Reading impairments: Dyslexias in Hebrew

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Dyslexia is a selective reading impairment, which can be acquired following brain damage, or developmental – from birth (Castles et al., 1999, 2006; Castles & Coltheart, 1993; Coltheart & Kohnen, 2012; Friedmann & Haddad-Hanna, in press; Jones et al., 2011; Marshall, 1984; Temple, 1997). It results from a selective impairment in one of the components of single-word reading. The single-word reading process is a multi-component process, and impairments in different components give rise to completely different patterns of impaired reading. Indeed, there are currently more than 15 known types of dyslexia, resulting from deficits in different loci in the reading process, each with different characteristics, and, subsequently, each requiring different treatment.

Another source of variation between individuals with dyslexia is the orthography in which the dyslexic person reads. The properties of each orthography interact with the specific dyslexia to derive the characteristics of reading in each dyslexia in each orthography. For example, Hebrew is much more problematic than orthographies such as Italian and Spanish for individuals with a dyslexia that results in reading via grapheme-to-phoneme conversion. This is because, unlike Italian, Hebrew letter strings do not include enough information for conversion to sound – they are underspecified for vowels and include many ambi-phonic letters (letters that can be converted to more than one sound, like ψ, which can be converted to s and sh) – and therefore accurate reading of Hebrew words has to be done via the lexical route. Reading a word via grapheme-to-phoneme conversion always yields more than one possible pronunciation, whereas in other languages such as Italian, grapheme-to-phoneme conversion usually yields the correct pronunciation of the word.

To describe the various types of dyslexia, and their interaction with the Hebrew orthography, we will first describe the reading model that we assume, and then describe the various dyslexias that can result from selective deficits in various components within this model. Finally, we report the manifestations of each of these dyslexias in Hebrew readers.
The dual route model for reading aloud and types of dyslexia

Figure 1 presents the dual route model for single word reading (cf. Ellis & Young, 1996; Coltheart et al., 2001). According to this model, the first stage of word reading includes orthographic-visual analysis. This stage is responsible for the encoding of abstract letter identities, for the encoding of relative position of letters within words, and for the binding of letters to the words they appear in (Coltheart, 1981; Ellis, 1993; Ellis et al., 1987; Ellis & Young, 1996; Humphreys et al., 1990; Peressotti & Grainger, 1995). A deficit in each of these three functions causes a different type of dyslexia, with different characteristics. Deficits in letter identity encoding result in letter-identification-visual dyslexia, which is characterized by letter substitutions and omissions (Cuetos & Ellis, 1999; Friedmann et al., 2012; Lambon Ralph & Ellis, 1997; Marshall & Newcombe, 1973). A somewhat similar impairment is visual agnosia for letters (Nielsen, 1937), in which the encoding of letter identity from the visual modality is impaired, but identification from other modalities such as the tactile and kinesthetic modalities is intact.

A deficit in the encoding of relative letter order within words results in letter position dyslexia – a dyslexia in which the cardinal symptom is migration of middle letters within words (Friedmann et al., 2010a; Friedmann & Gvion, 2001, 2005;
Friedmann & Haddad-Hanna, in press; Friedmann & Rahamim, 2007; Kohnen et al., in press). This dyslexia mainly occurs in migratable words, namely, in words in which a middle letter transposition creates another existing word.

A deficit in letter-to-word binding, namely, in the ability to focus attention on one word and attenuate attention to the words surrounding it, results in attentional dyslexia, a deficit that is characterized by migrations of letters between words (Davis & Coltheart, 2002; Friedmann et al., 2010b; Hall et al., 2001; Humphreys & Mayall, 2001; Price & Humphreys, 1993; Saffran & Coslett, 1996; Shallice & Warrington, 1977). In this dyslexia, letters migrate between words, but preserve their relative position within that word.

Another type of visual dyslexia, visual output dyslexia, results from a deficit in the output of the orthographic-visual analyzer. This impairment causes a failure in all three functions of the orthographic-visual analyzer – identity, position, and letter-to-word binding (Friedmann et al., 2012).

A final type of dyslexia that is located in the early stages of orthographic-visual analysis is neglect dyslexia. This dyslexia is a specific difficulty in shifting attention to one of the sides of the word, usually its left side. This dyslexia causes omissions, substitutions, and additions of letters in the neglected side (Ellis et al., 1987, 1993; Haywood & Coltheart, 2001; Vallar et al., 2010; and see Friedmann & Nachman-Katz, 2004; Nachman-Katz & Friedmann, 2007, 2008, 2009, 2010, for the developmental form of this dyslexia).

