Chapter 6
Types of Developmental Dyslexia in Arabic

Naama Friedmann and Manar Haddad-Hanna

Abstract Developmental dyslexia is a general term for various kinds of impairments in reading. More than 10 types of developmental dyslexia have been identified, each resulting from a deficit to a different stage in the reading process. The different deficits give rise to different patterns of errors in the various dyslexias and to different types of words that cause difficulty in reading. In this article we present types of developmental dyslexia that we have identified in Arabic, and survey their main characteristics, focusing on the unique properties of the Arabic orthography and their interaction with the manifestation of the various developmental dyslexia types. We present the patterns of developmental peripheral dyslexias, dyslexias that result from impairment at the orthographic-visual analysis stage, and of central dyslexias, which result from impairments at later stages. Within the peripheral dyslexias, we focus on the manifestation in Arabic of letter position dyslexia, which is caused by a deficit in letter position encoding and which results in letter position errors; on attentional dyslexia, a deficit in the attentional window in reading, which results in migrations of letters between words; on visual dyslexia, a deficit in the orthographic-visual analyzer that causes letter omissions, additions, substitutions, and migrations; and on left neglect dyslexia, a disorder that leads to visual errors only on the left side of words. We then report and discuss the manifestation of central dyslexias in Arabic: surface dyslexia—a deficit in the lexical route that causes reading via the sublexical route; vowel dyslexia—a selective impairment in vowel processing in the sublexical route that causes impaired reading of vowel letters; and deep dyslexia—a deficit in the sublexical and lexical routes, which causes reading via the comprehension of the word and leads to semantic and morphological errors. All but one of the dyslexias described here are reported for the first time in Arabic.

Keywords Attentional dyslexia · Arabic · Dyslexia · Deep dyslexia · Letter position dyslexia · Neglect dyslexia · Reading · Surface dyslexia · Visual dyslexia · Vowel dyslexia

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N. Friedmann (✉)
Language and Brain Lab, School of Education and Sagol School of Neuroscience,
Tel Aviv University, Tel Aviv 69978, Israel
e-mail: naamafr@post.tau.ac.il

M. Haddad-Hanna
Tel Aviv University, Tel Aviv, Israel
e-mail: manarhad@gmail.com

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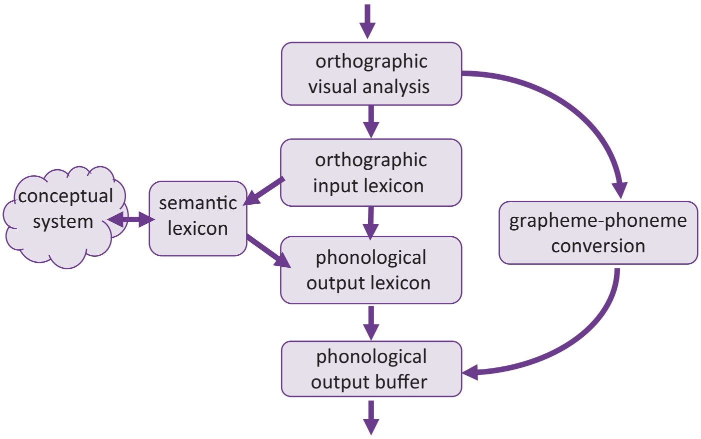
orthographic visual analysis
orthographic input lexicon
conceptual system
semantic lexicon
phonological output lexicon
grapheme-phoneme conversion
phonological output buffer

Fig. 6.1 The dual route model for single word reading

6.1 Introduction

Developmental dyslexia has many forms. Depending on the exact nature of impairment in the single word reading process, completely different patterns of impaired reading can arise. Indeed, there are currently more than ten known types of dyslexia, resulting from deficits in different loci in the reading process, each with different characteristics, and, subsequently, each requiring different treatment approaches.

Importantly, the different loci of impairment in the reading process are not the only source of principled heterogeneity between individuals with developmental dyslexia. The properties of the orthography in which the dyslexic person reads create another source for differences between individuals with dyslexia. For example, individuals with a dyslexia that causes reading only via grapheme-to-phoneme conversion may find it much harder to read in an orthography like Arabic, in which many words can be read in various ways via the sublexical route due to the underrepresentation of short vowels in the orthography, than in other languages, such as Italian, in which grapheme-to-phoneme conversion usually yields the correct word. In the current study we survey the way the special characteristics of the Arabic orthography affect the manifestation of developmental dyslexia in Arabic.

To describe the various types of dyslexia, we will first describe the reading model that we assume in this research, and then describe the various dyslexias that can result from selective deficits in various components within this model. In Fig. 6.1 we present the dual route model for single word reading. This model is the result of a work of cognitive neuropsychologists over the past 40 years, including Max Coltheart, John Marshall, Tim Shallice, Karalyn Patterson, Lyndsey Nickels, David Howard, Andrew Ellis, Andrew Young, and others. Whereas many models of reading exist, this model allows the best and most straightforward way, in our minds, to account for and predict the various types of dyslexia.

The first stage of word reading is orthographic-visual analysis. This stage is responsible for the encoding of abstract letter identities, for the encoding of the relative position of letters within words, and for the binding of letters to the words they appear in, by setting the attentional window that allows for the allocation of attention to a single word (Coltheart 1981; Ellis 1993; Ellis et al. 1987; Ellis and Young 1988; Humphreys et al. 1990; Peressotti and 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 and Ellis 1999; Friedmann et al. 2012; Lambon Ralph and Ellis 1997; Marshall and Newcombe 1973). When letter identity encoding is only impaired when accessed from the visual modality, but is unimpaired from other modalities such as the tactile and kinesthetic modalities, it is termed “visual agnosia for letters” (Nielsen 1937). 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 letters within words (Friedmann et al. 2010a; Friedmann and Gvion 2001, 2005; Friedmann and Haddad-Hanna 2012; Friedmann and Rahamim 2007; Kohnen et al. 2012). 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 mainly by migrations of letters between words (Davis and Coltheart 2002; Friedmann et al. 2010b; Hall et al. 2001; Humphreys and Mayall 2001; Price and Humphreys 1993; Saffran and Coslett 1996; Shallice and Warrington 1977). Another type of visual dyslexia results from a deficit in the output of the orthographic-visual analyzer. This impairment causes a failure in the output of the three functions of the orthographic-visual analyzer—identity, position, and letter-to-word binding. This kind of visual dyslexia is termed “visual output dyslexia” (Friedmann et al. 2012). Another 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. The main errors in this dyslexia are omissions, substitutions, and additions of letters in the neglected side (Vallar et al. 2010; and see Friedmann and Nachman-Katz 2004; Nachman-Katz and 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 the sublexical route, in which reading proceeds via grapheme-to-phoneme conversion. 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. This route allows the reader to know how to pronounce the word “now”, how to pronounce the word “no”, and to distinguish between the two according to their written forms. 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. Whereas this route is very efficient with non-words, 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".

A deficit in each of these routes creates a different pattern of dyslexia: a deficit in the direct lexical route causes surface dyslexia (Broom and Doctor 1995a; Castles et al. 2006; Castles and Coltheart 1993, 1996; Coltheart and Byng 1989; Coltheart and Funnell 1987; Coltheart et al. 1983; Ellis et al. 2000; Ferreres et al. 2005; Friedmann and Lukov 2008; Howard and Franklin 1987; Judica et al. 2002; Marshall and Newcombe 1973; Masterson 2000; Newcombe and Marshall 1981, 1984, 1985; Temple 1997; Weekes and Coltheart 1996). Readers with surface dyslexia cannot read via the lexical route, and therefore are forced to read all words by grapheme-to-phoneme conversion, as if they were new words. This not only makes their reading slower, but also causes problems in reading accuracy. For example, irregular words like *talk*, *walk*, *knife*, and *debt* might be read incorrectly. Even worse might be the case of potentiophones: 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", and the words *get* (jet), *island* (Iceland), *whose* (hose), *one* (own), and *phase* (face). Such deficit may also cause problems in the comprehension of homophones like *witch* and *which*.

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 non-words. This dyslexia is called "phonological dyslexia" (Broom and Doctor 1995b; Coltheart 1996; Friedman 1996; Glosser and Friedman 1990; Southwood and Chatterjee 1999, 2001; Temple 1997; Temple and Marshall 1983). A specific type of impairment in the sublexical route is *vowel dyslexia* (Khentov-Kraus and Friedmann 2011). Recent findings from Spanish, French, English, and Thai indicate that vowels and consonants are treated separately by the sublexical route (Duñabeitia and Carrerias 2011; Lee et al. 2001; New et al. 2008; Perea and Acha 2009; see Winskel 2011 for a review). A selective deficit in vowels creates 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).

In addition to these lexical and sublexical routes for reading aloud, the 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". These readers perform at normal levels in converting written words and non-words 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. 2013; Nation 1999; Seymour and 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 et al. 1987; Ellis and Young 1988; Luzzatti et al. 2001; Stuart and 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 non-words, and yields many semantic and morphological errors.

