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Ambiguity resolution in lateralized Arabic

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Abstract We examined ambiguity resolution in reading in Arabic. Arabic is an abjad orthography and is morphologically similar to Hebrew. However, Arabic literacy occurs in a diglossic context, and its orthography is more visually complex than Hebrew. We therefore tested to see whether hemispheric differences will be similar or different from previous findings in Hebrew. We also tested whether phonological recoding is a mandatory stage in reading Arabic. We used a divided visual field paradigm, where 32 participants performed semantic decisions on pairs of words in which the first word (presented centrally) was either a homophone (*bank*), heterophone (*tear*), or unambiguous. The second word was presented in the left, right, or central visual field. The results revealed larger effects of ambiguity for heterophones than for homophones in all conditions, and thus support the contention that phonological recoding is mandatory in reading Arabic. Hemispheric patterns were different from those found with Hebrew, and were similar in the peripheral visual fields, which can be interpreted as indicating a single processor, with the pattern indicating that this processor is the LH. The alternative hypothesis is that interhemispheric integration occurs in all conditions. The implications of these results for reading in Arabic are discussed.

Keywords Arabic · Ambiguity resolution · Reading · Laterality

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Word recognition requires readers to quickly access semantic representation. However, it often happens that readers encounter words that have more than one distinct meaning entailing a selection of meanings. A large amount of research has examined the timing of the interplay between orthographic, phonological, and semantic representation of words. Of special interest has been the relative involvement of the cerebral hemispheres in the process of ambiguity resolution. The consensus in the field is that the left hemisphere (LH) and the right hemisphere (RH) differ significantly in the way they process written words. Specifically, some studies (e.g., Burgess & Lund, 1998; Coney & Evans, 2000; Faust & Chiarello, 1998; Titone, 1998) have shown that this processing differs in the way the LH and the RH take advantage of word frequency and contextual information to access the appropriate meanings of words. According to this view, all meanings are immediately activated in the LH and shortly afterwards, one meaning is selected on the basis of word frequency and/or context. In contrast, in the RH, all meanings are slowly activated and maintained, regardless of word frequency and contextual information.

The majority of this research has been done on English speakers reading English and the models proposed to underlie these findings seem to reflect the characteristics of English, as do many psycholinguistic models (see Share, 2008 for a discussion of this Anglo-centrism). The two major models in the field propose somewhat different architectures: Beeman's (1998) fine/coarse coding model posits different structures of semantic networks in the two hemispheres. The network in the left hemisphere (LH) is proposed to be fast, fine grained, and highly selective, whereas the network in the right hemisphere (RH) is proposed to be slower, coarse grained, and is hypothesized not to have selection capabilities at all. In the second model, Federmeier's (2007) PARLO model, hemispheric architecture differs in the connections between lexical and semantic representations. In the LH, because comprehension and production processes share a common substrate, these connections are bidirectional. In the RH however, connectivity flows only bottom-up—from the lexical to the conceptual. Thus, top-down processing, such as priming by context and predictive processes are lateralized to the LH, while bottom-up processes and later processes of meaning integration occur also in the RH.

Recently Peleg and Eviatar (2012 for a review) have suggested another perspective on differential hemispheric involvement in reading, based on Hebrew. They proposed that hemispheric differences could arise as a result of different relations between orthography and phonology in the two hemispheres. Specifically, they posit that orthography, phonology, and semantics are fully interconnected in the LH, but that in the RH, there are no direct connections between orthographic and phonological representations—these are associated only via semantics. Thus, previous patterns of asymmetric performance with homophonic homographs such as *bank*, may be explained by this architecture more simply than by proposing differential hemispheric organization for semantics as proposed by Beeman (1998). This model is congruent with the PARLO model (Federmeier, 2007) and actually specifies the mechanisms by which it could work: When the homographic word *bank* is presented to the LH, the orthographic pattern is quickly and automatically translated into a phonological pattern which activates both meanings. However, because the meaning of *bank* as the side of a river is less frequent, it is not selected, so that activation of this meaning is either inhibited or deteriorates quickly. Thus in the LH, for early probes, both meanings are activated, and in later probes, only the more frequent, dominant meaning is activated. In the RH, the orthographic pattern activates semantic representations before phonology, and this takes longer, such that at early probes, neither meaning is activated, and at later probes, both meanings are still activated.

Hebrew orthography affords testing this model because Hebrew is an abjad (Daniels, 1990), a writing system that mainly represents consonants, and where optional vowels appear only in specialized texts such as children's books and poetry. Vowels appear as diacritical marks above, within, or below the consonants. For example, the combination of consonants and diacritics סֵפֶרis read as/*sefer*/, meaning 'book', whereas the same combination of consonants with different diacritics סַפָּר is read as/*sapar*/, meaning 'barber'. Diacritics are omitted in most texts, resulting in large numbers of both homophonic (e.g., *bank*) and heterophonic (e.g., *tear*) homographs.

When readers encounter the triad ספר without the diacritics and without context, they usually read it as/*sefer*/(book), because this form is more frequent in the language. This characteristic of Hebrew allows the dissociation of phonology and orthography. In homophonic homographs (e.g., *bank*), both orthography and phonology activate more than one meaning, whereas in heterophonic homographs (e.g., *tear*), orthography can still activate two meanings, but phonology does not. Once a phonological form has been assigned to the orthographic pattern, the ambiguity is resolved. This dissociation is rare in alphabetic, Indo-European orthographies such as English, in which vowels are represented as fully fledged letters, resulting in a small number of heterophones. This is the reason that studies of ambiguity resolution in general, have focused on homophones. Thus, phonological and orthographic ambiguities have always been confounded in studies using Indo-European orthographies.

In Peleg and Eviatar's (e.g., 2008, 2009, 2012) studies, the pattern of asymmetry with homophones replicated the results of studies that had used English. However, the pattern of asymmetry with heterophones was different, and revealed that when semantic ambiguity arises from phonological ambiguity, it is the RH that has faster and more efficient resolution than the LH.

The present study examined performance asymmetries in Arabic. Arabic is of special interest for several reasons. In terms of Peleg and Eviatar's model, because Arabic orthography is an abjad like Hebrew, the process of ambiguity resolution should be similar in the two languages. However, as detailed below, the linguistic situation of Arabic readers is complex. As will be shown, the study of the neurolinguistics of Arabic is crucial for theoretical reasons. In addition, Arabic is the official language of 27 countries, and has over 300 million speakers—it is the fifth most common language in the world. However, the psycholinguistics and neuro-linguistics of Arabic have only recently begun to be studied (e.g., Saiegh-Haddad & Joshi, 2014). In spite of the fact that in general, literacy levels are related to economic status, in Arab countries, the level of literacy is worryingly low

(Azzam, 1984; Maamouri, 1998; PISA 2009), irrespective of economic measures. The present study is part of an ongoing project to examine the reasons for this. Thus, the study of the neurolinguistics of Arabic is also crucial for practical reasons.

