morphological awareness is the same across different writing system. Furthermore, the relative strength of the connection between morphology and phonology, and between morphology and orthography also varies across different orthographies, making it operationally difficult to separately evaluate the contribution of morphological awareness to reading difficulties. Thus, it seems that morphology may not be a silver bullet with which to solve engrained reading difficulties.

This review has clinical implications. First, the absence of clear evidence of morphological awareness and semantic processing as specific deficits, beyond prediction by reading level, suggests that these skills might not be useful to include in a diagnostic toolkit for dyslexia. Certainly, the evidence that many children who struggle with reading also struggle with language (e.g., Joanisse et al., 2000; McArthur et al., 2000) suggests the importance of evaluating both language and reading skill in accurately diagnosing children with either dyslexia or a specific language impairment. Second, and in contrast, there is growing evidence that dyslexics can be skilled in using morphemes and semantic context in their reading (e.g., Bruck, 1990; Elbro & Arnbak, 1996). This latter finding is bolstered by the evidence that instruction in morphological awareness is more effective for poorer readers than for typically developing readers (Bowers, Kirby, & Deacon, 2010). Contrasting the effectiveness of morphological and phonological awareness training is a key next step. As we await data from randomized control trials, we advise treatments of dyslexia focused on morphology only for children who have not responded to intensive phonological awareness intervention.

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