In recent years, more and more studies have accumulated, indicating that subtypes of dyslexia that have been identified in acquired dyslexia also appear in a developmental form. For a comprehensive survey of this literature see Castles et al. (2006, 1999), Castles and Coltheart (1993), Coltheart and Kohnen (2012); Jones et al. (2011), and Temple (1997). Among the types of developmental dyslexia that have been reported one can find developmental surface dyslexia (Broom and Doctor 1995a; Castles et al. 2006; Castles and Coltheart 1993, 1996; Coltheart et al. 1983; Friedmann and Lukov 2008; Judica et al. 2002; Masterson 2000; Temple 1997; Valdois et al. 2003), developmental phonological dyslexia (Broom and Doctor 1995b; Howard and Best 1996; Temple 1997; Temple and Marshall 1983; Valdois et al. 2003), developmental vowel letter dyslexia (Khentov-Kraus and Friedmann 2011), impaired semantic route (Castles et al. 2010; Glosser et al. 1997), as well as developmental deep dyslexia (Siegel 1985; Stuart and Howard 1995; Temple 1988, 2003). Selective developmental peripheral dyslexias were also identified—letter position dyslexia (Friedmann et al. 2010a; Friedmann and Gvion 2005; Friedmann and Haddad-Hanna 2012; Friedmann and Rahamim 2007, in press; Keidar and Friedmann 2011; Kohnen et al. 2012), attentional dyslexia (Friedmann et al. 2010b; Keidar and Friedmann 2011; Rayner et al. 1989), and neglect dyslexia (Friedmann and Nachman-Katz 2004; Nachman-Katz and Friedmann 2007, 2008, 2009, 2010).

The aim of the current study is to survey the types of developmental dyslexia in Arabic, and to closely examine the effect the Arabic orthography has on the reading patterns in the various dyslexia types.

6.1.1 A Bit About Arabic Orthography

Arabic is written from right to left. It includes 28 letters that are written in a cursive style. All Arabic letters can be used as consonants and three of them can also be used as long vowels (و ي ا). The short vowels are usually not represented in the orthography, except for in texts for beginning readers, which include vocalization diacritics.

Arabic, as a Semitic language, has a rich morphological structure in both nouns and verbs (see Saiegh-Haddad & Henkin-Roitfarb, in this handbook). Most verbs are constructed from three-consonant roots that are incorporated in verbal templates, and many nouns are similarly constructed from a three-consonantal root incorporated in nominal templates.

Letter form The written form of each Arabic letter is determined by two factors: its position in the word—initial, middle, or final, and whether or not it ligates to the letter that precedes it. Whether or not a letter ligates to the preceding letter depends on the preceding letter: six of the Arabic letters: ا , د , ذ , ر , ز , و (A, D, ð, R, Z, W) do not ligate to the following letter. The combination of position and ligation creates four letter forms: a form for letters in the beginning of the word, a form for letters in the middle of the word that ligate to the preceding letter, a form for final letters that ligate to the preceding letter, and a form for final letters that do not ligate to the preceding letter. Middle letters that do not ligate to the preceding letter are written using the initial letter form.

As shown in Table 6.1, 20 letters change their form between initial/medial and final positions, and 8 letters only change their ligation according to whether or not they are ligated to the preceding letter. For example, the letter H is written هـ when in initial position (or non-ligating middle position), ـهـ when in middle position and ligating to the previous letter, ـه when in final position and ligating to the previous letter, and ه when final and non-ligating.[1]

Diglossia Another aspect of Arabic that might have an effect on the manifestation of dyslexia is the diglossic situation of Arabic (see Myhill, Chap. 9). Written Arabic is Standard Arabic (SA), whereas the individuals who read it speak one of the spoken Arabic vernaculars. In our study, all the participants were speakers of Palestinian Arabic (PA), which differs in phonology, lexicon, and syntax from SA. Growing up, Palestinian Arabic is the main language that children are exposed to, although they occasionally hear Standard Arabic in some TV programs, and in prayers, for example (Saiegh-Haddad 2012; Saiegh-Haddad & Henkin-Roitfarb, in this handbook). Thus, children grow up speaking Palestinian Arabic, and learn Standard Arabic only later, usually in school. Hence, Standard Arabic can be viewed almost as a second language.

In addition to the diglossic situation between Palestinian Arabic and Standard Arabic, most Arabic speakers in Israel also speak Hebrew as a second language, and most of them also read Hebrew. This multi-language situation creates an interesting test case for the interaction between diglossia and some types of dyslexia: for example in deep dyslexia, in which reading proceeds exclusively via meaning, then if naming and speaking occurs in PA, reading words presented in SA might result in

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[1] Throughout this article, we used the following phonemic transcriptions for vowels: i for kasra, i: for ي functioning as a long vowel, u for damma, w for و functioning as a long vowel, a for *fatħa*, and a: for ا functioning as the long vowel a. Hamza, ء which can appear alone, or with the letters *ʔalif, waw, yaʔ* (إ أ ئ ؤ), was transcribed as ʔ.

Table 6.1 Arabic letter forms

Final non ligated	Final ligated	Medial ligated	Initial (or medial non ligated)	IPA	Graphemic transcription
ا	ـا	ـا	ا	a	A
ب	ـب	ـبـ	بـ	b	B
ت	ـت	ـتـ	تـ	t	T
ث	ـث	ـثـ	ثـ	θ	θ
ج	ـج	ـجـ	جـ	ʒ	J
ح	ـح	ـحـ	حـ	ħ	Ħ
خ	ـخ	ـخـ	خـ	x	X
د	ـد	ـد	د	d	D
ذ	ـذ	ـذ	ذ	ð	ð
ر	ـر	ـر	ر	r	R
ز	ـز	ـز	ز	z	Z
س	ـس	ـسـ	سـ	s	S
ش	ـش	ـشـ	شـ	š	Š
ص	ـص	ـصـ	صـ	*ṣ*	*ṣ*
ض	ـض	ـضـ	ضـ	*ḍ*	*ḍ*
ط	ـط	ـطـ	طـ	*ṭ*	*ṭ*
ظ	ـظ	ـظـ	ظـ	ð	ð̣
ع	ـع	ـعـ	عـ	ʕ	ʕ
غ	ـغ	ـغـ	غـ	ɣ	Ɣ
ف	ـف	ـفـ	فـ	f	F
ق	ـق	ـقـ	قـ	q	Q
ك	ـك	ـكـ	كـ	k	K
ل	ـل	ـلـ	لـ	l	L
م	ـم	ـمـ	مـ	m	M
ن	ـن	ـنـ	نـ	n	N
ه	ـه	ـهـ	هـ	h	H
و	ـو	ـو	و	w/u:	W
ي	ـي	ـيـ	يـ	y/i:	Y
ة	ـة				Ḧ
ء (أ ؤ ئ)	ء (أ ؤ ئ)	ء (أ ؤئـ)	أ / إ	ʔ	ʔ

the production of words in PA. We explore this and other predictions regarding the effect of diglossia in the study reported below.

6.1.2 Participants

All the participants with the various types of developmental dyslexia reported in this study were Arabic speakers. They were speakers of Palestinian Arabic and readers of Standard Arabic. None of them had a history of brain lesions, neurological disease, or loss of consciousness.

They were children and adolescents enrolled in regular classes in regular schools in central Israel and in the Galilee, who had learning problems or reading problems at school. They had been identified prior to our research as having some learning disabilities or reading difficulties by the special education teachers or by the speech therapists in their schools, but the exact nature of their reading difficulties or the type of dyslexia they had was not precisely diagnosed. They were referred to our Language and Brain Lab by their parents, special education teachers, or speech therapists for further diagnosis, to find out what the basis of their reading difficulties or reading comprehension problems was. In total, approximately 150 such children were referred to us for further diagnosis. Of these children, we diagnosed 74 children with various types of developmental dyslexia on the basis of the Arabic TILTAN screening test (Friedmann and Haddad-Hanna 2009), which includes 207 words, 27 non-words, and 23 word pairs. The items in the screening test were selected so that they can detect the various types of dyslexia—including words that, when read through the grapheme-to-phoneme conversion route, can be read as other words, for the detection of surface dyslexia; migratable words, words with a lexical potential for middle letter migration, for the detection of letter position dyslexia; words with many orthographic neighbors for detecting visual dyslexia; words with a lexical potential for omission or substitution on the left or on the right, for the detection of neglect dyslexia; abstract words and function words for the detection of deep dyslexia. The test also included a list of word pairs in which migration of a letter between the words creates an existing word, for the detection of attentional dyslexia, and nonwords of various types of the detection of phonological and deep dyslexia, as well as peripheral dyslexias.

For each individual, we analyzed the types of errors made in oral reading of this word list. We selected for our further explorations of developmental dyslexia in Arabic the individuals who had a high rate of errors in reading the screening test.

The *control group* for each of the tests reported below included 26 participants in third to fifth grade, without reading or language disabilities, and without any known neurological impairment, from the same schools as the participants or from schools in the same area, with similar socioeconomic status.