Reading in Arabic

Similarities to Hebrew

Like Hebrew, Arabic is an abjad, where the graphemes represent consonants, and is written from right to left. Although long vowels in Arabic are represented by letters, similarly to Hebrew, optional short vowels are represented as diacritics above or below the letters. These diacritics are omitted in texts intended for skilled Arabic readers in newspapers and ordinary books. As in Hebrew, many isolated words are semantically and phonologically ambiguous. For instance, in addition to homophones, there are many heterophones. For example, the written forms of the word جَزَر "carrot"/jazar/and جُزُر "islands"/juzor/are orthographically indistinguishable when written unvowelized جزر)). The reader has to rely on context or prior knowledge to deduce the correct pronunciation and meaning of the intended words.

In Indo-European languages, morphological composition is achieved through concatenation, whereby adding a morpheme as the prefix or suffix of a word creates an inflectional meaning. Arabic, like Hebrew, has a nonconcatenative morphology in which the root and other phonemes of a word-pattern intermingle to create the desired inflectional meaning. For instance, the trilateral Arabic root comprising the consonants ك.ت.ب (<k.t.b>) combined with other letters spread throughout the word creates new words such as مكتبة (<maktaba> "library") or كتاب (<kitab> "book"). In the first, the root consonants appear in the second, third and penultimate (fourth) position, whereas in the second, the root consonants appear in the first, second and final position of the word. Thus, the root in Arabic (as in Hebrew) is not identified as a contiguous sequence of letters, and this may have important consequences for word recognition.

Differences from Hebrew

The native language of all Arabic speakers is a specific *Spoken Arabic Vernacular* (SAV) which is specific to a geographical area. However, throughout the Arabic-speaking world, formal functions such as speeches, religious sermons, news broadcasts, and all printed matter, occur in a common *Modern Standard Arabic* (MSA). Despite being two linguistically related codes, SAV and MSA are remarkably different in the phonological, morpho-syntactic, and lexical semantic domains (Ayari, 1996). This linguistic situation was part of the background in which Ferguson (1959) introduced the term 'diglossia'.

Eviatar and Ibrahim (2000) have further shown that Arabic speaking kindergarteners and first graders who are exposed to MSA, function as bilinguals. Saiegh-Haddad (2003) and Asaad and Eviatar (2013) have shown that the differences between the two forms of Arabic affect the acquisition of and access to letters that label sounds that occur only in MSA. Many researchers who examine reading acquisition in Arabic have suggested that the diglossic situation is a causal factor in the low levels of literacy in the Arabic-speaking world (e.g., Abu-Rabia, 2000; Maamouri, 1998).

Thus, if we consider all literate Arabic speakers as bilinguals (in SAV and MSA), then reading in Arabic resembles the situation of a bilingual speaker, where the orthography in one language activates the semantic representations, and therefore also the lexical representations in both languages. Dijkstra, Grainger and van Heuvan (1999) showed that cross-language activations occur differentially for orthographic, semantic, and phonological representations of words. They tested Dutch-English bilinguals' reactions to English words that varied in their degree of orthographic (O), phonological (P) and semantic (S) overlap (cognates and homophones) with Dutch words. Six different conditions were created: SOP, SP, SO, OP, O and P. For example, the word "hotel" overlaps in S, O and P. "List" on the other hand, overlaps in O only. Participants performed a lexical decision task in English. The results revealed facilitation effects of cross-linguistic orthographic and semantic similarity, relative to control words that belonged only to English. In contrast, phonological overlap resulted in inhibitory effects. The authors explained that phonological similarity resulted in a phonological inhibition effect because two distinct phonological representations were activated in the two languages. Thus, they suggest that cross-linguistic effects arose in all three types of representations, resulting in facilitation for orthographic and semantic representations, and inhibition for phonological representations.

Further, previous research on hemispheric functioning during the reading of Arabic suggests that the division of labor is different than it is while participants read Hebrew or English. Specifically, studies of interhemispheric integration during word and letter recognition reveal lower levels of RH involvement in Arabic than in Hebrew or in English (Ibrahim & Eviatar, 2009, 2012). It has been hypothesized that this is due to the characteristics of Arabic orthography, which create specific difficulties for the RH, and limit its participation in the process of reading (Eviatar, Ibrahim & Ganayim, 2004).

Unlike Hebrew, Arabic letters are written in a cursive form, with most words composed of connected letters (only 6 of the 28 letters do not connect with the letters to their left). The cursive form of Arabic decreases the distinctiveness of individual letters and introduces additional crowding that may further decrease letter resolution. In a series of studies, Eviatar and Ibrahim have shown that letter identification is slower in Arabic than in Hebrew and in English (e.g., Eviatar & Ibrahim, 2004), and that the RH seems to play a smaller part in letter (Eviatar et al., 2004) and in word (Ibrahim & Eviatar, 2012) identification.

Orthography and phonology

The present experiment, in which we compared access to the meanings of homophones and heterophones, is also relevant to the debate about the relative weight of phonological and orthographic information in reading Arabic. Taouk and Colheart (2004) reported that orthographic distortion inhibits reading in skilled readers but not in beginning readers, and suggested that reading acquisition in Arabic is characterized by movement from a phonological-recoding phase to an orthographic phase. On the other hand, Bentin & Ibrahim (1996), using a lexical decision task, found that written pseudowords that correspond to phonetic transliterations of SAV words (which are never written) were rejected more slowly than pseudowords which were not. This suggests that the phonological representations of the transliterations had been activated, even though deactivating them would have been the optimal strategy. This finding suggests that the phonological forms of letter strings are always automatically computed in Arabic.

The present study

Our main goal was to test whether, irrespective of the differences between the Hebrew and Arabic scripts, we would find patterns similar to Hebrew, in the manner in which homophones and heterophones in Arabic are processed in the two cerebral hemispheres. To do this, we used the divided visual field (DVF) paradigm to examine hemispheric differences in word recognition, using semantic and phonological ambiguity.

The DVF technique takes advantage of the fact that stimuli presented in the peripheral visual fields (usually two degrees off fixation) are initially processed by the contralateral hemisphere, such that stimuli presented to the left of fixation are initially processed exclusively by the right hemisphere and stimuli presented to the right of fixation are initially processed by the left hemisphere. Although information presented in this manner is subsequently transmitted to both hemispheres, imaging studies have shown that this initial lateralization holds true, such that stimuli presented in the left visual field (LVF) result in higher levels of activation and faster evoked responses in the RH, and stimuli presented in the right visual field (RVF) result in these patterns in the LH (Grill Spector, et al., 1998; Coulson, Federmeier, Van Petten, & Kutas, 2005). Because during normal reading words are usually fixated, we included a condition in which the targets were presented in the center of the visual field (CVF). Comparison of this condition with the peripheral conditions can clarify hemispheric relations during normal reading. Central presentations result in the simultaneous access of both hemispheres to the words. Thus, if performance in the CVF is more similar to the pattern in one peripheral visual field/hemisphere than in the other, we can conclude that that hemisphere is more prominent in the process of reading in the central visual field than the other. This has been termed 'metacontrol' (e.g., Hellige, 1993), and is interpreted as reflecting hemispheric division of labor when the stimuli are not lateralized.