Apart from the various impairments in the orthographic-visual analyzer, dyslexias can result from impairment in the following routes. The dual route model includes two routes for reading aloud: the lexical route, which includes the orthographic input lexicon and the phonological output lexicon and allows for reading of known words, and the sublexical route, in which reading proceeds via grapheme-to-phoneme conversion, which enables reading of new words. The orthographic input lexicon holds the orthographic information about the written form of words we know, and the phonological output lexicon holds the phonological information about the sounds of the spoken words we know: their consonants, vowels, stress position, and number of
syllables. The lexical route, i.e., the direct connection between these two lexicons, allows for a rapid and accurate conversion from a written word to its phonological form.

The other route for reading aloud is the sublexical route, in which letter strings are converted into sounds via grapheme-to-phoneme conversion. This route enables the reading of new words, which are not (or not yet) stored in the orthographic input lexicon. However, whereas this route is very efficient with nonwords, it is less accurate with existing words. This route would not be able to function well in the presence of ambiguity in the conversion of letters to sounds. For example, the grapheme-to-phoneme conversion route would not be able to distinguish between "now" and "no", and might pronounce now as "no". In Hebrew, the lexical route enables the correct reading of irregular words like ראש, which would otherwise be pronounced like קרוב. Another example is the word כרוב which may be pronounced, when read via the sublexical route, like קרוב.

A deficit in each of these routes creates a different pattern of dyslexia: a deficit in the lexical route causes surface dyslexia (Broom & Doctor, 1995a; Castles et al., 2006; Castles & Coltheart, 1993, 1996; Coltheart & Byng, 1989; Coltheart & Funnell, 1987; Coltheart et al., 1983; Ellis et al., 2000; Ferreres et al., 2005; Friedmann & Lukov, 2008; Howard & Franklin, 1987; Judica et al., 2002; Marshall & Newcombe, 1973; Masterson, 2000; Newcombe & Marshall, 1981, 1984, 1985; Temple, 1997; Weekes & Coltheart, 1996). Readers with surface dyslexia cannot read aloud via the lexical route, and therefore are forced to read all words by grapheme-to-phoneme conversion, as if they were new words. This clearly makes their reading slower, but also causes problems in reading accuracy. For example, irregular words like talk, walk, knife, and answer might be read incorrectly. Even worse might be the case of words that, when read via the sublexical route, may be read as other existing words. For example, the word now that, as mentioned above, can be read, using the sublexical route, as sounding like "no", as well as get (jet), island (Iceland), and one (own). Depending on the exact position of impairment in the sublexical route, readers with surface dyslexia may be good or poor in lexical decision of pseudohomophones (like nife) and in comprehension of homophones (like write and right).
Individuals who have a deficit in the sublexical route can read all words that are in their lexicon correctly, but fail to read new words and nonwords. This dyslexia is called "phonological dyslexia" (Broom & Doctor, 1995b; Coltheart, 1996; Friedman, 1996; Glosser & Friedman, 1990; Howard & Best, 1996; Southwood & Chatterjee, 1999, 2001; Temple, 1997; Temple & Marshall, 1983). Specific types of impairment in the sublexical route are vowel dyslexia (Khentov-Kraus & Friedmann, 2011) and voicing dyslexia (Gvion & Friedmann, 2010). Vowel dyslexia is a selective deficit in vowels that causes vowel letter omissions, substitutions, additions, and migrations whenever the reader reads via the sublexical route (when reading new words, and for individuals with surface dyslexia also when reading existing words via the sublexical route). Voicing dyslexia causes reading voiced letters are unvoiced (g → k) and unvoiced as voiced (p → b).

In addition to these lexical and sublexical routes for reading aloud, the dual route model includes a connection between the orthographic input lexicon and the conceptual-semantic system, which includes the semantic lexicon and the conceptual system, the amodal storage of our concepts. This access to semantics allows for the comprehension of written words. An impairment to the connection between the orthographic input lexicon and the conceptual-semantic system leads to a dyslexia that is described as "reading without meaning" or "direct dyslexia" (Lytton & Brust, 1989). These readers perform at normal levels in converting written words and nonwords into speech, but are very impaired in their comprehension of written words. Impaired comprehension of written words can also result from an impairment to the conceptual-semantic system itself, in which case the comprehension of heard words is also impaired (Castles et al., 2010; Friedmann et al., in press; Friedmann et al., 2011a; Glosser et al., 1997; Nation, 1999; Seymour & Evans, 1992).