6.1.3 Developmental Dyslexia Types in Arabic

Developmental Letter Position Dyslexia

One of the functions of the first stage of reading, the orthographic-visual analyzer, is the encoding of the relative position of letters within the word. This function is subject to a selective deficit, letter position dyslexia (LPD), which causes letter position errors in reading. LPD was first reported in its acquired form in Hebrew (Friedmann and Gvion 2001). The individuals reported by Friedmann and Gvion showed a selective deficit in letter position encoding, without migrations between words and without letter identity errors. Their main errors, in a variety of tasks, were migrations of letters within words. The errors occurred almost exclusively in middle letters, whereas first and final letters remained in their original positions (both when they were parts of the root and when they were part of an affix). Errors occurred mainly in “migratable” words, namely, in words for which a transposition of middle letters created another existing word (like *flies* and *files* in English). The patients did not make migration errors in symbol sequences or numbers.

The same dyslexia was also reported in a developmental form for Hebrew (Friedmann et al. 2010a; Friedmann and Gvion 2005; Friedmann and Rahamim 2007, in press; Keidar and Friedmann 2011: see Coltheart and Kohnen 2012, for a review), and recently also for English (Jones et al. 2011; Kohnen et al. 2012), and Italian (Luzzatti et al. 2011). The characteristics of letter position dyslexia in its developmental form are exactly like the ones of the acquired form: migrations of letters within words, mainly of middle letters, and mainly when the resulting word is another existing word, usually when the result is a more frequent word. Friedmann and Haddad-Hanna (2012) reported LPD in Arabic. They reported 10 children and adolescents with developmental LPD, and a person with acquired LPD, who all showed patterns of reading, reading errors, and effects on reading that are remarkably similar to the ones reported in Hebrew LPD.

The tendency of LPD readers to make more errors in migratable words is important when considering how LPD would be manifested in Arabic. In Arabic, migratable words are abundant due to a combination of the nature of Arabic orthography and morphology. Because of the underrepresentation of short vowels in the orthography, there are many degrees of freedom in reading Arabic. Thus, letter combinations resulting from letter migrations can be read in various ways, and one of them often yields another existing word. Another contribution to the large number of migratable words in Arabic is its Semitic morphology, which generates words from a consonantal root and a template. This yields many word pairs that only differ in the order of the root consonants (with the same template, such as يعملون and يعلمون, YʕMLUN and YʕLMUN in letter transliteration ‘work-3rd-mas-pl’ and ‘know-3rd-mas-pl’, or in their templates (with the same root), which may differ only in the position of a middle letter (for example, كاتب and كتاب, KATB and KTAB ‘writer’ and ‘book’). These properties of Arabic should result in an orthography in which many migration errors create another existing word, and therefore, given a tendency to produce lexical responses in dyslexia, more errors cannot be ruled out by the reader. Based on these considerations it seems that Arabic-speakers with LPD would make more migrations in reading, and it would be easier to detect letter position deficit in Arabic, compared to languages like English, in which the result of a migration of middle letters is usually a non-word.

These properties of Arabic, then, predict LPD to yield *more* errors in reading Arabic than in other, non-Semitic, languages. On the other hand, another property of Arabic orthography suggests that in Arabic the rate of migrations within words would actually be *smaller* than in other languages. This property is the letter forms, which in Arabic is determined by letter position (and ligation). For some Arabic target words a letter position error creates a word with the exact same letter forms, only in different positions (like تمهل – تهمل TMHL-THML in letter transliteration, ‘slowed down’—‘ignore’, in which the M and the H exchange positions but keep their form). For other target words, however, letter position errors create a word with different letter forms, as is the case when a ligated letter moves to a position after a non-ligating letter (like جهاز -جاهز JHAZ-JAHZ ‘device’- ‘ready’, in which the H alternates between middle-ligating and initial/middle non-ligating forms). In these cases, the same letter has different forms in different positions, and hence, transposing the letters in the middle of the word while keeping their original letter forms would create an orthographically illegal sequence. For example, a migration of the H, keeping its original form in the target word, جهاز would yield جاهز (with an H in a ligating form after a non-ligating letter, which should have been جاهز). Such a sequence is orthographically impossible in all common Arabic fonts. Therefore, when taking letter form into account, fewer words are truly migratable (Friedmann and Haddad-Hanna 2012). Thus, there are two opposing forces with respect to the manifestation of LPD in Arabic and the migratability status of Arabic words, one pulling toward more LPD errors in Arabic, the other pulling in the other direction.

And indeed, reading of texts and of a list of single words that were not selected for the identification of LPD, namely, that did not include enough migratable words, did not reveal LPD for any of the participants. However, once we presented them with migratable words (and migratable non-words) in which migration did not affect the letter form, their LPD was clearly detectible. In fact, LPD turned out to be quite frequent in our sample of Arabic readers with dyslexia, provided that the appropriate words were employed.

Our participants with LPD were 12 individuals with developmental LPD, aged 10.0–17.5 years (average 12.1). We included in this analysis individuals who made significantly more migrations than the normal rate in the oral reading of single migratable words. To assess their oral reading, we asked the participants to read aloud 244 words, of which 75 words were migratable: 45 migratable words that keep the letter form, 15 migratable words that require letter form change, and 15 migratable words that change only the ligation between letters rather than the whole letter form (see examples for the various word types in Table 6.3). The other 169 words were non-migratable. In addition, we asked the participants to read 27 non-words, 12 of which were migratable.

The participants’ reading aloud perfromance indicates that they make letter position errors in reading aloud, as shown in Table 6.1. Whereas Arabic readers without dyslexia in third to fourth grade made no more than a single migration error in the 75 migratable words (M = 0.7 % migrations, SD = 0.7), the participants with LPD made between 8 % and 37 % errors of middle letter migrations in the 75 migratable words (M = 18 % migrations, SD = 9 %).

The participants with LPD had a strong tendency to produce existing words, so they made errors predominantly on migratable words: whereas they made 18 % migrations in the migratable words, they made less than 1 % migration errors in reading the non-migratable words. In addition, most of their migration errors created existing words: 93 of the 102 migration errors they made in reading words were lexical.

Table 6.2 Letter position dyslexia: Average percentage (and SD) of migration errors in various word reading tasks

	Reading single migratable words	Reading migratable non-words	Migratable word-picture association	Migratable word-word association	Lexical decision: migratable non-words
LPD	18[a] (9)	33[a] (22)	57[a] (21)	31[a] (28)	51[a] (24)
Control	0.7 (0.7)	4.2 (6.3)	0 (0)	1.5 (2.7)	0 (0)

[a] Significantly poorer than the control group

Table 6.3 Examples of letter position errors made by the Arabic-speaking LPD participants

Arabic	Graphemic transcription	Phonemic transcription	Translation
Same form			
يعملون → يعلمون	YʕLMWN → YʕMLWN	yaʕlamu:n → yaʕmalu:n	they know → they work
يكتبون → يكبتون	YKBTWN → YKTBWN	yakbitu:n → yaktobu:n	they pent up → they write
يمشون → يشمون	YŠMWN→ YMŠWN	yašummu:n→ yamšu:n	they smell → they walk
يصنع → ينصع	YNṢʕ→ YṢNʕ	yanṣaʕ→ yaṣnaʕ	shines → makes
يحلمون → يحملون	YĦMLWN → YĦLMWN	yaħmilu:n → yaħlumu:n	carrying → dreaming
Ligation change			
جرسين → جسرين	JSRYN → JRSYN	jisrayn → jarasayn	two bridges → two bells
Form change			
جهاز → جاهز	JAHZ → JHAZ	jahiz → jihaz	ready → instrument

This tendency to only make a migration error when the result is another existing word is thus crucial for the diagnosis of LPD in Arabic: if one wants to be able to detect LPD, migratable words have to be included in the word list for diagnosis.

As shown in Table 6.2, the participants also made migration errors on reading migratable *non-words* aloud. They made migration errors on an average of 33 % of the non-words (8 %–75 %).

Letter form had a crucial effect on the rate of letter position errors of the participants with LPD. All participants presented the same pattern: they made fewer letter position errors when the change of position caused change in the letter form than when the position error did not change the letter form. In fact, they made almost no position errors that changed the letter form. Only one transposition of two consonant letters occurred out of a total of 45 words with a potential for form-change consonant migration. This is in contrast with the very high letter-position error rate of 21 %, when the middle letters that transposed did not change their letter form or letter ligation.

Similar results were found for the Arabic readers with developmental and acquired LPD reported in Friedmann and Haddad-Hanna (2012). We tested whether the existence of position-dependent letter forms in Arabic affects the rate of letter position errors in letter position dyslexia. We found, like in the present study, that there were fewer letter position errors when the word that resulted from the error required letter form change (2 % such errors), than when the word resulting from transposition includes the same letter forms as the original word (40 % errors). The participants not only refrained from moving letters that would change their own form, but also refrained from middle letter position errors when they created form change in the final letter, which did not move itself, but was affected by middle letter migration (4 % errors). In addition, even when only the ligation of the letter changed following migration, these errors occurred significantly less frequently (10 %) than migrations that did not change letter form and ligation. (See also Kinoshita et al. 2012, for a discussion of the effect of the position-dependent letter forms on transpositions in normal reading).

