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Abstract	Braille reading is a crucial literacy skill for blind individuals and an important model to study non-visual modes of communication. Many studies have addressed Braille reading in English, but no previous study targeted Arabic Braille reading. Here we report our findings on Braille reading accuracy and speed in three different age-groups of Arab participants in Israel: 10(±2.5) year-olds attending elementary schools (*N*=20), 16(±1.7) year-old high-school students (*N*=13) and young adults (23±2.6 years) (*N*=24). All participants read vowelized and unvowelized word lists and vowelized and unvowelized texts printed in Arabic Braille. The results showed that as in studies of English Braille reading, Braille reading rates in Arabic improve as a function of the readers' age. However, Arabic Braille readers were consistently slower compared to English Braille readers. In addition, Arabic Braille readers were prone to read less accurately, with participants of all age-groups committing more phonetic reading errors in the unvowelized word lists and texts compared to the vowelized reading tasks. On the other hand, the older participants did not commit mirror-image errors or letter-skipping errors, which were noted in the younger participants. We discuss the results in the light of the specific characteristics of Arabic, especially diglossia and the homography of unvowelized Arabic.
Keywords	Arabic - Blindness - Braille reading - Braille template - Tactile discrimination - Reading proficiency - Reading speed and accuracy - Visual impairment

Chapter 18
Braille Reading in Blind and Sighted Individuals: Educational Considerations and Experimental Evidence

Waleed Jarjoura and Avi Karni

Abstract Braille reading is a crucial literacy skill for blind individuals and an important model to study non-visual modes of communication. Many studies have addressed Braille reading in English, but no previous study targeted Arabic Braille reading. Here we report our findings on Braille reading accuracy and speed in three different age-groups of Arab participants in Israel: 10(±2.5) year-olds attending elementary schools (N=20), 16(±1.7) year-old high-school students (N=13) and young adults (23±2.6 years) (N=24). All participants read vowelized and unvowelized word lists and vowelized and unvowelized texts printed in Arabic Braille. The results showed that as in studies of English Braille reading, Braille reading rates in Arabic improve as a function of the readers' age. However, Arabic Braille readers were consistently slower compared to English Braille readers. In addition, Arabic Braille readers were prone to read less accurately, with participants of all age-groups committing more phonetic reading errors in the unvowelized word lists and texts compared to the vowelized reading tasks. On the other hand, the older participants did not commit mirror-image errors or letter-skipping errors, which were noted in the younger participants. We discuss the results in the light of the specific characteristics of Arabic, especially diglossia and the homography of unvowelized Arabic.

Keywords Arabic · Blindness · Braille reading · Braille template · Tactile discrimination · Reading proficiency · Reading speed and accuracy · Visual impairment

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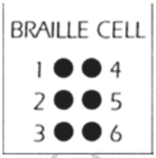
E. Saiegh-Haddad, R. M. Joshi (eds.), *Handbook of Arabic Literacy*, Literacy Studies,
DOI 10.1007/978-94-017-8545-7_18,

Fig. 18.1 The structure of the basic Braille cell matrix (template)



18.1 Introduction

Reading is an ability acquired in childhood that becomes a lifetime skill necessary for various occupations, including formal education, communication and leisure activity (Snow-Russel 2001). Individuals with severe visual impairments or total blindness use an adapted, standardized reading system called the Braille code which is based on tactile discrimination skills rather than on vision.

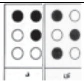
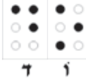
A basic Braille template (cell) is a tactile configuration of six raised (embossed) dots, organized in a matrix of 2 × 3 dots each. Various combinations of 5 dots, or any smaller number of dots, represent an alphabetical letter, a consonant, a vowel, a number, a diacritical mark or an abbreviated suffix. For example, the full six dot pattern represents an abbreviation of the word 'for' in English or the letter ظ ð̣ in Arabic Braille (Jarjoura 2004). The convention is that each raised dot has its own corresponding number starting with dot #1 in the left upper corner and continuing downwards on the vertical left axis of the matrix and then transferring to the upper right dot #4 and continuing downwards on the right vertical axis of the matrix (see Fig. 18.1).

