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Abstract morphemes and lexical representation: the CV-Skeleton in Arabic

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Abstract

Overlaps in form and meaning between morphologically related words have led to ambiguities in interpreting priming effects in studies of lexical organization. In Semitic languages like Arabic, however, linguistic analysis proposes that one of the three component morphemes of a surface word is the CV-Skeleton, an abstract prosodic unit coding the phonological shape of the surface word and its primary syntactic function, which has no surface phonetic content (McCarthy, J. J. (1981). A prosodic theory of non-concatenative morphology, *Linguistic Inquiry, 12* 373–418). The other two morphemes are proposed to be the vocalic melody, which conveys additional syntactic information, and the root, which defines meaning. In three experiments using masked, cross-modal, and auditory–auditory priming we examined the role of the vocalic melody and the CV-Skeleton as potential morphemic units in the processing and representation of Arabic words. Prime/target pairs sharing the vocalic melody but not the CV-Skeleton consistently failed to prime. In contrast, word pairs sharing only the CV-Skeleton primed reliably throughout, with the amount of priming being as large as that observed between word pattern pairs sharing both vocalic melody and CV-Skeleton. Priming between morphologically related words can be observed when there is no overlap either in meaning or in surface phonetic form.

Keywords: Mental lexicon; Morphology; CV-Skeleton; Semitic; Arabic; Word pattern; Vocalic melody; Priming

1. Introduction

Psychological research into the role of morphological structure in lexical processing and representation has been guided by the universal assumption that morphemic units

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consist of a sequence of segments with a specified phonetic content, and a specified meaning and/or function (e.g. Caramazza, Laudanna, & Romani, 1988; Feldman, 2000; Frost, Forster, & Deutsch, 1997; Grainger, Colé, & Segui, 1991; Marslen-Wilson, Tyler, Waksler, & Older, 1994). Such sequences of segments are defined on a linear or a non-linear basis depending on the language involved. In Indo-European languages such as English, morphological units are linear entities which convey a semantic meaning like {dark}, or a grammatical function like {~s} in the complex form *cows* (Aronoff, 1976; Scalise, 1986). In Semitic languages morphemic units are discontinuous in the sense that a surface form – for example the Arabic word [lamas] *touch* – is traditionally thought to consist of at least two interleaved elements: the meaning bearing unit {lms}, called the root, combined with the word pattern {faʕal},[1] which determines phonological structure and specifies lexical and syntactic function (Holes, 1995; Versteegh, 1997; Wright, 1995).

Previous research has provided ample evidence that linear and non-linear morphemic units play a crucial part in language processing. For example, word forms sharing linear morphemes like {~ness} in English prime each other reliably (Marslen-Wilson, Ford, Older, & Zhou, 1996), while Semitic words sharing discontinuous morphemes like the root {lms} prime each other regardless of semantic transparency (Boudelaa & Marslen-Wilson, 2000; Frost et al., 1997). Furthermore, non-linear Semitic word pattern morphemes like {faʕal} give rise to reliable priming between surface forms sharing them (Boudelaa & Marslen-Wilson, 2000; Deutsch, Frost, & Forster, 1998).

Nonetheless, since morphologically related words intrinsically share many aspects of meaning and form, the cognitive interpretation of morphemic effects remains controversial. Is, for example, the priming relationship between morphologically related English forms, such as *excitable–excite*, to be taken as evidence that morphemes are independent lexical units (Marslen-Wilson et al., 1994), or is it more parsimonious to think of this either as an interaction between form and meaning without an independent morphemic level (e.g. Joanisse & Seidenberg, 1999; Plaut & Gonnerman, 2000), or as reflecting inadequately controlled effects of form or meaning overlap between primes and targets (Rastle, Davis, Marslen-Wilson, & Tyler, 2000)?