Thus, migrations are less likely to occur when they create an illegal orthographic sequence. This is another consideration that should be taken seriously for the diagnosis of LPD in Arabic—not only should the list include migratable words, it also should include migratable words in which the migration does not change the form of any letter.

The migrations of participants with LPD in the current study involved both consonants and vowels. The participants made 16 % migrations that involved only consonant letters changing position, and 19 % migrations in which a consonant letter and a vowel letter swapped positions.

Table 6.3 presents examples of letter migrations that the participants made in reading single migratable words. (In this table and in all other tables in this chapter, the written target words are presented to the left of the arrow, and the oral response, which was an incorrect reading or an "I don't know" response, is presented to the right of the arrow. The left column presents the Arabic target word and response, the next columns present the orthographic transcription, the phonemic transcription, and the translation to English of the target and the response.)

When ascribing migrations in reading to letter position dyslexia, one has to make sure that the migrations indeed result from incorrect letter position encoding in reading, and not from flawed production. This can be tested in two ways: administering reading tests that do not involve oral production, and testing word and nonword production in tasks that do not involve reading.

The reading tasks that do not involve oral production that our participants undertook included: lexical decision, word-to-picture matching, and semantic matching between written words. The lexical decision task included 40 letter sequences, of which half were real words, and half were migratable non-words (like "pecnil"). The participants were asked to decide whether each letter sequence was a word or not.

Another task required migratable word-to-picture matching. This task included triads of a written migratable word and two pictures. The participant was asked to silently read the target word, and to choose the appropriate picture from between two pictures—one matching the word and one depicting its migration counterpart. For example, the written word أسنان, ʔSNAN 'teeth' appeared with a picture of teeth and a picture of a man (corresponding to the migration counterpart, انسان, ʔNSAN ‘person’).

The migratable word association task included 37 triads of words, a target word and two words—one semantically related to the target word, and one related to a migration counterpart of the target word. For example, the participants were asked to choose the word that was more closely related to أسنان ʔSNAN ‘teeth’, from between the word فرشاة, FRŠAḦ, ‘(tooth)brush’, and the word رجل RJL ‘man’, which is related to the migration counterpart of ʔSNAN ‘tooth-brush’, ʔNSAN ‘person’). Here, too, the participant was requested not to read the words aloud and only to mark the matching word.

If the deficit indeed lies in the letter position encoding stage in the orthographic-visual analyzer, the participants are expected to fail not only in reading aloud but also in these reading tasks without reading aloud. If, however, their deficit is in the production stage, they should succeed in these tasks. The results were clear-cut: each of the participants showed a deficit in at least one of these tasks, making migration errors also when no reading aloud was involved. They made an average of 51% errors in the decision on the lexicality of migratable non-words (20%–90% errors, SD=24%); an average of 57% errors in the migratable word-picture matching task (20%–90% errors, SD=21.7%); and 31% in the word association task (6%–94% errors, SD=28%). As summarized in Table 6.2, the performance of the LPD group in each of these tasks was significantly poorer than that of the control participants.

Their performance in the naming and repetition tasks led to the same conclusion: none of them made more migration errors in speech production than did the normal controls, indicating that their difficulty in reading aloud did not result from a production deficit, but rather from a reading deficit in the orthographic-visual analyzer.

Thus, LPD clearly exists in Arabic: it results from a deficit in the orthographic-visual analyzer, in the function of letter position encoding, and its profile is affected by the properties of the Arabic orthography, mainly in that migrations within words only occur when the migration does not cause a form change of any of the letters in the target word.

Importantly, whereas the parents and/or teachers of these children felt that their reading fell short of the level expected from their age and grade, previous reading assessments of these children did not reveal any impaired performance. However, once we used the appropriate type of stimuli, which, in the case of Arabic LPD, are migratable words in which migration does not change the letter forms in the word, the difficulty of the children was very clearly exposed. Using these stimuli, we could detect the high rate of migration errors they made in reading aloud (an average of 21%) and in word comprehension tasks (up to 57% errors), each of them making significantly more errors than children of the same age without dyslexia.

Developmental Attentional Dyslexia

Attentional dyslexia is a reading deficit in which letters migrate between neighboring words, but are correctly identified and keep their correct relative position within the word. For example, the word pair *goat coal* can be read as *goal coal* or even *goal coat*. Another type of error that frequently occurs in attentional dyslexia is the omission of one of the instances of a letter that appeared in the same position in the two words. Such an error would cause the word pair *goat coal* to be read as *got coal*. Additional errors that occur less frequently than the two above are letter migrations from a word that no longer exists in the visual field ("buffer migrations"), and intrusions of letters from a neighboring word to the corresponding position without erasing the original letter in the same position (Friedmann et al. 2010b).

Descriptions of attentional dyslexia in Hebrew and English indicate that almost all migrations preserve the relative position of the migrating letter within the word, namely, the final letter in one word migrates into the same position, the final position, in the other word. This indicates that the between-word position can be impaired while the within-word position encoding remains intact. Letters migrate both horizontally and vertically, namely, from words above and below, to the left and to the right of the target word. Crucially, the lexical status of the migration result affects whether or not such error would occur. Many more migrations occur in attentional dyslexia when the result of migration is an existing word.

What are the predictions for the effect of Arabic orthography on the manifestation of developmental attentional dyslexia in Arabic? Clearly, given the lexical response effect explicated above, languages in which more position-preserving migrations between words create existing words are bound to give rise to more errors in the reading of individuals with attentional dyslexia. Because of the underrepresentation of short vowels and because of the Semitic morphological structure, position-preserving migrations between words are expected to often create existing words in Arabic. On the other hand, letter form can pull the rope in the other direction. We have already seen that in letter position dyslexia, letter forms reduce the rate of letter position errors in Arabic compared with other languages, because changes in letter form block migrations. This factor can reduce the rate of between-word migrations as well. Given that most migrations between words occur in final letters, and that final letters that ligate to the previous word often have a different form than the ones that do not ligate, migrations of the final letter between words might cause many letter form changes, and hence be blocked.

The results indicated, first, that the rate of developmental attentional dyslexia in Arabic was relatively low. Out of the 74 participants with dyslexia we tested, only two participants showed a reading pattern that is characteristic of developmental attentional dyslexia, one of whom had additional types of dyslexia as well.

The pattern of errors of these two participants was similar to those described in the literature from Hebrew (Friedmann et al. 2010b). The participants with attentional dyslexia, LA, a girl aged 9.1, and BO, a boy aged 9.0, made predominantly letter migrations between words. LA made between-word migrations in 22 % of the word pairs and in 10 % of the words presented one above another in the list; BO made 26 % and 6 %, respectively.

In addition, like the Hebrew-speaking developmental attentional dyslexics reported by Friedmann et al. (2010b), LA also made omissions of letters that occurred in the same position in the two words. She made 22 % such doubled letter omissions.

In most cases, when the participants read the target words incorrectly they ended up producing an existing word—LA produced only three non-words, and BO had six non-word errors. Migration errors between words occurred both horizontally, between two words in a pair, and vertically, when the words were presented one above the other in a list. (Some other responses were "don't know" responses, as shown in Table 6.4). Table 6.4 presents examples of between-word errors that the participants made in reading word pairs.

Developmental Visual Dyslexia

Visual dyslexia is a deficit in the orthographic-visual analysis stage that causes visual errors in reading (Crutch and Warrington 2007; Cuetos and Ellis 1999; Lambon Ralph and Ellis 1997; Marshall and Newcombe 1973). Visual errors are substitutions, omissions, and additions of letters. An error is defined as visual error when at least half of the letters in the error response are present in the target word (Morton and Patterson 1980). Because there are other types of dyslexia that result from a deficit in the orthographic-visual analyzer and present specific types of errors (such as letter position errors in LPD), a further condition for classifying an error as a visual error is that the participant's errors cannot be accounted for by a specific deficit in the orthographic-visual analyzer such as letter position dyslexia, attentional dyslexia, or neglexia (Friedmann et al. 2012). (For example, the errors of a person who makes predominantly letter migrations, even if these errors are consistent with the definition of half of the errors in the response present in the target, would not be defined as visual errors, but rather as the more specific error type: letter position errors.) Visual dyslexia has two subtypes: one that results from a deficit in the orthographic-visual analysis system that selectively impairs the ability to encode abstract letter identity, and one that results from a deficit in the output of the orthographic-visual analyzer (Friedmann et al. 2012).

We identified 6 Arabic-speaking children who had developmental visual dyslexia, all of whom had visual dyslexia of the second type, namely, a deficit in the output of the orthographic-visual analyzer. The error types they made in reading aloud included substitutions, omissions, additions, migrations of letters within words, and between words, as shown in Tables 6.5 and 6.6. Each of the participants with developmental visual dyslexia made all these kinds of errors, and none of them showed a tendency to make errors on a specific side of the words. They made 42 % errors on average in word reading (range: 27 %–50 %, SD = 8 %).