In Arabic Braille, the discrimination between Braille vowels and Braille consonants is considered a prerequisite for proficient reading. The Braille vowels are actually standard Braille templates that represent diacritics in visual Arabic. These templates in Arabic Braille have totally different phonological representations in other languages (see Fig. 18.2).

Some Braille templates in one language have no parallel representation in another language and in other cases the template for a consonant in one language serves as a vowel in a different language. For instance, the Arabic letter ***ḍ*** ض representing the phoneme /***ḍ***/ and the Hebrew letter צ/*ts*/ and the English Braille abbreviation for '*the*' share the same template (see Fig. 18.3). Another example is the representation of the letter Y ي (representing the consonant/*y*/ and the long vowel/i:/) in Arabic, 'iy' in English and 'Yod-Hirik'- יוֹד חיריק in Hebrew by the same template (see Fig. 18.3b).

Braille 'writing' is by necessity performed using a machine, i.e., it is a typing-related skill based, unlike handwriting, on an accurate timing of both hands. For non-electronic media, letters are printed by a Perkins-Brailler, a standard mechanical hand-used Braille 'typewriter'. This generates the various spatially-organized patterns as small raised dots on a surface of the printed page. Braille letters are printed from left to right in all languages, including Arabic and Hebrew (Jarjoura 2004). In recent years various software programs and hardware devices have become available for converting the standard computer keyboard for Braille printing and on-line Braille reading.

Fig. 18.2 Examples for Braille letters representing different phonological units in three languages

Arabic* Braille	English Braille	Hebrew* Braille
		

18.2 Tactile Discrimination for Braille

Tactile perception is served by a sensory system that is quite different from the visual one. However, as in visual reading (in which part of the skill relates to acquired eye-movement abilities) Braille reading requires the establishment of a motor component—the tactile scanning of the text—as a necessary aspect of the Braille reading skill. Thus, the specific structure and characteristics of the tactile sensory system as well as the generation of effective motor tactile scanning routines pose specific challenges for the acquisition of Braille reading skills. The skin surface (i.e. the finger-pads) includes three types of mechano-receptors: slowly-adapting (SA), rapidly-adapting (RA) and Pacinian fibers. The first respond to stationary or slow contact of the finger-pads with embossed tactile surfaces, whereas the other two types respond to dynamic, active tactile scanning by light-touch movements of the finger-pads across surfaces of tactile stimuli. All mechano-receptors are connected to the corresponding spinal cord segments. In Braille reading with the finger-pads, these fibers run into the dorsal spinal root in segments C4–C5 and then through the antero-lateral tract (pain, discriminative light touch and temperature) and the dorsal-column tract (proprioception, vibration and sense of graph-aesthesia) to the thalamus in the contra-lateral hemisphere. Thalamo-cortical tracts continue to the cerebral parietal cortex where wide-range neural representations of the sensory facets of the tactile stimuli are consciously and volitionally processed (Johansson and Vallbo 1979).

There is good evidence in support of the notion that the physical aspects of the Braille letters are matched and named on the basis of tactile physical features; i.e., that Braille reading skills are highly specific to the template that is consistently used for printing. Studies (Millar 1986; Grant et al. 2000) have shown that proficient Braille readers (English) are not universally more effective in terms of tactile performance than sighted readers and that if sufficient training and practice is afforded for the sighted non-Braille reader participants, their discriminative performance for Braille letters improves. On the other hand, multiple studies (Grant et al. 2000; Van Boven et al. 2000; Kauffman et al. 2002; Goldreich and Kanics 2003, 2006; Jehoel et al. 2009) have shown that blind adults significantly out-performed sighted adults in various tactile discrimination tasks throughout the lifespan. One should keep in mind however, that blindfolded, sighted participants may perform significantly better than sighted participants in tactile discrimination tasks (Kauffman et al. 2002).