Research in Semitic languages has already proved helpful in clarifying these issues. As noted above, non-morphological semantic factors can not be invoked to account for priming between Semitic word pairs sharing opaque roots, nor can they be invoked to explain word pattern priming in these languages. Nevertheless, such root priming is still potentially open to a form-based account, given the common segmental (orthographic or phonological) content across primes and targets. Semitic words sharing a root, whether transparent or opaque, share by necessity at least two consonants. Similarly words sharing a word pattern will share vocalic and often consonantal materials as well. A more clear-cut evaluation and analysis of the role of form-based factors in lexical representation, as opposed to potential pure morphological factors, could be made if these sources of potential phonetic overlap were also stripped out of the equation. The morphological system of Arabic, as conceived of within the framework of the multilinear morphological

[1] In representing the abstract structure of the word pattern, it is conventional to use the consonants /f,ʕ,l/ to indicate the slots to be occupied, respectively, by the first, second, and third letters of the root.

theory developed by McCarthy (1979, 1981, 1982), offers such a possibility. The next section presents this approach in its wider linguistic context.

1.1. Linguistic analyses of Arabic morphology

The oldest and most influential view of Arabic morphology is the *root and pattern* approach, which dates back to the work of the medieval Arab lexicographers (Bohas & Guillaume, 1984; Holes, 1995; Versteegh, 1997). On this traditional view, as mentioned above, all surface word forms result from the interleaving of two abstract morphemes, a root and a word pattern. The root is exclusively consonantal, while the word pattern consists mainly of vowels, though it can involve consonants as well. Functionally, the root conveys semantic meaning, while the word pattern contributes morpho-syntactic information such as *perfective*, *active*, or *causative*. The Arabic surface form [batar] *cut*, for example, is the result of combining the root {btr} *cutting* with the word pattern {faʕal} which conveys an *active*, *perfective* meaning. Two critical features define this approach. The first is the claim that the standard three-consonantal root is a unitary entity that has no further internal structure. The second is a similar claim about the unitary nature of the word pattern. Recent developments in linguistics, however, have questioned both these claims.

With respect to the root, Bohas (1997, 2000) argues that this level of analysis ignores salient phonetic and semantic regularities in the language. Many words share only two consonants, but nonetheless exhibit the kind of semantic link typical of words sharing a root (e.g. [batta] *cut*, [batara] *sever*, [batala] *cut*, [battaka] *cut off*). On the traditional root and pattern account such words are classed as synonyms, each with a different root, and their shared form is disregarded. Consequently Bohas (1997) suggested that the underlying organizational unit of the Arabic lexicon is not the root but a more abstract two-consonantal entity called the *etymon*. In the above examples, the etymon is {b,t}, and it conveys the general meaning of *cutting*. In recent priming experiments, we have found psycholinguistic evidence consistent with these suggestions (Boudelaa & Marslen-Wilson, 2001a).

Turning to word patterns, their status as unitary elements – which is the focus of the present research – has been challenged by McCarthy's influential multi-linear approach, where the word pattern is viewed as consisting of two further underlying morphemes (McCarthy, 1979, 1981, 1982). These separate out the linguistic information carried by the word pattern into two components labeled the *vocalic melody* – the sequence of vowels specified by the word pattern – and the *CV-Skeleton* – the overall abstract pattern of consonants (C) and vowels (V) that it also specifies.

From this perspective, the surface form [batar] *cut* is argued to consist of the consonantal root {btr}, the vocalic melody {a-a}, and the CV-Skeleton {CVCVC} as illustrated in Fig. 1. With respect to the consonantal root, McCarthy's approach is similar to the traditional *root and pattern* view, since on both accounts this unit is thought to convey the general semantic load, which will be more or less transparently reflected in the meaning of the resulting surface form. The vocalic melody conveys syntactic meaning such as voice (active/passive). The CV-Skeleton contributes a rich variety of other syntactic information, as well as specifying the phonological shape of the word. It also

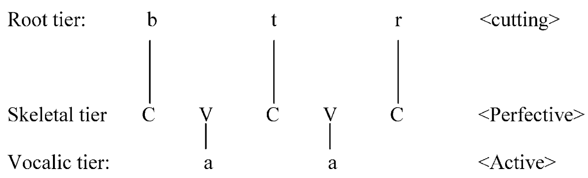

Fig. 1. Multi-linear representation of the complex form [batar] *cut*.

plays a fundamental role in determining rhyme in the Koran and in Arabic poetry – words sharing only a CV-Skeleton like [raħiim]–[duxuul] *merciful–entering* are viable rhyming words in the language (Kaye, 2001; Wright, 1995). The critical further point is that the CV-Skeleton, in contrast to the vocalic melody and the consonantal root, is a phonologically underspecified morpheme that consists only of a generic consonant and vowel sequence, and has no specific surface phonetic content associated with it.