Importantly, this pattern of errors of the six participants did not stem from a phonological output deficit. This can be deduced from the good performance of these participants on tests of phonological output that do not involve reading, and from a reading input test that does not involve phonological output. In a test of non-word repetition (ARABLIP, Haddad-Hanna and Friedmann 2010), five of the six participants with developmental visual dyslexia performed within the normal range, and made no more than 3 errors on the 42 complex non-words they repeated. One participant, AH, made many errors in the non-word repetition task, so it seems

Table 6.4 Examples of between-word errors made by the Arabic-speaking attentional dyslexia participants in reading a list of word pairs

Arabic	Graphemic transcription	Phonemic transcription	Translation
Migrations between words			
مفر قطَر[1]	QṬR MFR		
أسد حبى → أسد قبى	ĦBA ʔSD → QBA ʔSD	Ħaba: ʔasad → qaba: ʔasad	crawl lion → non-word, lion
حصار عمان → حصان, مش عارفة	ʕMAN ĦṢAR → *D.K*, ĦṢAN	ʕamma:n ħisa:r →*D.K* ħisa:n	Amman siege → horse, DK
Omissions of a doubled letter			
حمير سرير → سر, مش عارفة	SRYR ĦMYR → SR, *DK*	Sari:r ħami:r → sir *D.K*	bed donkeys → secret, DK
بان صالون → بان صالو	ṢALWN BAN → ṢALW BAN	*ṣa:lun* ban → *ṣa:lu* ban	living room appear → living room (Pal. Arabic), appear
مفر قطر → مفر قط	QṬR MFR → QṬ MFR	qaṭar mafar → qiṭ mafar	Qatar escape → Qatar, cat

The target Arabic word pairs are presented here from left to right for the ease of comprehension of the transcription and translation

D.K I don't know

[a] In this example, this word pair appeared above the next, and the migration was vertical, namely the letter K migrated from the top word to the word below it

Table 6.5 Examples of visual errors made by the Arabic-speaking participants with developmental visual dyslexia

Arabic	Graphemic transcription	Phonemic transcription	Translation
Migration			
وزير → وزري	WZYR → WZRY	Wazi:r → wazri:	minister → non-word
معطف → مطعف	MʕṭF → MṭʕF	miʕṭaf → miṭʕaf	coat → non-word
أمل → ألم	ʔML → ʔLM	ʔamal → ʔalam	hope → pain
Omission			
أكلت → أت	ʔKLT → ʔT	ʔakalat → ʔat	she ate → non-word
فادي → دي	FADY → DY	fa:di → di	name → non-word
مجدي → مجد	MJDY→ MJD	majdi → majd	name → name
Addition			
جاء → جاءت	JAʔ → GAʔT	ja:ʔ → ja:ʔat	he came → she came
صور → ضصور	ṣWR → DṣWR	ṣu:r → ḍaṣu:r	pictures → non-word
شر → شعر	ŠR → ŠʕR	šar → šaʕr	evil → hair
Substitution			
ضرب → عرب	ḍRB → ʕRB	ḍarb → ʕarab	beating → Arabs
كتان → كتاب	KTAN → KTAB	Kitta:n → kita:b	linen → book
كرم → كتم	KRM → KTM	karm → katam	generosity → mute

Table 6.6 Distribution of errors of the 6 participants with developmental visual dyslexia out of 204 words each participant read

Total visual errors	Add—middle	Sub of visually similar letters	Om—middle	Mixed error—om + sub/add in several positions	Mig	Mig + add	Mig + om	Mig + sub	Mig between words	Om/sub/add—right	Om/sub/add—left
512	43	59	76	115	22	11	33	15	10	67	61

sub letter substitution, *om* letter omission, *add* letter addition, *mig* letter migration within word

that he also had a deficit in phonological output, but, crucially, he also had a deficit in reading input. His input reading deficit is indicated by his poor performance in lexical decision on 50 letter strings, that included 35 non-words for which letter addition, substitution, omission, migration, or diacritic marks errors creates an existing word; and by his chance performance, indicating a guessing pattern, in a written word comprehension task that required him to circle one of two migratable words that was semantically related to a third word (see the section on letter position dyslexia for the description of this test). Three other participants with visual dyslexia were tested in these input reading tasks, and all of them performed poorly on these tasks (average of 63 % correct on the lexical decision tasks, and 53 % correct on the migratable words association task), indicating an input-reading, rather than output-speech, impairment.

As shown in the examples in Table 6.5, unlike in LPD, migrations in visual dyslexia occur also in exterior letters—the first and the last letters do not necessarily preserve their within-word position.

Developmental Neglect Dyslexia

Neglect dyslexia is a dyslexia that has been thoroughly described in its acquired form, for a large number of individuals with acquired neglect dyslexia in several languages (Arduino et al. 2002, 2003; Arguin and Bub 1997; Behrmann et al. 1990; Bisiach et al. 1986; Bisiach et al. 1990; Caramazza and Hillis 1990; Cubelli et al. 1991; Ellis et al. 1987; Ellis et al. 1993; Haywood and Coltheart 2001; Miceli and Capasso 2001; Patterson and Wilson 1990; Reznick and Friedmann 2009; Riddoch et al. 1990. See Vallar et al. 2010 for a review). Developmental neglect dyslexia has so far been reported only in Hebrew (Friedmann and Nachman-Katz 2004; Nachman-Katz and Friedmann 2007, 2008, 2009, 2010). Readers with neglect dyslexia at the word level (neglexia) neglect one side of the word. This results in omissions, substitutions, or additions of letters on one of the sides of the word, typically on the left side. Research in Hebrew showed that the left side of the word is more sensitive to neglect errors when it is part of the affix, and is almost never omitted when it is part of the root (Reznick and Friedmann 2009).

One feature of Arabic orthography that would lead to a different manifestation of neglexia from the one known from studies of (acquired) neglect dyslexia in English, Italian, and other European languages, is the reading direction in Arabic. Because Arabic is read from right to left, neglexia, which typically manifests itself on the left side of words, would affect the end, rather than the beginning, of words in Arabic.

One of our Arabic-reading participants, CR, showed this pattern of developmental neglect dyslexia. CR was a 10 year-old girl, in fourth grade. She made many visual errors in her oral reading: substitutions, letter omissions, additions, and migrations within words. She made no semantic errors. In the task of oral reading of single words, non-words, and word pairs presented in lists, she made 74 (47 %) visual errors on the word list, 12 (44 %) visual errors on the non-word list, and 13 visual errors (57 % of the pairs) on the list of word pairs. Therefore, we initially suspected that she had visual dyslexia. However, when we further analyzed her visual errors, we realized that her errors shared an important common feature—almost all of them occurred on the left side of the words. Namely, her errors actually resulted from neglect dyslexia. In total, 57 of her 74 visual errors on single words occurred on the left side of the word (77 %), and so did 10 of her 12 errors on non-words. In reading the 23 word pairs, 11 of her 13 visual errors occurred on the left side of the words.[2] Thus, her error pattern indicated neglexia. Examples of her errors are given in Table 6.7.

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[2] An error was classified as left-side error when it occurred from a certain position in the word and until the end (left-side) of the word: namely, when the erroneous response was identical to the target word to the right of an identifiable neglect point in the target word, and shared no letters in

Table 6.7 Examples of errors of an Arabic-speaking girl with developmental neglect dyslexia

Arabic	Graphemic transcription	Phonemic transcription	Translation
Omission on the left			
بابا → باب	BABA → BAB	ba:ba → ba:b	daddy → door
وثبوا → وثب	WθBUA → WθB	waθabu: → waθaba	they jump → he jumps
Addition on the left			
ذباب → ذبابة	ðBAB → ðBABḦ	ðuba:b → ðuba:ba	flies → fly
ورقة → ورقارة	WRQḦ → WRQARḧ	waraqa → waraqa:ra	paper → non-word
Substitution on the left (same number of letters)			
جرح → جرّة	JRĦ → JRḦ	jarħ → jarra	wound → jar
ربحتم → ربحتل	RBĦTM → RBĦTL	rabiħtum → rabiħtul	you win → non-word
جمع → جمل	JMʕ → JML	jamaʕa → jamal	collect → camel
(different number of letters)			
طيارة → طياريقة	ṬYARḦ → ṬYARYQḦ	ṭayya:ra → ṭaya:riqa	plane → non-word
سلاح → سنيحة	SLAħ → SNYĦḦ	sila:ħ → saniħa	weapon → non-word
كمال →كان	KMAL → KAN	kama:l → ka:n	perfection/name → was
شعير → شعياج	ŠʕYR → ŠʕYAJ	šaʕi:r → šaʕYa:j	barley → non-word
كرة →كركر	KRḦ → KRKR	kura → karkar	ball → non-word
ضيعَّ → ضيالام	ḌYʕ→ ḌYALAM	ḍayyaʕa→ ḍaya:la:m	wasted → non-word
همام→ همايا	HMAM→ HMAYA	hamma:m→ hama:ya:	name → non-word

CR never omitted the words on the left side, only letters on the left side of the word. In reading the 23 word pairs, she made no omissions of the left word, indicating that her neglexia was at the word- rather than the text-level.