Millar (1977) tested 12 proficient Braille readers (mean age, 10.2 years). They were asked to discriminate and name English Braille letters presented in pairs. The

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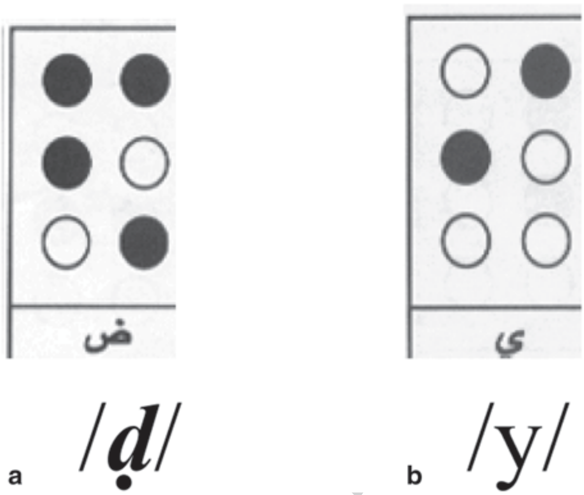

Fig. 18.3 Braille template representing **a** ض, and **b** ي in Arabic

letters were of two sizes: standard and enlarged. Only two of the faster (most fluent Braille readers) subjects were able to name the enlarged letters without mistakes; four participants were able to correctly name the enlarged letters after a single training session. The slower Braille readers needed an average of 8.2 training sessions before they succeeded in correctly naming the enlarged letter pairs in the two test trials. All participants took longer to name the enlarged letters compared to the standard letters, and the response speed differences were larger for the slower participants compared to the faster participants.

18.3 Experimental Studies in Sighted Naïve participants

Tactile discrimination and matching of Braille letters was also tested in sighted individuals (e.g., Loomis 1981; Heller 1989; Grant et al. 2000; Goldreich and Kanics 2003). These studies lend support to the notion that Braille letter discrimination can be enhanced by intensive tactile experience, even in sighted adults; this discrimination learning, however, is contingent on the participants being blindfolded during the tactile training experience. For example, Kauffman et al. (2002) compared the performance of 24 healthy, sighted subjects (mean age: 25 years) on a Braille character discrimination task. Participants were randomized into one of four sub-groups: blindfolded with intensive tactile stimulation, blindfolded and non-stimulated, sighted with intensive tactile stimulation and sighted, non-stimulated. Subjects in the blindfolded groups (stimulated and non-stimulated) were completely visually deprived for 5 consecutive days using a specially designed blindfold. The tactile 'stimulated' groups (sighted and blindfolded) took part in an intensive tactile stimulation program for at least 6 h per day (4 h of Braille learning and 2 h of playing tactile games). These participants were told to use predominantly their right index finger. The non-stimulated groups were given 6 h of free time without

Book ID: 321407_1_En ChapterID: 18 Dispatch Date: 14/12/2013 ProofNo: 1

specific instructions. All participants were tested using a computerized Braille character recognition task on days one, three and five of the experiment. All participants were blindfolded during the Braille testing session, in which consecutive bilateral presentations of Braille letter templates were raised in opposition to both the right and the left index finger-pads, simultaneously. Participants were asked to judge whether the Braille letter pair was of the same formation or of a different formation. Results showed that blindfolded subjects performed better than sighted subjects in the Braille discrimination task. Furthermore, the stimulated sub-groups showed significantly more improvement in Braille recognition ability compared to non-stimulated sub-groups. Thus, there is good support for the notion that Braille letter discrimination can be considered as a perceptual or perceptual-motor skill and as such Braille letter discrimination learning would be subject to the advantages and constraints imposed on procedural skill learning and procedural memory consolidation in other sensory and sensory-motor domains (Karni et al. 1994; Karni 1996; Karni and Bertini 1997; Bitan and Karni 2004; Ari-Even Roth et al. 2005; Goldreich and Kanics 2006; Censor et al. 2006; Dorfberger et al. 2007).