On the one hand, given the morphological similarities between Hebrew and Arabic, we expected to replicate previous patterns found with Hebrew. Thus, for homophones, we expected that the LH will select the more frequent meaning of the homographs, whereas the RH will reveal the effects of both meanings. This would be a replication of the findings in both English and Hebrew. For heterophones, we expected to see more efficient RH than LH processing. This is because phonological recoding of orthography is fast and automatic in the LH, so that performance for heterophones with subordinate targets is expected to be affected most strongly, due to the multiple phonological entries in the RVF/LH. On the other hand, because it has previously been suggested that the RH is involved to a smaller extent, or maybe not at all, in word recognition in Arabic (Ibrahim & Eviatar, 2012), we may find patterns that differ from what has been found in both English and Hebrew. In either case, the data will add information about hemispheric functions during the reading of Arabic.

In order to examine the effects of ambiguity in Arabic in general, and in the visual fields/hemispheres specifically, we computed an 'ambiguity effect'. This effect is computed as the difference in the manner in which readers decided that two words were related, where we manipulated the ambiguity of the first word. Thus, we compared the latency and accuracy of trials in which one of the pair was ambiguous, to trials in which both words were unambiguous (did not entail more than one meaning). Thus, if people took longer (or made more errors) deciding that *bank* and *river* are related, than that *boat* and *river* are related, we would interpret this as reflecting the effects of the ambiguity of the word *bank,* in which the dominant meaning of *bank* as a financial institution interferes with the activation of the meaning of *bank* as the side of a river. Differences in this ambiguity effect in peripheral visual fields and the central presentation would suggest differential involvement of the cerebral hemispheres in the process of meaning activation.

To summarize, we presented our participants with pairs of words which were either semantically related or not. Of the pairs that were semantically related, we manipulated the first word, which was either ambiguous or not. Of the ambiguous words, half were homophonic homographs and half were heterophonic homographs. For each type of homograph, half the related words were related to the dominant, more frequent meaning, and half were related to the subordinate, less frequent meaning of the homograph. The second word of each pair was presented either in the LVF (directly to the RH), the RVF (directly to the LH), or centrally, where it was available to both hemispheres simultaneously. We examined the differences between the ambiguity effects for pairs of words that included heterophonic and homophonic homographs in the visual field presentation conditions. If the process of accessing meaning from print in Arabic is similar to the process in Hebrew, then the ambiguity effect for subordinate meanings of homophonic and heterophonic homographs should be equivalent in the LVF, but higher for heterophones than homophones in the RVF. In addition, if skilled readers do not automatically compute the phonological form of words in Arabic, then there should be minimal differences between the patterns for heterophonic and homophonic homographs overall. Patterns in the central presentation condition will be informative about hemispheric dominance during normal reading.

Methods

Participants

Thirty-two undergraduates aged 19–25 participated. All were healthy, right-handed and native speakers and skilled readers of Arabic, without attentional or learning disorders, and had normal or corrected-to-normal vision. The experiment was approved by the Psychology Department Ethics Committee.

Design

The dependent measure was the ambiguity effect, as described above. The critical stimuli consisted of 60 homographs (28 unique heterophones and 32 unique homophones. Examples of the stimuli are shown in Table 1 and all are listed in the "Appendix". The experiment utilized a lateralized semantic decision task. Each trial consisted of two stages. In the first stage, a homograph or an unambiguous word was displayed in the center of the visual field for 750 ms. Immediately afterwards the second word appeared in one of the visual fields (LVF, RVF, or CVF) for 150 ms. The task of the participants was to decide if the two words were semantically related or not. For each homograph, we constructed 5 types of relationships between the first and second words:

1. The first word was a homograph and the second word was related to the dominant, more frequent meaning. For example, صباح/sabah/(morning)- فجر/fajr/(dawn)
2. The first word was a homograph and the second word was related to the subordinate, less frequent meaning. For example, صباح/sabah/(forehead)- جبين/jabin/(forehead)
3. The first word was an unambiguous word related to the dominant meaning of the homograph, paired with the same second word. For example, شمس/shams/(sun)- فجر/fajr/(dawn)
4. The first word was an unambiguous word related to the subordinate meaning of the homograph paired with the same second word. For example, رأس/ra's/(head)- جبين/jabin/(forehead)
5. The first word was a homograph and the second word was unrelated to either of two meanings. For example, صباح/sabah/- خاتم/khatem/(ring). Responses to these trials were not analyzed.

All five conditions appeared once in each visual field. Thus, the 60 homographs resulted in 300 unique word pairs. Each word pair appeared 3 times (once in each visual field) resulting in 900 trials. Participants performed the experiment in three sessions, which were spaced 3 weeks apart (to minimize the effects of repetition), where each session consisted of 300 trials. Within each session, the trials were ordered randomly, but the visual field of the homographs was counterbalanced across sessions. Within each session, 240 trials required a 'yes' response and 60 required a 'no' response. As mentioned, the trials requiring a 'no' response were not included in the analyses.

Stimuli

The sixty unique homographs and their unambiguous related words were selected on the basis of four pretests:

Table 1 Relatedness ratings for the stimulus word pairs from the third pretest. The scale of relatedness ranged from 1 to 5 (see text). Word examples in Arabic with their transliteration and English translation are illustrated

	Homophones				Heterophones			
First word	Ambiguous e.g., صباح /sabah/ (morning; forehead)		Unambiguous e.g., شمس/shams/(sun); رأس/ra’s/(head)		Ambiguous e.g., رجل /rajol/(man); /rijl/(leg)		Unambiguous e.g., أم/’om/(mother); كف/kaf/(palm)	
Related Second word	Dominant فجر /fajr/ (dawn) M = 4.26 *SD* = 0.34	Subordinate جبين /jabin/ (head) M = 4.18 *SD* = 0.6	Dominant فجر /fajr/ (dawn) M = 4.57 *SD* = 0.41	Subordinate جبين /jabin/ (head) M = 4.46 *SD* = 0.38	Dominant امرأة /’emra’a/ (woman) M = 4.45 *SD* = 0.3	Subordinate قدم /qadam/ (foot) M = 4.2 *SD* = 0.36	Dominant امرأة /’emra’a/ (woman) M = 4.54 *SD* = 0. 35	Subordinate قدم /qadam/ (foot) M = 4.5 *SD* = 0.37
Unrelated second word	M = 1.58 *SD* = 0.41							

Dominant meaning

A list containing 82 homographs and their paraphrased multiple meanings were presented to 50 adult native Arabic speakers who were asked to circle the most frequent sense. The dominant meaning was defined as the meaning chosen by at least 65 % of the subjects.

Validity of frequency

The validity of the above selection was tested by asking 50 other participants to write their first association to the homographs. The homographs whose frequency judgment accorded with the previous test were used in the experiment.