Her errors clearly resulted from a deficit in reading (neglexia), rather than an impairment at the phonological output buffer. In a picture naming task (SHAMS, Haddad-Hanna et al. 2010), she made 17 errors, but these errors were mainly semantic (which she never produced in reading), and none of them was phonological or involved the end (the left side) of the word. In addition, a non-word repetition task (ARABLIP) showed that she did not have specific difficulties with the ends of words. In fact, she made no errors at all in non-word repetition.

Thus, developmental neglect dyslexia also exists in Arabic, and it presents a reading pattern similar to the one reported for acquired neglect dyslexia. Given the reading direction in Arabic, when this impairment affects the left side of words, in Arabic it affects the end, rather than the beginning of the words.

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common to the left of the neglect point (see discussions with regard to the definition of neglect errors in Ellis et al. (1987) and Vallar et al. (2010)). Therefore, for example, a left-sided error could be an omission or substitution of the last (leftmost) letter or an omission or substitution of all the last 4 letters.

Developmental Surface Dyslexia

So far, we have described the manifestation in Arabic of dyslexias that result from an impairment in the orthographic-visual analyzer. We now move to present and discuss impairments in later stages of reading, in the lexical and sublexical routes.

Individuals with surface dyslexia read via grapheme-to-phoneme conversion due to a deficit in the lexical route. Reading via the grapheme-to-phoneme conversion route instead of via the lexical route (which connects the orthographic input lexicon and the phonological output lexicon) creates several problems in reading. Firstly, individuals with surface dyslexia make more errors in reading irregular words than expected for their age. When presented with irregular words such as *listen,* door*,* or *come*, they are likely to read them incorrectly, because the accurate reading of such words requires the word-specific knowledge that is contained in the lexical route, and specifically, in the orthographic input lexicon. Regular words, namely, words for which reading via the sublexical route results in the correct phonological form, are usually read correctly. In this dyslexia, non-words, which are read only via the sublexical route, which is intact for individuals with surface dyslexia, are also read well. Surface dyslexia usually also affects the reading rate, causing a slower reading process (Spinelli et al. 1997). For individuals with surface dyslexia whose orthographic input lexicon is impaired, comprehension is impaired too: homophones like *which* and *witch*, which can only be distinguished on the basis of the orthographic input lexicon but sound the same when read via the sublexical route, are indistinguishable for them. Finally, data from Hebrew (Friedmann and Lukov 2008) show that words that can be read via the sublexical route as other existing words (*potentiophones*), are more susceptible to errors. For example, whereas a word like “now” can be read via grapheme-to-phoneme conversion sounding like “no”, an irregular word like “knife” cannot be read as another existing word, in which the k is sounded out, and hence, might be read correctly when the reader monitors the production of only existing words.

How do these characteristics manifest when a surface dyslexic reads Arabic? There are almost no homophonic letters in the Standard Arabic orthography. This could lead to better chances of correct reading, even via the sublexical route. On the other hand, short vowels are not represented in the orthography, so words can include consonant strings that are underspecified for vowels. In this case, a reader with surface dyslexia, who reads only via the grapheme-to-phoneme conversion route, has to guess the appropriate vowel, which is missing from the orthographic representation of the word. Notice, that the definition of irregular words has to be refined when we come to consider reading in surface dyslexia in Arabic. Whereas irregular words in English are words that include silent letters (like *talk, comb,* or *knife*), and words that include ambi-phonic graphemes (a letter or a group of letters) that can be converted in two or more ways into phonemes and are converted, in the specific word, into the less frequent phoneme (like the letter *i*, which is pronounced one way in *kid* and another way in *kind*), in Arabic, irregularity takes a different form. In Arabic (as is the case also in Hebrew, see Friedmann and Lukov 2008), a considerable source of irregularity is the underrepresentation of short vowels, which leads to many degrees of freedom in reading many words. Therefore, ambiguity in

Table 6.8 Examples of errors made by the Arabic-speaking participants with surface dyslexia

Arabic	Graphemic transcription	Phonemic transcription	Translation
Incorrect choice of unspecified (lexically determined) vowels			
جمعة → جمع	JMʕḦ→JMʕ	jumʕa→jamaʕa	Friday → collected
ضربة → ضرب	ḍRBḦ→ ḍRB	ḍarba→ ḍaraba	blow (noun) → he hit
فتحة → فتح	FTĦḦ → FTĦ	fatħa → fataħa	open/fatħa → opened
كي → كِي	KY → KY	kay → ki	because → non-word
سوف→سوف	SWF → SWF	sawfa → su:f	will → non-word
كسرة → كسر	KSRḦ → KSR	kasra →kasara	piece → he broke
اصطفوا → اصْطَفَوَا	AṣṭFWA→ AṣṭFAWA	Ɂisṭafu:→ Ɂisṭafawa:	(they) lined → non-word
Incorrect application of specific conversion rules and dialect homophones			
ورقة → ورقت	WRQḦ → WRQT	waraqa → waraqat	paper → non-word
طمّ → طم	ṭM → ṭM	ṭamma → ṭam	covered → covered (Pal. Arabic)
الشمس→ الشّمس	ALŠAMS→ ALŠAMS	Ɂaššams→ Ɂalšams	the-sun → phonologically non-exiting sequence
اذاً → اذا	AðA → AðA	Ɂeðan → Ɂeða:	so → if
ضار → دار	ḍAR → DAR	ḍa:r → da:r	harmful → house
وضيع → وديع	WḍYʕ → WDYʕ	waḍi:ʕ → wadi:ʕ	inferior → male name

conversion is an important source of irregularity, and hence, of difficulty for individuals who read via the grapheme-to-phoneme conversion route.

This irregularity in Arabic would clearly lead individuals with surface dyslexia to incorrect reading, especially in cases where there are potentiophones that differ only with respect to their vowels. For example, the word فتحة, FTħḦ could be read in various ways if read via grapheme-to-phoneme conversion, because of the underspecification of the vowels on the first two letters. The correct reading of this letter string according to the lexicon is *fatħa* (the name of a diacritic marker representing the vowel/a/), but reading it via the sublexical route could lead to some other phonological strings that are existing words, such as *fataħa* 'he opened', which is written as فتح, FTħ.

Within our group of participants, nine participants had surface dyslexia. One of them had a pure surface dyslexia, and 8 had surface dyslexia in addition to another dyslexia. Most of the errors they made were in the vowel pattern of words, when this vowel pattern was lexically, but not orthographically specified (see examples in Table 6.8). These errors were especially frequent in potentiophonic words like *fatħa*.

Other errors that these participants made related to letters that are homophonic in their spoken dialect. For example, in some dialects of the Palestinian Arabic spoken in Israel, D and ð (د, ذ) sound the same. This infiltrated into the reading of the participants with surface dyslexia who speak this dialect, causing them to read one as the other, and hence, to have more homophonic-like and potentiophonic words than we had initially expected (see examples in Table 6.8). This dialectal homophony also led these participants to make errors in lexical decision, accepting non-words that for them were pseudo-homophones, as they included d instead of ð, or vice versa.

One frequent source of difficulty for Arabic-readers with surface dyslexia was words ending with UA (e.g., اصطفوا, AṣṭFWA). This letter combination is irregular because according to the conversion rules it should be read as *wa,* but it actually stands for the masculine plural ending of past-tense verbs, read as */u:/*.

Other errors that were frequent for the participants with surface dyslexia related to the conversion of special orthographic symbols such as *shadda* (◌ّ), which denotes the doubling of the consonant; *hamza* (ء), which appears alone or with a vowel letter and denotes a glottal stop; *tanwin fatħa*, (اً), which appears as a double fatħa; the diacritic sign for the vowel */a/*, sometimes followed by *ʔalif,* but which requires pronouncing an ‘n’ sound, which is not written, *ta:ʔ marbu:ṭa*(ة, transcribed in the examples as Ḧ), which appears in the end of the word and sounds like *fatħa (short a)* in unvoweled Arabic, but sounds like *t* when it appears in the end of the first word in a construct state nominal; and *ʔalef makṣu:ra* (ى), a short *a* sound that appears at the end of a word, written as the letter y without the dots diacritics (for example, مكوى, MKWA, iron). (For a discussion of the structure of Arabic language and orthography, see Saiegh-Haddad & Henkin-Roitfarb, Chap. 1).

The participants’ error rate in word reading was quite high for words underspecified for vowels (that are not potentiophones, 31 % errors), for potentiophones (41 %), for words with sounds that are indistinguishable in their dialect (9 % errors), and for words with the special symbols described above (69 % errors). Their reading of non-words, which are read on the basis of grapheme-to-phoneme conversion rules, on the other hand, was quite good—they read 91 % of the non-words correctly (in this analysis we excluded the errors that result from the participants’ additional dyslexia, if there was one).

Developmental Vowel Dyslexia

Vowel dyslexia is a disorder that results from an impairment in the sublexical route, which selectively impairs the way the sublexical route processes vowels (Khentov-Kraus and Friedmann 2011). Individuals with vowel dyslexia omit, substitute, transpose, and add vowel letters. Relevant examples in English might be reading *bug* for *big*, *form* for *from*, and *boring* as *bring*, or *bring* as *boring*.