According to an accepted neurobiological and cognitive model, long-term memory can be divided into declarative ('what') memory and procedural ('how to') memory (Squire and Zola 1996). According to this dichotomy, the first is considered a more cognitive and flexible system for the explicit recollection of events and factual information. The second is perceived as a memory system that serves the retention of performance gains acquired implicitly during the actual execution of given tasks (Karni 1996). Declarative knowledge (of facts and events) is typically distinguished from procedural knowledge by being accessible to awareness, being often acquired through a single experience and involving cortico-limbic brain systems. Procedural skill learning, on the other hand, is evident by improvement of the performance of a given task; it is not necessarily conscious, requires multiple repetitions and is subserved by different cortical areas (Karni 1996; Squire and Zola 1996). Both declarative and procedural knowledge can be acquired either by explicit or by implicit learning instructions.

Jarjoura (2012) investigated the efficiency of a newly developed standardized intervention approach for initial Braille learning for naïve sighted, blindfolded subjects ($n=31$, mean age 27.2 (SD±4.6), 8 males and 23 females). Participants of both groups (intervention and control) were native speakers of Arabic. Sighted, blindfolded naïve young adults with no prior experience with Braille were assigned randomly into two groups. In the first session, both groups were trained in 6 blocks of 16 trials each, with paired, standard Braille letters (S-S format) that were presented for palpation only to their right index finger. Immediately after the training phase, the control group had 20 min of free break while the study group (intervention group) underwent 20 min of explicit instruction, by the researcher, on the spatial structure of the Braille template and other specific features of the Braille code, such as enumeration and various dot-combinations. Immediately after, both groups continued training in four blocks of the S-S format Braille letter pairs. Tactile discrimination time and verbal responses were recorded for speed and accuracy after a 24 h interval, on the following day, as well as after a 3 month interval. Both groups showed robust within-session and between-session learning effects, including the expression of delayed gains (Karni 1996) and very effective long-term retention. However, after the 3 month interval, while both groups showed additional gains in trained Braille letter discrimination compared to the performance at 24 h post-training, the participants were slightly slower in discrimination of Braille in an enlarged format compared to their achievements 3 months previously. But, the intervention group was better in this transfer condition indicating that the intervention may afford a better opportunity for generalization of the skill to Braille letters of different sizes. In a follow-up test 6-months post-training, both groups maintained their previous (3 months) speed and accuracy achievements to a similar degree.

18.4 Pre-literacy Educational Approaches for Young Blind Children

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Various pre-literacy educational approaches (Wormsley and D'Andrea 1997; Pena and Zapata 2002) have been developed and implemented in children with blindness or severe visual impairments. These programs are skill-oriented and, thus, focus on improving specific skills such as fine motor abilities, tactile discrimination (of various materials rather than the Braille dots), fine-motor coordination, muscle strength, general language abilities, age-related play skills and precision and accuracy in motor performance. Work towards improving auditory memory and naming abilities in verbal tasks is often included. Later, in the literate stage, young blind children are explicitly instructed in various cognitive-lingual skills for text decoding, e.g. Braille letter naming and Braille letter numeration (i.e., repeated training on the child's ability to explicitly report the 6-dot matrix for various letters, numerals and symbols). There is also emphasis on tactile-motor training for Braille discrimination and recognition, e.g. general tactile investigation of the raised dots in Braille code, tactile discrimination of a specific Braille cell's configuration, the ability to maintain a coherent spatial orientation of lines and columns and printing skills using bilateral hand coordination (Perkins Brailler). Practice on letter naming and dot enumeration and tactile motor training are the two major instructional methods assumed to enhance Braille reading ability and to improve Braille reading accuracy and speed. However, numerous studies have found that reading speed and accuracy are also affected by contextual constraints, hand usage, and age (Mousty and Bertelson 1985; Knowlton and Wetzel 1996; Trent and Truan 1997).