Relatedness of word pairs

For each of the first appearing words (homographs and their unambiguous related words), two unambiguous second words were selected, one related to the dominant meaning and the other to the subordinate (less frequent) meaning. Two unrelated targets were also paired with each homograph by randomly re-pairing related word-pairs. The third pretest measured the degree of relatedness (or un-relatedness): thirty new participants rated the degree to which each target was related to the meaning of the homograph on a scale of 1–5, with 5 representing a strong association and 1 no association. The presentation of word pairs was counterbalanced by using four stimulus lists, each of which contained two of the four related conditions described above, for each target word. Unrelated pairs were equally distributed among the lists. The means of these ratings are shown in Table 1, which also describes the design of the stimulus set.

Lexical pretest

Finally, another 30 students were asked to perform a simple lexical decision task to make sure all the target words were equally recognizable and that there was no difference between them. There were no differences in response times or accuracies for the different categories of words.

Apparatus

Stimulus presentation and responses were controlled and recorded by a Dell GX-260 PC P4-1800-14H. An adjustable chin-rest kept participants' eyes at a fixed viewing distance from the computer screen (57 cm). Stimuli were displayed in white Ariel font (size 20) on a gray screen, in three possible locations: the center of the screen, or at 2° of visual angle to the left or to the right of the fixation point. The experiment was written in E-Prime and responses were collected via an E-Prime response box.

Procedure

At the beginning of each trial, a fixation cross was presented in the center of the screen for 650 ms. Then the first word appeared in the center of the screen for 750 ms, and was either a homophonic homograph, a heterophonic homograph, or an unambiguous word. Immediately afterwards, the second word, which was always unambiguous, was presented either in the center or in one of the peripheral visual fields for 150 ms. The second word was either related to the dominant meaning, to the subordinate meaning, or unrelated. The task was to decide whether the two words were semantically related or not. The next trial began 2 s after the response. Participants performed 30 practice trials which did not appear in the experimental trials.

Results

Correlations between RT and errors revealed that there were no speed-accuracy tradeoffs in any of the conditions, $p > .09$. The raw latency and % error scores were analyzed and showed that both dependent variables reflected a significant effect of visual field, for errors, $F(2, 62) = 10.72$, $p < .001$, $\eta_p^2 = .26$, for RT, $F(2, 62) = 35.13$, $p < .0001$, $\eta_p^2 = .53$. Responses were better with central than peripheral presentation for errors, $F(1, 62) = 11.30$, $p < .005$, $\eta_p^2 = .15$; and for RT, $F(1, 62) = 60.47$, $p < .0001$, $\eta_p^2 = .49$. Responses were better in the RVF than in the LVF, for errors, $F(1, 62) = 10.13$, $p < .005$, $\eta_p^2 = .14$; and RT, $F(1, 62) = 9.78$, $p < .005$, $\eta_p^2 = .14$. Thus, we see the classic patterns of the divided visual field paradigm that reflect the effects of acuity and of LH specialization for language tasks.

In order to examine semantic access, we computed the difference between responses to ambiguous and unambiguous primes. Recall that the same targets were paired with homographs and with unambiguous words with the same meaning as either the dominant or the subordinate form of the homograph. This measure indexes the effect of the ambiguity of the homographs on access to meaning. The cell means are illustrated in Fig. 1.

The analyses of these effects in errors and RT revealed slightly different interaction effects. For errors, there is a significant interaction between visual field and phonology, $F(2, 62) = 4.07$, $p < .05$, $\eta_p^2 = .12$, and between frequency and phonology, $F(1, 31) = 9.07$, $p < .01$, $\eta_p^2 = .23$. For RT, only the interaction of visual field and frequency is significant, $F(2, 62) = 3.26$, $p < .05$, $\eta_p^2 = .06$. Both measures show main effects of phonology [errors: $F(1, 31) = 27.55$, $p < .0001$, $\eta_p^2 = .47$; RT: $F(1, 31) = 4.17$, $p < .05$, $\eta_p^2 = .12$] (with heterophones resulting in larger ambiguity effects than homophones) and of frequency [errors: $F(1, 31) = 58.69$, $p < .0001$, $\eta_p^2 = .65$; RT: $F(1, 31) = 47.81$, $p < .001$, $\eta_p^2 = .61$], with subordinate meanings resulting in larger ambiguity effects than dominant meanings.

Planned comparisons following up the interactions with visual field revealed that performance in the two peripheral fields was the same: for RT there were no

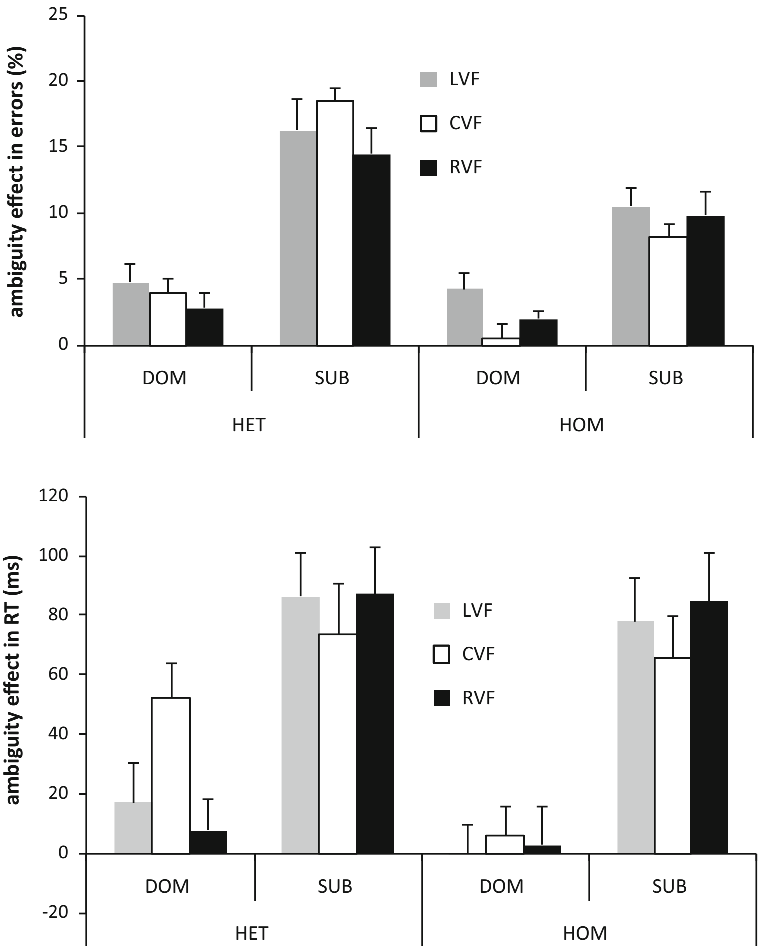

Fig. 1 *Top panel* Cell means (in %) of Ambiguity effect. *Error bars* are standard errors. *Bottom panel* Mean of response time (in ms) of Ambiguity effect. *Error bars* are standard errors. *LVF* left visual field, *RVF* right visual field, *CVF* central visual field. *Het* heterophonic first word, *Hom* homophonic first word, *UnAmb* unambiguous first word, *Dom* dominant, more frequent meaning, *Sub* subordinate, less frequent meaning

interactions with visual field when only the peripheral conditions were included in the analysis, $p > .6$; for errors, this analysis showed only that the ambiguity effect was slight larger in the LVF (8.9 %) than in the RVF (7.3 %), $F(1, 31) = 8.49$, $p < .01$, $\eta_p^2 = .17$. In both peripheral visual fields, for words related to the dominant, more frequent meanings of both types of homographs, there were no differences in degree of ambiguity effect either in errors or RT. This is similar to the findings in Hebrew. For words related to the subordinate meanings, heterophones resulted in more errors than homophones in both peripheral visual fields, LVF: $F(1, 31) = 5.59$, $p < .05$, $\eta_p^2 = .15$; RVF: $F(1, 31) = 7.64$, $p < .05$, $\eta_p^2 = .20$. This is different from the findings in Hebrew, where this effect was found in the RVF and not in the LVF. In the CVF, heterophones resulted in larger ambiguity effects in the dominant condition in both measures, and in the subordinate meanings for errors. Thus, the interactions in the overall analyses listed above are due to differences between the central presentation and the peripheral presentations, not to differences between the peripheral visual fields. We return to this issue below.