Finally, a dyslexia that results from a deficit in both the sublexical and the lexical route (between the orthographic input lexicon and the phonological output lexicon) is called "deep dyslexia" (Coltheart, 1980; Coltheart et al., 1987; Ellis & Young, 1996; Johnston, 1983; Luzzatti et al., 2001; Morton & Patterson, 1980; Stuart & Howard, 1995). Because none of the reading aloud routes are available for readers with deep dyslexia, they are forced to use a route that is not usually employed for reading aloud:
the semantic route. They read via a path that involves the identification of the word in the orthographic input lexicon, activation of the relevant meaning in the conceptual-semantic system, and then naming of the concept. Reading exclusively through this path causes considerable difficulty in reading abstract words, function words, and nonwords, and yields many semantic and morphological errors.

Dyslexia in Hebrew

Hebrew is a Semitic language that is read from right to left. Words in Hebrew are morphologically complex, derived from a three consonant root and templates. In the orthography without diacritics (without nikkud), which is the orthography that is read in every context except for very young children acquiring reading, prayers and poetry, vowels are not consistently represented. Vowels in the end of the word are almost always represented by vowel letters (י ו ע א), whereas middle /a/ and /e/ vowels are almost never represented, and /i/ and /o/ are only partly represented. In addition, each of the vowel letters can also be read as a consonant, and 4 other letters also have ambiguous conversion to sound. These characteristics of the Hebrew orthography cause specific interactions with the different dyslexia types.

Surface dyslexia. This underrepresentation of vowels and ambiguity of letters creates many degrees of freedom in reading Hebrew. This causes a considerable difficulty to individuals with surface dyslexia (Friedmann & Lukov, 2008, 2011). The large number of degrees of freedom results in individuals with surface dyslexia reading words inaccurately via grapheme-to-phoneme conversion. In addition, because Hebrew has many potentiophones (like יָדְבַּג, as mentioned above), reading via the sublexical route often results in another existing word so the reader cannot rule out the erroneous response based on lexicality considerations.

Dyslexias of the orthographic visual analyzer. Another effect of the underrepresentation of vowels, as well as the Semitic morphology, which constructs nouns and verbs from a three-consonantal root, incorporated in a nominal or verbal template, is that they make the orthographic space in Hebrew very dense, namely, a
change of a single letter in a word usually creates another existing word. As a result, peripheral dyslexias, i.e., dyslexias that result from orthographic-visual analyzer impairment, are manifested more clearly in Hebrew than in other languages. In the case of visual dyslexia, and the letter omissions and substitutions that characterise it, in many cases a letter substitution creates another existing word. Because of this property of the Hebrew orthography, Hebrew readers with visual dyslexia often cannot rule out their error responses on the basis of lexical status (Friedmann et al., 2012). In the case of letter position dyslexia, letter transposition within words often results in another existing word, leading to an elevated number of transposition errors in reading Hebrew than other languages (Friedmann & Gvion, 2001; Kohnen et al., in press). Similarly, letter migrations between words, which are characteristic of attentional dyslexia, more often create existing words, and as a result attentional dyslexia is also more notable in Hebrew.

*Neglect dyslexia.* Neglect dyslexia at the word level usually affects the left part of words. Most cases of neglect dyslexia have been described in English and Italian, where neglect dyslexia affects the beginning of words. In Hebrew, which is read from right to left, the affected side is the actually the end of the words. Another property of Hebrew that interacts with neglect dyslexia is the morphological structure of Hebrew words. Reznick and Friedmann (2009) demonstrated that individuals with neglect dyslexia keep shifting their attention towards the left side of the word as long as the search for three root consonants is in action. Once the 3 letters have been identified, omissions occur. Thus, individuals with neglect dyslexia omit almost only template morphemes and never omit root consonants.

Additionally, neglect dyslexia at the sentence level affects the end of sentences, unlike in left-to-right languages in which the beginning of sentences are affected. This causes many omissions of optional words that appear at the end of sentences (Friedmann et al., 2011b).

*Deep dyslexia.* Finally, deep dyslexia, in which readers read via the semantic system, also interacts with the morphological richness of Hebrew. Reading morphologically
complex Hebrew words in deep dyslexia results in morphological errors, usually keeping the root and changing the template and inflection. Interestingly, Faran et al. (2009) reported that action verbs are typically read in the present tense, even when they are written in the past or future tenses.
References