In Israel, a standardized preparatory program for Braille learning is administered in all educational programs for children with severe visual impairments or total blindness (Kadmon 1998). The program details 9 different fields of developmental function that are specifically targeted: (1) palpation skills (2) games for acquiring basic language concepts (3) games for enhancing word familiarity (4) affordance of basic familiarity with books, including Braille books, and reading behaviors (5) listening skills and auditory differentiation ability (6) hand movement skills relevant to Braille reading (7) perceptual differentiation between 'similar', 'equivalent' and different' (8) tactile differentiation of Braille code without naming, and later with naming (9) familiarity with the Perkins-Brailler and producing Braille-dot printing.

This graded program offers direct training in tactile discrimination and matching skills of Braille cells.

In elementary school, blind Israeli students are taught the same curricular program as their sighted peers. Curricular textbooks are printed in Braille and assignments are printed but similar academic achievements are expected from blind students and sighted students in order to prepare the blind children for high school level and university studies. Adaptations of educational and teaching methods (e.g., detailed oral descriptions; tactile exploration) are usually implemented when required on an individual basis.

18.5 Teaching Approaches for Braille

Lowenfeld, Abel and Kedris (1969), as cited in Harley and Rawls (1970) found that two-thirds of the teachers in residential and day school programs implement the word or sentence method for Braille teaching, whereas a third of the teachers surveyed began Braille instruction with the sequential introduction of the Braille alphabet, printing, tactile-discrimination and recognition of single letters (Grade 1 Braille). Most current conventional programs for teaching Braille are initiated by a sequential, single Braille character introductory program. Next, two-character words, followed by short word presentation, longer words and then short sentences are gradually introduced with abbreviations and contractions (Grade 2 Braille). Once short texts have been introduced, children are encouraged to implement and acquire reading habits such as fast reading and two hand usage in tactile discrimination.

Steinman et al. (2006) compared the development of print and Braille reading in children in relation to Chall's stage model (Chall 1983) of reading development which includes a pre-reading stage (stage 0) and five succeeding stages. On the basis of the comparison, the authors concluded that readers of both print (visual) and Braille (tactile) text formats may progress through similar acquisition stages. Currently, there is no developmental model that directly addresses the issue of Braille literacy and Braille reading development.

In Israel, for both Hebrew and Arabic native speakers, primary school children with severe visual impairments or blindness begin Braille learning with a focus on the letters a, b, l and k which are constituted of raised dots on the left axis of the basic Braille template. The logic is that these "simpler" letters are made of a minimal dot quantity of 1–3 and are arranged only in a vertical, serial spatial configuration. In this phase (I) letter printing, tactile discrimination and recognition (naming and enumeration) are taught. In phase II instruction continues with printing, tactile discrimination and recognition (naming and enumeration) of letters with one or two dots on the right vertical axis (such as the letters M /*m*/, Š/ š/ and R /*r*/, in Arabic) and a few basic vowels that are constituted of an additional single raised dot on the right axis of the basic Braille template.

Later, in the 1st grade, more complex and high density dot configurations (e.g., the Braille letters corresponding to the Arabic letters T /*t*/ or Q /*q*/) are taught (phase III). These letters are followed by word and short sentence Braille reading, Braille

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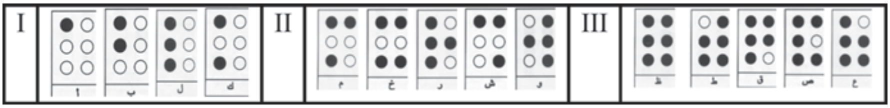

Fig. 18.4 Examples of Braille letters introduced in the different 'phases' (*I–III*) of Braille teaching in the Arabic language

printing exercises and training on simple reading comprehension skills. (Fig. 18.4: phase I, phase II, phase III.) One should note that diglossia (see Myhill, in this collection) is also a factor in Arabic Braille teaching (Abu-Rabia 2000; Saiegh-Haddad 2004, 2005, 2007, 2012; Leikin et al. 2009; Ibrahim 2009); the words and sentences used in Braille reading instruction are identical (at phase III onwards) to the standard Arabic school materials for sighted students.