It can be seen in Fig. 1 that the interaction of frequency and phonology in errors resulted from the large effect of phonology for pairs of words that included the subordinate meaning, $F(1, 31) = 22.64$, $p < 0001$, $\eta_p^2 = .42$, and much smaller effect of phonology for pairs including dominant meanings, $F(1, 31) = 3.33$, $p = .08$, $\eta_p^2 = .10$.

In order to test metacontrol, we compared the CVF condition to each of the peripheral fields separately. Comparison of performance in the CVF with performance in the LVF/RH, and in a separate analysis with performance in the RVF/LH, revealed two significant interactions. In errors, the analyses revealed an interaction between visual field and phonology (in the comparison with the RVF, $F(1, 31) = 8.99$, $\eta_p^2 = .22$; in the comparison with the LVF, $F(1, 31) = 4.15$, $p < .05$, $\eta_p^2 = .12$). Follow-up analyses are shown in section A of Table 2. It can be seen that the effects of phonology are largest in the CVF, and smallest in the LVF. The second interaction that was found in both analyses is between visual field and frequency in RT (in comparison with the RVF, $F(1, 31) = 5.38$, $\eta_p^2 = .15$; in comparison with the LVF, $F(1, 31) = 4.40$, $p < .05$, $\eta_p^2 = .12$). Follow up analyses are shown in Section B of Table 2. It can be seen that the effects of frequency are larger in the peripheral visual fields than in the central presentation condition.

Discussion

The present study had two goals. The first was to examine Peleg and Eviatar's proposal regarding the functional architecture of reading in the two cerebral hemispheres that was based on Hebrew, in another language that affords this test. The second was to investigate phonological effects in ambiguity resolution in Arabic, because previous findings have suggested a different hemispheric division of labor during word recognition in Arabic than in Hebrew and English (Ibrahim & Eviatar, 2012). In order to achieve these aims, we examined the disambiguation of Arabic homophonic versus heterophonic homographs in both the central and the peripheral visual fields.

Recall that in Hebrew, there was a larger difference between ambiguity effects for heterophones and homophones in the RVF/LH than in the LVF/RH. Peleg and Eviatar interpreted this as reflecting the relative insensitivity of the RH to phonology, and the relative hypersensitivity of the LH to phonology. They found that in the LVF/RH, heterophones and homophones resulted in equivalent ambiguity effects, whereas in the RVF/LH, the ambiguity effect for heterophones was much larger than for homophones, and revealed a different timeline (Peleg & Eviatar, 2012). Our findings with Arabic are different: We see larger ambiguity effects for heterophones than for homophones in all of the conditions. This finding supports the

Table 2 Follow up analyses of the interactions of visual field and phonology interaction in % errors and of the VF and frequency interaction in RT in the metacontrol analyses

Presentation condition	F, $df = 1,31$	Effect size (η_p^2)
(A) Simple effects of phonology on the ambiguity effect in % error scores in each visual presentation condition		
CVF	37.76, $p < .001$	.55
RVF/LH	8.78, $p < .01$	.22
LVF/RH	4.18, $p < .05$	.12
(B) Simple effects of frequency on the ambiguity effect in RT in each visual presentation condition		
CVF	9.16, $p < .005$	.23
RVF/LH	29.61, $p < .001$	.49
LVF/RH	36.44, $p < .0001$	.44

proposal of Bentin and Ibrahim (1996), that phonology is automatically and mandatorily computed while reading single words in Arabic. Specifically, the results indicate that phonological access is evident in all of the visual presentation conditions when accessing the meaning of Arabic heterophones.

The pattern of performance in the peripheral visual field conditions in our study is equivocal. One interpretation of our results, based on the findings from letter identification and lexical decision tasks, is that we see identical performance patterns in the two peripheral visual fields because these reflect the functions of a single processor, the LH. Thus, under this interpretation, stimuli presented to the LVF were transferred by the RH to the LH with minimal processing, and so show the same patterns revealed by stimuli presented in the RVF, directly to the LH.

An alternative interpretation suggests that this identical pattern in the two peripheral visual fields results from interhemispheric collaboration in both conditions—a process that is especially sensitive to phonology. It may be the case that upon reading written words in Arabic, phonological representations might be activated simultaneously from both MSA (literary Arabic) and SAV (Spoken Arabic), and thus be a load for one hemisphere to handle. For example, in MSA, the heterophone قبلة means 'kiss' when pronounced/qubla/, and 'direction of Muslim prayer' when pronounced/qibla/. However, in SAV, the form of the word 'kiss' is/bose/, and the form of the word 'direction of prayer' is/qible/or/'ible/. Thus, these multiple phonological entries in the two forms of Arabic might require both the right and left hemispheres to collaborate in order to inhibit other candidates and select the right one when accessing meanings.

Recall that Eviatar and Ibrahim (2000) have also shown that Arabic speakers function as bilinguals once formally exposed to MSA. Within that framework, the Bilingual Interactive Activation+ (BIA+) model (Dijkstra and van Heuven, 2002) maintains that upon the presentation of a word, orthographic, phonological, and semantic representations from both languages are activated. Activation level is assumed to depend on the overlap of the input word in the two languages. MSA written words might activate SAV phonological representations, especially as many words overlap and thus, might function as cognates. These are words that have a similar form, pronunciation and meaning, such as in the MSA–SAV example ماء/ma'/and مي/maj/for 'water'.

As mentioned in the introduction, Dijkstra et al. (1999) tested Dutch–English bilinguals' reactions to English words varying in their degree of orthographic, phonological, and semantic overlap (cognates and homophones) with Dutch words. Participants performed a progressive demasking task and a visual lexical decision task. Of interest to us, is their report that phonological similarity resulted in an inhibition effect. They suggest that this occurred because two distinct phonological representations were activated, one in each language. The authors explained that because the manifestation of English and Dutch phonemes is different, phonological inhibition occurs when a given letter string activates incompatible phonological forms (Brysbaert, Van Dyck, & Van De Poel, 1999; Nas, 1983). These activated non-identical phonological representations compete, resulting in a delayed identification of the target word. This may be the same situation that occurs for homographs which are also pronounced differently in MSA and SAV, as described above. These findings imply that activation of the lexical items in both languages leads to the activation of the corresponding phonological segments in both languages. In terms of our study, if phonology from both languages is co-activated in bilinguals, the different phonological codes of both MSA and SAV may compete until selection takes place, and this selection may require hemispheric integration.