The argument that roots, vowels, and skeletons are distinct morphemic units is made by McCarthy (1981, 1982) on classical linguistic distributional grounds, showing how each can be varied independently of the other two. Consider for example the pair [katab]–[kuutib] *write–be corresponded with*. This is a case where the two surface forms share the root {ktb}, with the general semantic load of "writing", but diverge with respect to their vocalic and skeletal morphemes. In [katab] the vocalic morpheme is the active {a-a}, and the skeletal morpheme is the *declarative* sequence {CVCVC}, while in [kuutib], the vocalic morpheme is the *passive* {u-i}, and the skeletal morpheme is the *reciprocal*[2] sequence {CVVCVC}. Note that on the root and pattern approach these words are analyzed as having two different word patterns, {faʕal} and {fuuʕil}, with no further internal structure.

If we turn to pairs like [katab]–[faʒʒar] *write–explode*, here the commonality between the two forms is not in terms of the root but of the *active* vocalic morpheme {a-a}. In [katab] the root is {ktb} and the skeleton is {CVCVC}, while in [faʒʒar] the root is {fʒr} and the skeletal morpheme is the *extensive*[3] sequence {CVCCVC}. On the traditional analysis, these two words would again be analyzed as having two different word patterns, {faʕal} and {faʕʕal}, and therefore as being linguistically unrelated. The rationale of McCarthy's analysis is that this fails to capture the fact that pairs like this are systematically related, sharing the active voice, and that this reflects a distinct underlying morpheme, the vocalic melody, which carries this information.

The third pole of the argument is illustrated by pairs like [kaalam]–[kuutib] *talk to each other–be corresponded with*, where the only commonality is in the CV-Skeleton, which here conveys a *reciprocal* meaning. Both words have different roots – {klm} in [kaalam] and {ktb} in [kuutib] – and different vocalic melodies – {a-a} and {u-i}, respectively – but they share the reciprocal skeleton {CVVCVC}. Again, on the traditional analysis, these two words have different word patterns, {faaʕal} and {fuuʕil}, and are therefore linguistically unrelated. McCarthy's view is that this also fails to capture an important

[2] Reciprocal means that the action described by a root combined with such a CV-Skeleton is being mutually exchanged by two people.

[3] Extensive means that the action is done for a long time or with great force or violence (Wright, 1995).

linguistic regularity across these and many other forms in the language. This regularity is captured in the multi-linear framework by postulating the additional morpheme, the CV-Skeleton.

Although we will take these concepts developed by McCarthy as the basis for the empirical work described here, it should be acknowledged that the notion of the CV-Skeleton has been the subject of much debate in the decades subsequent to McCarthy's thesis (McCarthy, 1979). If the CV-Skeleton is viewed more generally as a "prosodic template", providing a framework whereby phonetic material from different linguistic levels is fused together to create surface forms, there is continuing disagreement about the nature of the information encoded in the skeleton. At variance with McCarthy's view of templates as encoding not only the presence of a segment but also whether it is [−syllabic] or [+syllabic], was the X-Slot model, in which templates are viewed as an unspecified sequence of empty slots labeled as simple points or Xs (Clements & Keyser, 1983; Kaye & Lowenstamm, 1984; Levin, 1985). This view was predicated on the observation that in some cases a slot in the template may associate either with a consonant or a vowel. A second important contender has been the moraic view, which holds that the substance of the prosodic template should be specified in terms of directly prosodic units such as moras, syllables, feet and prosodic words, with phonological positions viewed as terminal points where prosody intersects with segments (Hayes, 1989; Hyman, 1985; McCarthy & Prince, 1996).

For the purposes of the current research, however, viewing the prosodic template as a sequence of consonants and vowels, or as a sequence of empty X-Slots, or indeed as a sequence of moras, does not make a material difference. The word pairs we describe as sharing a CV-Skeleton also share the same sequence of X-Slots and the same number of moras.[4] Furthermore, the issue of how the CV-Skeleton is to be characterized as a phonological entity is orthogonal to the question at issue here, which is whether it functions as a morpheme in the psycholinguistic, cognitive domain.