Even when diglossia is not an issue, as in English and Italian, within the first school year and throughout the elementary school years, Braille reading children fare lower on basic phonological, semantic and orthographic skills than sighted peers on both speed and accuracy measures (Packer 1989; Legge et. al. 1985, 1989; Greaney and Reason 1999; Wetzel and Knowlton 2000). Many of the gaps in academic achievements between blind and sighted school children are usually met through individual support administered by teachers with special education training in the mainstream elementary and high-school systems as well as in elementary school special education programs.

18.6 Fluency and Accuracy Measures in English Braille Readers

Nolan and Kedris (1969) reviewed nine studies and summarized them by focusing on the effects of multiple factors that may affect English Braille reading. The review addressed the effect of aspects such as word length, familiarity, Braille specific orthography (the influence of the numbers and position of dots, and influence of Braille contractions) and context on recognition thresholds for words. The contribution of these factors to Braille word reading at the elementary school level as well as in low-intelligence readers was assessed. The reviewers also addressed the effect of character recognition training on Braille reading. Data relevant to the current review is presented in Table 18.1.

The data presented by Nolan and Kedris (1969) clearly reveals a consistent advantage for regular readers in mainstream schools compared to both visually impaired and blind readers in regard to their reading rates using a word-per-minute measure (Table 18.1). Large print readers attained, barely, half the reading rates of the regular readers. The reading rates of the Braille readers, while closing, at high-school level, the gap vis-à-vis the large print readers, were nevertheless more than twice as much lower than those of the regular readers.

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Table 18.1 Reading rates (in words-per-minute, wpm) in the 6th grade and high-school level in regular readers, large print readers and English Braille readers (based on the Nolan and Kedris (1969) review)

Readers' groups	6th grade	High-school
Regular readers	Average 6th grade reader, 179 wpm	Average high school reader, 215 wpm
Large print readers	Large print 6th grade reader, 79 wpm	Large print high school reader, 95 wpm
Braille readers	Braille 6th grade reader, 59 wpm	Braille high school reader, 83 wpm

Knowlton and Wetzel (1996) investigated the effects of various reading tasks on the reading performance of expert adult Braille readers. The reading rates of their sample of expert adult English Braille readers varied greatly. Many of the subjects read at rates that were significantly faster than the average of 90 wpm often reported in the literature on Braille reading, with some individuals attaining reading rates of 240 words per minute in studying a test text. However, the authors argue that any measure of the reading rate for Braille reading must take into consideration more than a perceptual process of word recognition because reading constitutes much more than the recognition of words *per se*. For example, oral reading was 30 % slower compared to silent reading (Knowlton and Wetzel 1996).

The Texas School for the Blind and Visually Impaired (TSBVI-1997; http://www.tsbvi.edu/instructional-resources/1020-assessment-kit#Contents) developed an assessment kit for various individual Braille reading related skills for the blind or visually impaired. This source provides some additional information regarding the average Braille reading rates in English. The average reading rates for 3rd graders are reported as 51 wpm and this rate increases very moderately to 67 wpm by the 6th grade; these rates are consistent with the average reading rate (90 wpm—Grades 5–12) that were reviewed by Nolan and Kedris (1969) 30 years earlier. College students were found to read Braille at a rate twice as fast as 5th graders (115 wpm).