Ostensibly, these findings seem at odds with previous studies on Arabic that suggested that the RH is not involved in word decoding (e.g., Eviatar & Ibrahim, 2004; Ibrahim & Eviatar, 2012). However, Ibrahim and Eviatar's studies did not investigate semantic processing, but rather letter identification (Eviatar & Ibrahim, 2004) and lexical decision (Ibrahim & Eviatar, 2012). In both of these studies, access to meaning was not required, and the task could have been done via orthographic knowledge alone (e.g., Graigner, Dufaut, Montant, Ziegler, & Fagot, 2012). Thus, it may be the case that when performance of the experimental task is based on orthographic knowledge, the limitations of the RH in letter identification in Arabic (Eviatar et al., 2004) result in patterns reflecting minimal involvement of the RH. However, when access to the meaning of words is crucial, such as required by the semantic decision task in this study, both hemispheres need to collaborate, especially in order to select the right meaning from the multiple phonological options. How this process of collaboration occurs and what it entails, are questions to be resolved by future research. We are undertaking some of the required research in our lab.

Generally speaking, the consensus in the field suggests that initial semantic processing in the left hemisphere might be similar to later semantic processing in the right hemisphere (Koivisto, 1997), but at some point, a broader range of word meaning are available in the right hemisphere than in the left hemisphere (Chiarello, 1998). In the case of heterophones in Arabic then, the diverse options are available in both hemispheres and thus affect ambiguity resolution.

The results of our comparisons between performance in the central and the peripheral presentations reveal the complexity of examining interhemispheric interaction during reading. Overall, the pattern of lateralization in Arabic was similar to the one shown in other languages, with better performance in the RVF/LH than in the LVF/RH, reflecting LH specialization for linguistic tasks, and best performance in the central presentation condition, where the stimuli were presented at fixation. However, unlike findings in other languages (e.g., Chiarello, 2013), the central presentation condition resulted in patterns that were significantly different from both of the peripheral visual fields. In general, this type of pattern is interpreted as reflecting interhemispheric collaboration in processing centrally presented stimuli, supporting the 'two processors' rather than the 'one processor' interpretation of the patterns in the peripheral visual fields that were suggested above. However, if there is one processor only (the LH), the difference between the central presentation condition and the peripheral conditions could be due to the combined effects of acuity differences between the center and the periphery of the visual field, and the specific characteristics of Arabic orthography. As mentioned in the introduction, it is difficult to distinguish between letters in Arabic. Given that acuity is much higher in the center than in the periphery, it is probable that the words were recognized faster in the center than in the peripheral visual fields, allowing more time for semantic processing. This may underlie our finding that the effects of meaning frequency were significantly smaller in the central presentation condition than in the periphery, while the effects of phonology were larger in the central condition than in the periphery. When stimuli were presented in the center, the LH had more information about the words than when they were presented in either of the peripheral fields. Thus, when processing time is limited (as in the peripheral conditions), the effects of frequency will be larger, because lower frequency meanings may take longer to be activated and so result in slower response times. However in the central condition, where the words are identified faster, these lower frequency meanings have time to emerge and thus response times are closer to those of the higher frequency meanings. The same logic can be used for the pattern of the effects of phonology, which shows larger effects in the central presentation condition than in the peripheral conditions. Here again, higher acuity in the central condition results in faster identification of the words, allowing more time for phonological effects to affect response accuracies.

In sum, the findings reported in this study were obtained using Arabic stimuli with a semantic decision task. The results support the conclusion that the LH is dominant for word processing in Arabic, in general. The results are equivocal in terms of hemispheric involvement in access to meaning in Arabic. Our findings cannot distinguish between the hypothesis that the RH is less involved in meaning identification in Arabic than in Hebrew, from the hypothesis that it is more involved, such that all of the conditions reflect interhemispheric interactions. We are in the process of testing these hypotheses directly via functional imaging methods. In addition, to date, the majority of the psycholinguistic examinations of reading in Arabic have utilized single words or word pairs. It is important to examine sentence and text reading in Arabic as compared to other languages as well.

Importantly, our findings underline the strong effects of orthography on linguistic functions that are more complex than letter and word identification. Arabic is similar enough to Hebrew to have resulted in the similar hemispheric patterns resulting from manipulations of morphological form in a lexical decision task (e.g., Eviatar & Ibrahim, 2007). The fact that hemispheric patterns for meaning activations in Arabic and in Hebrew are different, together with the large differences between the Arabic and Hebrew orthographies, emphasize the scope of orthographic effects on the access to the meanings of words.

Our results also have implications for tests of reading abilities in which reading in Arabic is compared to reading in other languages, such as the PISA tests. It may be the case that reading and comprehending translation equivalents take longer in Arabic than they do in other languages, because decoding requires more resources than it does in many other languages, mainly because Arab speakers read a script that does not represent their speech.

Appendix

1. Pairs of ambiguous (homophones) and unambiguous prime words and related dominant meaning.

Prime						Target		
Ambiguous			Unambiguous					
فرد	/fard/	individual	إنسان	/’insan/	human	شخص	/shakhs/	person
زوج	/zawj/	husband	التزام	/iltizam/	commitment	شريك	/sharik/	partner
سن	/sin/	age	عجوز	/’ajouz/	old woman	عمر	/’omr/	age
صبر	/sabr/	patience	ساعة	/sa’a/	hour	انتظار	/intethar/	waiting
قرش	/qirsh/	shark	صياد	/sayyad/	fisherman	بحر	/bahr/	sea
وحدة	/wahda/	unit	متر	/metr/	meter	قياس	/qeyas/	measurement
روضة	/rawda/	kindergarten	العاب	/’al’ab/	games	طفولة	/tofoula/	childhood
امر	/’amr/	issue	شأن	/sha’n/	issue	موضوع	/mawdoo’/	subject
صباح	/sabah/	morning	شمس	/shams/	sun	فجر	/fajr/	dawn
طعم	/ta’m/	taste	حموضة	/homouda/	sourness	مذاق	/mathaq/	flavor
بيت	/bayt/	house	عائلة	/’a’ela/	family	دار	/dar/	house
عين	/’ayn/	eye	نظر	/nathar/	sight	قرنية	/qarneyya/	cornea
اقدام	/’aqdam/	feet	جوارب	/jawareb/	socks	حذاء	/hetha’/	feet
أجل	/’ajal/	aye	موافقة	/mowafaqa/	consent	نعم	/na’am/	yes
محيط	/muhit/	ocean	شاطئ	/shate’/	beach	بحر	/bahr/	sea
عصر	/’asr/	epoch	وقت	/waqt/	time	زمن	/zaman/	time
يمين	/yamin/	right	يسار	/yasar/	left	جهة	/jeha/	direction
جبن	/jobn/	cheese	حليب	/halib/	milk	بقرة	/baqara/	cow
حاجب	/hajeb/	eyebrow	كحل	/kohl/	kohl	رمش	/romsh/	eyelash
خيار	/kheyar/	cucumber	خس	/khas/	lettuce	خضار	/khudar/	vegetable
جنس	/jens/	sex	فرحة	/farha/	joy	متعة	/mota’a/	pleasure
قانون	/qanun/	law	دولة	/dawla/	state	دستور	/dustour/	constitution
كأس	/ka’s/	trophy	خسارة	/khasara/	loss	فوز	/fawz/	victory
جبهة	/jabha/	front	سلاح	/silah/	weapon	حرب	/harb/	war
شوكة	/shawka/	fork	سكين	/sekin/	knife	ملعقة	/mel’aqa/	spoon
عضو	/’adu/	member	برلمان	/barlaman/	parliament	كنيست	/knesset/	Knesset