If a person reads normally, via the lexical route, vowel dyslexia would only be manifested when s/he reads non-words, because only when s/he uses the grapheme-to-phoneme conversion route does the deficit in this route evince. For readers with vowel dyslexia who also have surface dyslexia, the picture is different. Because they read even existing words via the sublexical route, they make vowel errors not only when reading non-words but also when reading existing words.

Interesting interactions of vowel dyslexia with Arabic relate to three aspects of the Arabic orthography. Firstly, unlike Hebrew, the only language in which vowel dyslexia has been documented so far, each vowel letter in Arabic corresponds to a single long vowel. This would allow for the assessment of the question of whether vowel dyslexia occurs in Hebrew because of the ambiguity of vowel letters. If it does, we should not expect vowel dyslexia to occur in Arabic. Another interesting aspect of the Arabic orthography relates to the differences between long and

Table 6.9 Examples of errors made by the Arabic-speaking participants with developmental vowel letter dyslexia

Arabic	Translation	Phonemic transcription	Graphemic transcription
Vowel addition			
جمع → جميع	GMʕ → GMYʕ	jamaʕa → jami:ʕ	plural → all
عمان → عامان	ʕMAN → ʕAMAN	ʕamma:n → ʕa:ma:n	Amman → 2 years
كوب → كواب	KWB → KWAB	ku:b → kwa:b	cup → non-word
Vowel migration			
جهاز → جاهز	JHAZ → JAHZ	jiha:z → ja:hiz	device → ready
يجود → يوجد	YGWD → YWGD	yaju:d → yu:jad	(he) grants to → exists
ختام → خاتم	XTAM → XATM	xita:m → xa:tim	end → ring
Vowel omission			
بحار → بحر	BĦAR → BĦR	biħa:r → baħr	seas → sea
ملاك → ملك	MLAK → MLK	mala:k → malik	angel → king
شعار → شعر	ŠʕAR → ŠʕR	šiʕa:r → šaʕar	symbol → felt
Vowel substitution			
صالون → صولون	ṣALWN → ṣWLWN	ṣa:lon → ṣulon	salon → non-word
سكين → سكان	SKYN → SKAN	sikki:n → sukka:n	knife → population

short vowels. Arabic clearly distinguishes long from short vowels, and whereas the long ones are always encoded orthographically (and unambiguously so), the short vowels are almost never represented in written words. Therefore, Arabic provides a rare opportunity to test whether another type of vowel error occurs: whether, on top of vowel substitution, addition, migration and omission, individuals with vowel dyslexia also make short vowels long, and long vowels short. Thirdly, we have seen that Arabic letter-forms modulate migrations that result from an impairment at the orthographic-visual analyzer level, in LPD. Data from Hebrew vowel dyslexia indicate that vowel position errors are frequent in vowel dyslexia. We therefore found it interesting to assess whether letter-form also affects migrations that result from an impairment at the sublexical route or only migrations that result from a deficit in the early stage of the letter position encoding function in the orthographic-visual analyzer.

Vowel dyslexia, although never reported in Arabic, was surprisingly frequent in our sample of Arabic readers with developmental dyslexia. In fact, it was one of the most frequent types of dyslexia in our sample. The sample included 13 participants with vowel dyslexia, who made more errors in vowel letters than the control group, and more errors in vowel letters than in consonants. In total, they made vowel errors on 43.3 % of the single words in the TILTAN test that included vowel letters. These vowel errors were 15.7 % vowel additions, 14.9 % vowel migrations, 13.2 % vowel omissions, and 6 % vowel substitutions (see examples in Table 6.9). Many of the vowel addition and omission errors were in fact shortening of a long vowel, or elongation of a short vowel. This is because short vowels are not represented in the orthography, whereas long ones are represented with a vowel letter. We encoded the responses accordingly. Namely, when a participant said a short vowel, we wrote down his response, and encoded the short vowel he said with no vowel letter; when the participant said a long vowel, it was encoded with the relevant vowel letter. Therefore, the encoding of a target word with a short vowel sound (that is not represented in the orthography) that was read with a long sound included an addition of a long vowel letter. When the participants read the long vowel letter as a short vowel, it was encoded as the omission of this letter.

Similar to the Hebrew-readers with vowel dyslexia reported by Khentov-Kraus and Friedmann (2011), the Arabic-speaking participants made errors both when the vowel letter functioned as a vowel (i, a, u) and when it functioned as a consonant (y, ʔ, w). This is expected, given that vowel dyslexia is only manifest when one reads via the sublexical route, and the sublexical route does not have the information about the function of a vowel letter in a particular word.

Importantly, the errors in reading were not a result of difficulties in the spoken production of vowels, as indicated by the good performance of the participants in the ARABLIP non-word repetition test, as well as by their spontaneous speech and performance in the picture naming task.

Finally, a very interesting pattern was observed with respect to the vowel migration errors. Above we described the effect of letter form on letter migrations that result from a deficit at the orthographic-visual analysis stage: in LPD, letter form change blocks migrations. However, vowel dyslexia results from a deficit at a later stage of written word processing, in which letter form is no longer encoded. Therefore, vowel migrations that result from vowel dyslexia showed a different pattern: as exemplified in Table 6.9, vowel position errors occurred even when they required a change in letter form (such as جهاز →جاهز). This supports the distinction between vowel migrations that result from vowel dyslexia and vowel migrations that result from LPD, and suggests a way to distinguish between the two.

Developmental Deep Dyslexia

Deep dyslexia is characterized primarily by semantic errors in reading, as well as by morphological and visual errors, a severe deficit in the reading of function words that results either in substitution for another function word or complete inability to read them; better reading of nouns than verbs and adjectives; and better reading of imageable and concrete words compared to abstract words (Coltheart 1980; Coltheart et al. 1987; Marshall and Newcombe 1973). This reading pattern was interpreted within the dual route model as multiple lesions in both the sublexical grapheme-to-phoneme conversion route and in the direct lexical route between the orthographic input lexicon and the phonological output lexicon, which force the reader to read via meaning (Ellis and Young 1988). Deep dyslexia has been studied intensively in its acquired form, but several studies have also reported cases of developmental deep dyslexia, with reading patterns that are similar to those reported for acquired deep dyslexia (Johnston 1983; Siegel 1985; Stuart and Howard 1995; Temple 1988, 1997).

The interaction of the unique properties of Arabic with deep dyslexia yields two main aspects in which deep dyslexia in Arabic would be manifested differently than in other languages. Firstly, the diglossic situation is expected to affect the reading of individuals with deep dyslexia. Written Arabic is Standard Arabic, whereas the Arabic spoken by our participants is Palestinian Arabic, which differs in phonology, lexicon, and syntax from the standard, written Arabic. In addition, our participants also speak Hebrew as a second language. This creates an interesting test case for the interaction between diglossia and deep dyslexia: if reading proceeds exclusively via meaning, and if naming and speaking occur in Palestinian Arabic, reading words presented in Standard Arabic might result in the production of words in Palestinian Arabic. The additional language that the participants speak and the multi-language culture they live in might also give rise to the preference of some Hebrew words that are used also in the Arabic-speaking environments.

A second interaction of the properties of Arabic and deep dyslexia relates to morphology in Arabic. Arabic, as a Semitic language, has a rich morphological structure in both nouns and verbs. Verbs are typically built from three-consonant roots that are incorporated in verbal templates, and many nouns are similarly constructed from a three-consonantal root incorporated in nominal templates. This allows for the investigation of the types of morphological errors that occur in deep dyslexia: would the root be kept and the template changed? Will the other type of errors also occur, with the template kept and the root changed? In addition, since some syntactic properties such as passive voice and tense are signaled in verb inflection, inflection plays a crucial role in the probability of correct reading. The reading of various types of inflection (tense, passive, subject agreement) was therefore assessed.

Five of our participants showed a reading pattern that was typical of developmental deep dyslexia. We will describe here the reading pattern of FA, a 15 year-old Palestinian Arabic-speaking boy. FA was supported by a remedial teacher and occupational therapist for reading problems, writing problems, and difficulty in coping with school assignments. FA was healthy, and has never sustained brain injury; therefore, one can assume that his dyslexia is developmental. The fact that FA's brother, HA, was also deep dyslexic further supports the congential, and possibly genetic source of FA's dyslexia.

We administered to FA an oral reading task of a long list of words that was sensitive to the special characteristics of deep dyslexia. The task included single words of various kinds that were selected to detect deep dyslexia: function words, abstract versus concrete nouns, words with a common synonym or words that are usually produced in another language (Palestinian Arabic, Hebrew, or English), morphologically complex verbs, inflected for various tense and agreement forms, and verbs with a bound object pronoun, and morphologically complex nouns. In addition, FA read non-words.

FA's reading was very slow and impaired and he got tired very quickly. During the test he complained he had a headache because of having to read, and three meetings were required to finish reading the list of 236 words. FA read a mere 4 % of the words correctly.