Students of different age-groups with a visual impairment generally read at a much slower rate than students without a visual impairment due to the slower non-visual (tactile) reading modality (Packer 1989; Legge et. al. 1985, 1989; Wetzel and Knowlton 2000). Not only does the reading of Braille, and large print of standard texts, generally require more time than reading regular print by vision, but the time needed to explore and interpret various pictorial information presented as tactile or enlarged graphics can be a tedious and time-consuming process. Therefore, extended time seems to be an obvious accommodation for this population of visually impaired students. Researchers have suggested that time extensions (based on classroom experience or research data) on the order of 1.5–2 times the standard (sighted) time allotted for print reading is appropriate for students with low vision reading large print (Gompel et al. 2004; Morris 1974; Packer 1989; Spungin 2002). Similarly, for Braille readers, a time extension on the order of 2–2.5 times the normal print reading time was suggested (Kedris et al. 1967; Morris 1974). Recently, a 5-fold increase in the allotted reading time was suggested for experienced adult Braille readers (Wetzel and Knowlton 2000).

Table 18.2 Reading rates (*in words per minute-wpm*) for two Arabic reading tasks in elementary, high school and young adults, blind participants. Note that the unvowelized text included almost twice as many more words than the vowelized text

Texts: Age-groups	Vowelized, Arabic text (*70 words/541 letters*)	Unvowelized, Arabic text (*134 words/667 letters*)
Adults (*N*=24)	46 wpm	57 wpm
High-school students (*N*=13)	35 wpm	44 wpm
Elementary school children (*N*=16)	25 wpm	37 wpm[a]

[a] Only three children were able to perform the task

18.7 Performance in Arabic Braille Readers

Jarjoura (2010) investigated Braille reading proficiency speed and accuracy in three age-groups of Arab participants in the northern district of Israel: adults, mean age 23.3 (±2.55) (*N*=24), high-school students, mean age 16.4 (±1.7) (*N*=13) and elementary school children, mean age 10.3 (±2.8) (*N*=16). Participants were asked to read aloud two different texts in Arabic in two conditions: with and without vowels. The unvowelized texts were simplified and adapted from news websites while the vowelized text was based on elementary school level texts in Arabic. Reading rates (in words per minute) in the two reading tasks are summarized in Table 18.2.

The Braille reading rates measures presented in Table 18.2 show that adult blind participants consistently achieved higher Braille reading rates compared to the younger age-groups of blind participants in both Arabic reading conditions. Nevertheless, the between-group differences were significant only for the vowelized Arabic reading speed ($F_{(2, 38)}=7.6$, $p<0.01$); no significant difference was found in the non-vowelized Arabic reading rates, ($F_{(2, 35)}=0.32$, p=n.s.) possibly because only very high performers from the youngest age-group were able to complete the text and were included in the statistical analysis. One should note that the switch to unvoweled text reading occurs in Braille teaching, as in print teaching for sighted children, during the 5th grade; the young participants in the current study were recruited from the 5th and the 6th grades.

In the same study (Jarjoura 2012) reading errors were also analyzed. The errors committed were sorted into five types according to whether tactile-perceptual or linguistic aspects were focused on: substitution of mirror-reversed letters (such as p and q or b and d in printed English) (Millar 1985, 1997); one dot discrimination errors (Millar 1997; Nolan and Kedris 1969); missing letters; phonetic errors in vowels (Saiegh-Haddad 2004, 2007; Abu-Rabia and Taha 2006; Abu-Rabia 2007); lexical violation (Ibrahim et al. 2002; Saiegh-Haddad 2004; Abu-Rabia and Taha 2006).

The results showed that in the vowelized Arabic Braille text, the youngest age-group tended to commit the greatest number of errors, while adults were more accurate. Adults showed errorless performance in the mirror-image inversion and missing letter categories. Phonetic errors in vowels and one dot discrimination errors were the most common type of errors encountered in adults. The high-school students self-corrected significantly more than the adults, while the youngest age-group's reading was characterized by an intermediate number of self-corrections.