Prime						Target		
Ambiguous			Unambiguous					
عرق	/'araq/	sweat	غدد	/ghodad/	glands	افرازات	/ifrazat/	secretions
موقع	/mawqe'/	site	حاسوب	/hasoub/	computer	انترنت	/internet/	internet
أدب	/'adab/	literature	قصة	/qisa/	story	نص	/nas/	text
ورد	/ward/	flowers	زهور	/zuhoor/	flowers	بستان	/bustan/	garden
عود	/'ud/	oud	غناء	/ghena'/	singing	عزف	/'azf/	playing
سائل	/sa'el/	liquid	عصير	/'asir/	juice	ماء	/ma'/	water

2. Pairs of ambiguous (homophones) and unambiguous prime words and related subordinate meaning.

Prime						Target		
Ambiguous			Unambiguous					
فرد	/fard/	gun	جريمة	/jarima/	crime	طخ	/takh/	shooting
زوج	/zawj/	couple	رقم	/raqam/	number	اثنان	/ethnan/	two
سن	/sin/	tooth	طاحونة	/tahouna/	grinder	ناب	/nab/	fang
صبر	/sabr/	cactus	تفاحة	/tufaha/	apple	فاكهة	/fakeha/	fruit
قرش	/qirsh/	dime	مال	/mal/	money	نقود	/nuqud/	money
وحدة	/wahda/	loneliness	شراكة	/sharaka/	partnership	اتحاد	/'itihad/	unity
روضة	/rawda/	garden	بستان	/bustan/	garden	زهور	/zuhur/	flowers
امر	/'amr/	order	فرض	/fard/	obligation	طلب	/talab/	request
صباح	/sabah/	forehead	رأس	/ra's/	head	جبين	/jabeen/	forehead
طعم	/ta'm/	lure	فريسة	/farisa/	prey	صيد	/sayd/	fishing
بيت	/bayt/	stanza	شاعر	/sha'er/	poet	قصيدة	/qaseeda/	poem
عين	/'ayn/	spring	شراب	/sharab/	drink	ماء	/ma'/	water
اقدام	/'aqdam/	prowess	جرأة	/jur'aa/	boldness	شجاعة	/shaja'a/	bravery
أجل	/'ajal/	eternity	نهاية	/nihaya/	end	اخرة	/akhera/	afterlife
محيط	/muhit/	surroundings	طبيعة	/tabi'a/	nature	بيئة	/bi'a/	environment
عصر	/'asr/	afternoon	مساء	/masa'/	evening	مغرب	/maghrib/	sunset time
يمين	/yamin/	swear	الله	/Allah/	God	حلفان	/helfan/	swearing
جبن	/jobn/	cowardice	رعب	/ro'b/	horror	خوف	/khawf/	fear
حاجب	/hajeb/	janitor	حارس	/hares/	guardian	بواب	/bawab/	doorman
خيار	/kheyar/	option	امكانية	/imkaneya/	possibility	احتمال	/ihtemal/	possibility
جنس	/jens/	type	صنف	/sanf/	kind	نوع	/naw'/	kind
قانون	/qanun/	qanun	لحن	/lahn/	melody	موسيقى	/musiqa/	music
كأس	/ka's/	glass	زجاج	/zujaj/	glass	كوب	/koob/	glass
جبهة	/jabha/	forehead	رأس	/ra's/	head	وجه	/wajh/	face
شوكة	/shawka/	thorn	شجرة	/shajra/	tree	وردة	/warda/	flower
عضو	/'adu/	organ	جسد	/jasad/	body	جسم	/jism/	body

Prime						Target		
Ambiguous			Unambiguous					
عرق	/'araq/	arak	نبيذ	/nabith/	wine	كحول	/kohool/	alcohol
موقع	/mawqe'/	location	منطقة	/mantiqa/	area	مكان	/makan/	place
أدب	/'adab/	manners	لطف	/lutf/	courtesy	سلوك	/suluk/	behavior
ورد	/ward/	lion	شبل	/shibl/	cub	أسد	/asad/	lion
عود	/'ud/	stick	عكاز	/'okaz/	walking stick	عصا	/'aasa/	stick
سائل	/sa'el/	Who asks questions	صحفي	/sahafi/	reporter	مقابلة	/muqabala/	interview

3. Pairs of ambiguous (heterophobes) and unambiguous prime words and related dominant meaning.

Prime						Target		
Ambiguous			Unambiguous					
عجل	/'ajal/	wheel	سيارة	/sayara/	car	دولاب	/dulab/	tire
شباك	/shubak/	window	منظر	/manthar/	view	نافذة	/nafitha/	window
اذن	/'uthon/	ear	حاسة	/hassah/	sense	سمع	/sama'/	hearring
قسم	//qism	part	فصل	/fasl/	chapter	جزء	/joz'/	part
دين	/deen/	religion	عقيدة	/'aqida/	belief	إيمان	/'iman/	faith
عالم	/'aalam/	world	طبيعة	/tabi'ah/	nature	دنيا	/dunia/	world
بركة	/birka/	pool	بحر	/bahr/	sea	سباحة	/sibaha/	swimming
فراش	/firash/	mattress	ليل	/layl/	night	نوم	/nawm/	sleep
سحاب	/sahhab/	zipper	بنطلون	/bantalon/	trouser	جرار	/jarrar/	zipper
أرز	/'aroz/	rice	طعام	/ta'am/	food	مقلوبة	/maqluba/	maqluba
قبلة	/qubla/	kiss	زواج	/zawaj/	marriage	حب	/hob/	love
ملك	/malek/	king	دولة	/dawla/	state	حاكم	/hakem/	ruler
رجل	/rajol/	man	أم	/'om/	mother	امرأة	/'emra'a/	woman
سلطة	/salata/	salad	بصل	/basal/	onion	خضار	/khudar/	vegetables
جزر	/jazar/	carrot	حيوان	/haywan/	animal	أرنب	/'arnab/	rabbit
سنة	/sana/	year	يوم	/yawm/	day	شهر	/shahr/	month
شعر	/shi'r/	poetry	أدب	/'adab/	literature	قصيدة	/qasida/	poem
عظمة	/'athma/	bone	حركة	/haraka/	movement	مفصل	/mifsal/	joint
حجة	/hajah/	old woman	حفيد	/hafid/	grandchild	عجوز	/'ajouz/	old woman
عشرة	/'ashara/	ten	اثنان	/'ethnan/	two	رقم	/raqam/	number
ظهر	/thahr/	back	عنق	/'onoq/	neck	رقبة	/raqaba/	neck
دقة	/daqqa/	melody	لحن	/lahn/	melody/notes	أغنية	/'ughniya/	song
ذرة	/thora/	corn	عدس	/'adas/	lentil	حبوب	/hoboub/	grains
حمل	/haml/	pregnancy	جنين	/janin/	fetus	طفل	/tifl/	child
حداد	/hidad/	mourning	موت	/mawt/	death	عزاء	/'azaa'/	consolation
سفر	/safar/	travel	عودة	/'awdah/	return	رحيل	/rahil/	departure