There are, in any case, several reasons for choosing to build on McCarthy's original CV-Skeleton view of the template. The first is that it provides a straightforward contrast with the widely held root and pattern approach, where the word pattern is viewed as a unitary mono-morphemic entity. Having found that the word pattern plays a significant role in Arabic word processing in our earlier research (Boudelaa & Marslen-Wilson, 2000, 2001b), our goal here is to explore its potential decomposability into the two further morphemic components identified by McCarthy. The second reason for focussing on the CV-Skeleton view is because this is the only version of multi-linear morphological theory where the prosodic template is explicitly claimed to be "a morpheme or a string of morphemes" (McCarthy, 1982, p. 192), rather than a purely phonological component. As such this model offers an appropriate framework for investigating the way morphological structure affects cognitive organization. Finally, the distinction between vowels and

[4] This is not to say that the three approaches have identical implications for morphological structure in Arabic. There are, for example, word pairs which would be related on an X-Slot view of the template, but not on a CV-Skeleton view. One such example would be the pair [fassar]–[quutil] *explain–be fought*, whose members share the prosodic template on an X-Slot approach, but not on a CV-Slot account since the two words have the CV-Skeletons {CVCCVCV} and {CVVCVCV}, respectively.

consonants as categorical cognitive entities that play a critical role in discriminating among different linguistic systems (Ramus, Nespor, & Mehler, 1999), and that are likely to be selectively damaged or spared (Caramazza, Chialant, Capasso, & Miceli, 2000), is nicely embodied in the CV-Skeleton view of the template.

In summary, we will take the multi-linear analysis proposed by McCarthy (1979, 1982) as a starting point, and will consider Arabic words as potentially sharing a morphological relationship by virtue of having a vocalic melody or a CV-Skeleton in common. This will allow us to ask whether or not these abstract linguistic units can be shown to contribute to cognitive processes of lexical access and representation. Before moving to the first experiment in the series reported below, we summarize earlier behavioral and neuropsychological research in Indo-European and Semitic languages that looked at the differential roles of consonants, vowels and CV-Skeletons.

1.2. Consonants, vowels and CV-Skeletons in Indo-European languages

Although the distinction between a phoneme and the position it occupies in a phonological structure has long been formalized in modern phonological theory, the empirical evidence bearing on the qualitative distinction between consonants, vowels, and CV-Skeletons in cognitive psychology is both scarce and inconsistent. With respect to the CV-Skeleton, Romani (1992) found reading latencies to be significantly quicker for targets presented in the context of a nonce auditory prime with an identical CV-structure compared to a prime with a different CV-structure. However, this pattern of results was not replicated in a subsequent experiment (Romani, 1992). Similarly, Meijer (1996) showed that a target Dutch word like "DAS" *scarf*, where the CV-structure is CVC, was named more quickly and accurately when preceded by a prime which also had a CVC structure (e.g. "NOK" *ridge*) relative to a prime which had a CVCC structure (e.g. "NERF" *grain*). However, in a further experiment, no advantage was found for words with matching structures of the syllable nucleus. The target "MEEUW" *tendon*, where the syllable nucleus is VV, yielded the same response time irrespective of whether it was paired with the word "PEES" *sea-gull*, which had the same syllable nucleus VV, or the word "KAM" *comb*, which has a mismatching syllable nucleus, namely V. According to Meijer (1996) this was evidence that a word's CV-structure was independently stored in and retrieved from the mental lexicon, and that words with different nuclei have similar CV-structures. Sevald, Dell, and Cole (1995) also found significant CV-structure effects in a repeated pronunciation task. By contrast, Roelofs and Meyer (1998) did not find any such effects in an implicit priming study. Dutch target words appearing in the context of a set of words with which they share the same CV-structure had no advantage over targets appearing in the context of a set with a diverging CV-structure.

Equally uncertain is the relative role of consonants and vowels in lexical processing. According to Berent and Perfetti (1995) and Lee, Rayner, and Pollatsek (2001), there is a temporal distinction between the contribution of consonants and vowels during the reading of English. At early stages of word identification, consonant information makes a significant contribution, and vowel information makes little or no contribution. Later on in the word identification process, the contribution of vowel information increases markedly. Lukatela and Turvey (2000), however, found lexical decision latencies to be similarly fast irrespective of whether the target is preceded by a prime with which it shares consonants, or vowels. Also, no advantage for consonants over vowels was found in lexical decisions in Italian (Colombo, 2000).