In the unvowelized Braille text reading task, no significant differences were found between the three age-groups in any of the six error types; in other words, all error types were found to be distributed evenly across age levels. The most common error type in both Arabic Braille reading task types was the phonetic error (vowel switching). This may reflect a characteristic of Semitic orthography, where 'real' letters representing consonants and vowels are inferred from the context. A similar finding was reported by previous studies with sighted, native Arabic readers (Abu-Rabia and Taha 2006; Abu-Rabia 2007). However, in the Arabic Braille reading tasks, for the vowel switching errors, there was a significant group (reading experience) effect in the *vowelized* Arabic Braille text reading condition but not in the *unvowelized* Arabic Braille text reading condition. The findings suggest that tactile skill related errors in unvowelized Arabic Braille reading shows no significant reading experience differences from 5th grade and up to young adulthood, but lexical and phonologic errors decrease with reading experience.

Another interesting finding was revealed in relation to the mirror-error type. The blind adult readers committed some mirror-errors while reading unvowelized Braille text but no such errors were present in the reading of the vowelized Braille text. On the other hand, the elementary school and high school participants made some mirror-errors in the vowelized Braille text reading task but not in reading the unvowelized Braille text. In addition, the one-dot error type was found in both Arabic Braille reading tasks in all age-groups. Both error types (mirror-image error and one-dot error) are considered tactile-based errors. Note that in Braille about half the alphabet is a mirror-image of the other half (compared to the p–q and b–d in English).

18.8 Conclusion

There is good support for the notion that Braille letter discrimination can be considered as a perceptual or perceptual-motor skill and as such Braille letter discrimination learning would be subject to the advantages and constraints imposed on procedural skill learning and procedural memory consolidation in other sensory and sensory-motor domains (Karni 1996; Karni and Bertini 1997; Bitan and Karni 2004; Goldreich and Kanics 2003, 2006). Although skilled reading requires multiple language and pragmatic skills, one should note that one dot discrimination errors in Braille letter reading persist into adulthood, even in the context of a text (Nolan and Kedris 1969; Millar 1997; Jarjoura 2012).

There is significant variance between the different studies on Braille reading rates and reading accuracy as a function of Braille reading experience. Moreover, the measurement methods for obtaining these assessments differ from response times (speed) in Braille letter discrimination to text reading (Millar 1977, 1997; Grant et al. 2000; Van Boven et al. 2000; Kauffman et al. 2002; Jarjoura 2012). Most studies, moreover, are concerned with Braille reading of English and very little is known about Braille reading in other languages. New data (Jarjoura 2012) regarding Arabic Braille reading proficiency and tactile discrimination speed and accuracy suggests that the contributions of Braille reading experience are not of a simple nature. Braille reading and especially Braille reading error rates in Arabic seem to be differentially affected by factors such as vowelized vs. unvoweled text reading. Moreover, diglossia and tactile-perceptual aspects may exert their effect on speed and accuracy of Braille reading in a differential manner.

Some limitations of the reading proficiency measurements in the various studies might be related to the heterogeneous study groups of blind or visually impaired participants and the relatively small number of subjects in each study compared to numerous studies rconducted with larger numbers of sighted print readers. Consequently, both limitations must be addressed and controlled in future studies in order to achieve more consistent measures of Braille reading proficiency in order to study and improve Braille reading instruction in blind and visually impaired individuals.

A significant issue is the unique features of the Arabic Braille orthography. The vowelized Arabic text is significantly longer and more complex for reading than the unvowelized Arabic text due to the necessity for activating more serial phonological abilities in order to read, thus affecting reading speed as well as accuracy. Another issue that needs to be directly addressed is that the majority of the older blind participants in the Arabic community in Israel are actually multi-lingual individuals because they are formally involved in the learning of Arabic, Hebrew and English Braille reading in the different Israeli educational institutes in respect to their age and educational level. Consequently, Braille consonants and vowels of the different languages (all of which use the very same Braille template) may actually have consolidated into multiple phonological representations in memory serving the different languages. Therefore, interference phenomena may affect reading fluency and accuracy in each specific language.

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