The error types that characterized FA’s reading were exactly the ones that are typical of deep dyslexia. He made semantic errors, which is the error type that defines deep dyslexia. For example, he read طبل ṭBL ‘drum’ as دف DF, ‘a hand drum’, and يوميات, YWMYAT ‘diary’, as دفتر DFTR, ‘notebook’. Another type of error that is frequent in deep dyslexia, morphological error, was also frequent in FA’s reading. For example, he read تفاحة TFAĦḦ ‘an apple’ as تفاح TFAĦ ‘apples’, and كاتبتني, KATBTNY, ‘she-wrote-me’ as كتاب KTAB ‘book’. He also made visual-then-semantic errors, reading تراب TRAB ‘soil’ as عصفور, ʕṣFUR ‘bird’, probably via the visual error غراب, ƔRAB ‘crow’. He made some visual errors, such as رحمة RĦMḦ, ‘mercy’ which he read as حمامة ĦMAMḦ ‘dove’.

Because readers with deep dyslexia read via the semantic route, the reading of words that do not carry a precise semantic content, such as function words and abstract words, is severely impaired. And indeed, FA read correctly only 2 of 20 function words. He made errors of reading another function word instead of the target function word, such as الى ‘to’ → من ‘from’, visual errors, أنه ‘that-he’ → الله ‘God’, substitutions with visually similar words in Palestinian Arabic, هل, a yes/no question word → هوا ‘air’ in Palestinian Arabic, don’t know responses, and visual or semantic errors.

Abstract words are also especially difficult when reading via the semantic route. Indeed, FA read only 2 of the 25 abstract words correctly. Most of his errors were semantic errors, and other errors included morphological, visual-then-semantic, visual or semantic (شمعة ŠMʕḦ ‘candle’ → شمس ŠMS ‘sun’), semantic or morphological (مكتب ‘office’→ كتاب ‘book’; مفتاح ‘key’ → مفتوح ‘opened’), visual, and unclear errors, as well as “don’t know” responses. FA substituted 17 of the abstract words for concrete words or proper names.

Morphological errors are also characteristic of deep dyslexia. And indeed, FA’s reading of the two sets of morphologically complex words, the nouns and the verbs, was very impaired. In reading the morphologically complex verb list, FA could not read even a single verb correctly. He made 34 % morphological errors, mainly comprised of inflection errors and omissions of the bound pronoun, and 17 % morphological and visual errors. The rest were visual-then-semantic errors, visual errors, errors that could be classified as either morphological, visual, or semantic, and “don’t know” responses. Interestingly, he also made what could be interpreted as morphological-then-semantic errors. For example, he read يجيبانه, YGYBANH ‘they-both-are-answering-him’, as سيّارة SYARḦ, ‘car’. We suggest that what led to this error was first a morphological decomposition of the word, which isolated the root جيب GYB and then, because this root word means ‘jeep’, a further semantic error which led to the word ‘car’. This kind of error has an important bearing on the order of morphological decomposition and semantic processing. Just like the consistent order of visual-then-semantic errors indicates the not-too-surprising fact that visual analysis of written words precedes semantic processing, the order of morphological-then-semantic errors indicates that the morphological decomposition occurs in a pre-semantic stage. This result supports studies of morphological decomposition that suggested an early, pre-semantic locus for morphological processing (Deutsch et al. 2000; McCormick et al. 2008; Rastle et al. 2000; Rastle and Davis 2008; Reznick and Friedmann 2009).

In reading morphologically complex nouns, FA showed a similar pattern. He managed to read correctly only 2 of the 35 words. He made mainly semantic errors (سيّارات ‘cars’ → ساق ‘drove’), morphological errors (جذور ‘roots’ → جذر ‘root’), visual errors, and visual-then-semantic errors (جارة, GARӪ ‘neighbor’ → دجاجة DGAGӪ ‘hen’, probably via جاجة GAGӪ, ‘hen’ in Palestinian Arabic).

To examine the effect of the special diglossic situation in Arabic on deep dyslexia, we presented FA with a list of words in Standard Arabic that have common synonyms in Palestinian Arabic or in Hebrew. FA could not read correctly even a single word from this list, which included 34 words. Again, he mainly made semantic errors, and also had some morphological, visual-then-semantic or visual errors. One particularly interesting visual-then-semantic error was made for the target word شاحن ŠAĦN ‘charger’, which he read as مريض MRYḌ ‘sick’, probably via the visual error ساخن SAXN, which means ‘sick’ in Palestinian Arabic. This error is not only a good example of visual errors occurring before the semantic ones during the reading of a word, but also shows the effect of diglossia on his reading. Other words were read with a more direct indication of the effect of diglossia and bilingual context on his reading: FA read دار, DAR ‘house’ in SA, as ‘bet’, house in PA, he read هاتف, HATF ‘phone’ in SA, as تلفون, ‘telefon’, an international word, used also in PA. Furthermore, because many speakers of PA are also speakers of Hebrew as a second language, and because some Hebrew words have become part of spoken PA, FA, who had basic knowledge of Hebrew, read some words as their Hebrew counterpart. For example, the word حاسوب, ĦASWB ‘computer’ in Arabic, was read *maxšev*, which is the Hebrew word for computer.

Another girl with developmental dyslexia, SU, who was tested when she was 16 years old, further demonstrated the crucial effect of the Arabic diglossia on reading in deep dyslexia. For example, when presented with the SA word for ‘sit’ جلس JLS, SU read the PA counterpart of the word, (قعد) أعد, ʔʕd ‘sit’ in Palestinian Arabic, and the word طبيب, ṬBYB, medical doctor in SA, was read *daktor*, the word used in PA. In addition, semantic errors usually did not only include a semantic paralexia but were also produced in PA, when the word was initially presented in SA. For example, the word لوح, LWĦ, ‘blackboard’ in Standard Arabic, was read as *maħħay*, ‘eraser’ in Palestinian Arabic. Like FA, she also read some words as their Hebrew counterpart. For example, she read the Arabic word بريد, BRID ‘post’, as the Hebrew word for post *doʔ*ar, and like FA, she also read the SA word for computer as its Hebrew counterpart.

In non-word reading, both FA and SU showed very severe impairment. FA could not read any item from the 47 non-word list. He lexicalized 38 of the non-words, reading them as words, and produced 8 “don’t know” responses. His lexicalizations involved mainly visual errors: كدنرة KDNRӪ → كبيرة KBYRӪ ‘big’, and visual-then-semantic errors such as خزال, XZAL → زرافة, JRAFӪ ‘giraffe’, probably via غزال ɣZAL ‘deer’. We presented SU with 39 three-to-five letter non-words. She could read only one of them. She responded to 17/39 non-words with a “don’t know” response, and commented several times “I know all the letters but I cannot read it nevertheless”. She made (11) lexicalizations; for some of them she said she knew it was not the target word. For example, for the non-word *rugaa,* she read *giraa* (glue) and said “I know it should start with ‘r’ but what actually goes out of my mouth is giraa.”

6.2 Conclusion

This large-scale study of dyslexia in Arabic had two aims: to describe the effect of the special nature of the Arabic orthography and language on the manifestation of dyslexia, and to identify and characterize types of dyslexia in Arabic. Our results clearly show the intricate interactions between the characteristics of Arabic and the manifestation of each type of dyslexia.

This research identified and described for the first time 7 types of developmental dyslexia in Arabic: letter position dyslexia, attentional dyslexia, visual dyslexia, neglect dyslexia, surface dyslexia, vowel dyslexia, and deep dyslexia. The mapping of the various types of developmental dyslexia in Arabic joins a growing body of evidence for the existence of types of developmental dyslexia, each very similar to the respective type of acquired dyslexia. (For a comprehensive survey of this literature, see Brunsdon et al. 2002; Castles et al. 1999, 2006; Castles and Coltheart 1993; Coltheart and Kohnen 2012; Jones et al. 2011; Marshall 1984; Temple 1997.)

The mapping of types of developmental dyslexia has theoretical, as well as clinical and educational implications. Theoretically, more and more research seeks the functional and biological sources of dyslexia. Our findings indicate that a single source of deficit is not likely to be able to account for such a variety of developmental dyslexia subtypes. Rather, the various types of dyslexia, in Arabic as in other languages, can be naturally accounted for by a neuropsychological approach ascribing each type of developmental dyslexia to a deficit in a different component of the reading processes, similar to subtypes of acquired dyslexia (Castles et al. 2006; Castles and Coltheart 1993; Coltheart et al. 1983; Marshall 1984; Temple 1997).

The identification of subtypes of developmental dyslexia in Arabic also bears clinical and educational implications. With respect to diagnosis, given that each type of dyslexia has different characteristics and different types of words sensitive for its exposure, and given the interaction of each dyslexia and the properties of Arabic orthography, when one comes to diagnose an Arabic-speaking person with dyslexia, the diagnosis tools should accommodate the specific types of dyslexia and their specific manifestations in Arabic.

Furthermore, given that the source of each type of dyslexia is different, different types of treatment and approaches for reading instruction are required for the different dyslexias.

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