Prime						Target		
Ambiguous			Unambiguous					
اله	/elah/	God	الله	/Allah/	God	خالق	/khaleq/	khaleq
سحر	/sihr/	magic	ساحر	/saher/	magician	خدعة	/khed'a/	trick

4. Pairs of ambiguous (heterophones) and unambiguous prime words and related subordinate meaning.

Prime						Target		
Ambiguous			Unambiguous					
عجل	/'ijl/	calf	حليب	/halib/	milk	بقرة	/baqara/	cow
شباك	/shibak/	net	صياد	/sayyad/	fisherman	سمك	/samak/	fish
اذن	/'ithn/	permission	موافقة	/mowafaqa/	consent	سماح	/samah/	permission
قسم	/qasam/	swearing	وعد	/wa'd/	promise	حلفان	/helfan/	swearing
دين	/deen/	religion	نقود	/noqoud/	money	مال	/mal/	money
عالم	/'alem/	scientist	نتيجة	/natija/	finding	باحث	/baheth/	researcher
بركة	/baraka/	blessing	صلاة	/salah/	prayer	نعمة	/ne'ma/	grace
فراش	/farash/	butterflies	نمل	/naml/	ants	حشرة	/hashara/	insect
سحاب	/sihab/	cloud	نجمة	/nijma/	star	سماء	/sama'/	sky
أرز	/'arz/	cedar	سوريا	/surya/	Syria	لبنان	/lubnan/	Lebanon
قبلة	/qibla/	direction of prayer	حج	/hajj/	pilgrimage	مكة	/makka/	Mecca
ملك	/malak/	angel	عدن	/'adan/	Eden	جنة	/jannah/	paradise
رجل	/rijl/	leg	كف	/kaf/	palm	قدم	/qadam/	foot
سلطة	/sulta/	power	رئيس	/ra'ees/	president	حكومة	/hokouma/	government
جزر	/juzor/	islands	شاطئ	/shate'/	beach	بحر	/bahr/	sea
سنة	/sunna/	Sunna	نبي	/nabi/	prophet	شريعة	/shari'a/	Islamic Law
شعر	/sha'r/	hair	دماغ	/demagh/	brain	رأس	/ra's/	head
عظمة	/'athama/	greatness	غرور	/ghoroor/	arrogance	كبرياء	/kebreya'/	pride
حجة	/hujja/	pretext	سبب	/sabab/	reason	عذر	/'othr/	excuse
عشرة	/'ishra/	companionship	اتحاد	/ittihad/	unity	شراكة	/sharaka/	partnership
ظهر	/thohr/	noon	شمس	/shams/	sun	صباح	/sabah/	morning
دقة	/diqa/	accuracy	تحديد	/tahdid/	precision	تفاصيل	/tafasil/	details
ذرة	/tharra/	atom	فيزياء	/fizya'/	physics	كيمياء	/kemya'/	chemstry
حمل	/hamal/	lamb	غنم	/ghanam/	sheep	خروف	/kharouf/	sheep
حداد	/haddad/	blacksmith	خشب	/khashab/	wood	نجار	/najar/	carpenter
سفر	/sifr/	book	نصارى	/nasara/	Christians	إنجيل	/enjeel/	gospel
اله	/'alah/	machine	انتاج	/'intaj/	production	مكنة	/makana/	machine
سحر	/sahar/	early dawn	نهار	/nahar/	day	شروق	/shuruq/	sunrise

5. Pairs of homographs with unrelated word targets. (For transliteration and transliteration of primes, see lists above).

Prime	Target		
فرد	عصير	/'asir/	juice
زوج	لوح	/lawh/	board
سن	تلفون	/telefon/	telephone
صبر	غيمة	/ghaima/	cloud
قرش	صف	/saf/	classroom
وحدة	توت	/tout/	strawberry
روضة	ثلاجة	/thalaja/	refrigerator
امر	نور	/nour/	light
صباح	خاتم	/khatem/	ring
طعم	مسلسل	/musalsal/	program
بيت	باص	/bas/	bus
عين	كعكة	/ka'aka/	cake
اقدام	دهان	/dahan/	painter
أجل	مظلة	/mithala/	umbrella
محيط	فيل	/fil/	elephant
عصر	قميص	/qamis/	shirt
يمين	شاشة	/shasha/	screen
جبن	كلب	/kalb/	dog
حاجب	حائط	/hae't/	wall
خيار	مقلمة	/maqlama/	pencilcase
جنس	طنجرة	/tunjara/	casserole
قانون	خبز	/khubz/	bread
كأس	قفص	/qafas/	cage
جبهة	قلم	/qalam/	pencil
شوكة	شاي	/shai/	tea
عضو	فحم	/fahm/	coal
عرق	صورة	/sura/	picture
موقع	باب	/bab/	door
أدب	سجادة	/sujada/	rug
ورد	شاحنة	/shahina/	truck
عود	قطار	/qitar/	train
سائل	حقيبة	/haqiba/	bag
عجل	محبة	/mahaba/	love
شباك	كلمة	/kalima/	word
اذن	سيارة	/sayara/	car
قسم	بندورة	/bandora/	tomato
دين	طقس	/taqs/	weather
عالم	دجاج	/dajaj/	chiken
بركة	ليمون	/laimun/	lemon
فراش	ورقة	/waraqa/	paper

Prime	Target		
سحاب	بطيخة	/batikha/	watermelon
أرز	نادي	/nadi/	club
قبلة	دفتر	/daftar/	notebook
ملك	طائرة	/ta'ira/	plane
رجل	طاولة	/tawila/	table
سلطة	رصيف	/rasif/	pavement
جزر	معلم	/mu'alem/	teacher
سنة	ورقة	/waraqa/	paper
شعر	خزانة	/khazana/	cupboard
عظمة	غطاء	/ghitaa'/	cover
حجة	ظلام	/thalam/	darkness
عشرة	قط	/qit/	cat
ظهر	برتقال	/burtuqal/	orange
دقة	فريق	/fariq/	team
ذرة	عرس	/'urs/	wedding
حمل	صيف	/sayf/	summer
حداد	رحلة	/rihla/	trip
سفر	نمر	/nimr/	tiger
اله	شرفة	/shurfa/	balcony
سحر	مطبخ	/matbakh/	kitchen

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