Neuropsychological data may provide a firmer ground for a categorical distinction between consonants and vowels. In general, aphasic speech involves more errors in the processing of consonants than vowels. Canter, Trost, and Burns (1985), for example, report error rates of 12% for vowels as opposed to rates of nearly 70% for consonants across a variety of tasks. Several other studies also report differences in the same direction (Béland, Caplan, & Nespoulous, 1990; Blumstein, 1978; Boatman, Hall, Goldstein, Lesser, & Gordon, 1997; Monoi, Fukusako, Itoh, & Sasanuma, 1983). However, there are also cases where vowels are more impaired than consonants (e.g. Caramazza et al., 2000; Romani, Grana, & Semenza, 1996), suggesting a potential dissociation, although the neural substrate for this remains unclear.

1.3. Consonants, vowels and CV-Skeletons in Semitic languages

The contribution of consonants, vowels and CV-Skeletons needs to be approached on a different basis in the Semitic languages, where each type of element is primarily associated with distinct morphological functions. Previous research demonstrates that the root morpheme, composed exclusively of consonants, is involved in the processing of Arabic words (Boudelaa & Marslen-Wilson, 2001b), and Hebrew words (Frost et al., 1997). Vowels, in contrast, can never be part of the root, and only occur as part of the word pattern (which can also include consonants). As we have seen, there is also good evidence for the psychological role of the word pattern in lexical processing of both Arabic and Hebrew.

The few neuropsychological reports available on Semitic aphasic speech suggest that, where consonants and vowels are separately affected, this is in the context of the morphological units to which they belong. Prunet, Béland, and Idrissi (2000) describe a native Arabic speaking aphasic, ZT, whose errors change the order of root consonants, but not of the vowels (or consonants) belonging to the word pattern. Thus, given a surface form like [mamduuħ] *praised*, where the root is {mdħ}, and the word pattern is {mafʕuul}, ZT would produce a non-word like *[madmuuħ], where the first and second consonants of the root are swapped. But he almost never produces an error where a root consonant is swapped with a word pattern consonant. Barkai (1980) describes a Hebrew aphasic, Dudu, who does not make errors on root consonants, but on the vowels and consonants of the word pattern. For example, when prompted with the Hebrew form [higdilu] *they enlarged*, which is comprised of the root {gdl}, and the word pattern {hifʕilu}, Dudu would output the form [gadlu] where the root consonants are intact and in the correct order, but some of the word pattern vowels and consonants are lost or changed.

In summary, the evidence so far suggests that the differential role played by consonants and vowels in Semitic languages is a consequence of the morphological units to which they belong (roots and word patterns). However, there is little evidence relevant to the potential dissection of the word pattern into two further components (the vocalic melody and the CV-Skeleton). Most previous research has been conducted on the assumption that the word pattern is a unitary entity with no internal structure.

This question is of course the focus of the current research. We use masked, cross-modal, and auditory–auditory priming to ask whether pairs of words sharing only the vocalic (e.g. [katab]–[faʒʒar] *write–explode*), or only the skeletal morpheme (e.g. [kuutib]–[naaqaʃ] *be corresponded with–discuss*) will prime each other. In using priming as a window into the structure of the mental lexicon, we assume that facilitation between morphologically related words reflects contact with the same underlying morphemic entity in the processing of the prime and target, and that this can be separated from possible priming effects between words that are otherwise semantically, orthographically, or phonologically related. If Arabic words sharing only the vocalic morpheme or only the CV-Skeleton prime each other significantly relative to appropriate controls, this will be taken as evidence that vocalic melodies and CV-Skeletons are independent cognitive entities. These contrasts will also allow us to determine whether vocalic and skeletal morphemes contribute equally to the word recognition process. We will compare the priming in these two conditions with facilitation in a third condition where the prime and target share both vocalic and skeletal morphemes (e.g. [katab]–[sahar] *write–stay up*). In this condition, prime and target share the same word pattern, as traditionally defined. Since we have found consistent priming among words sharing a word pattern in earlier research, we expect the same results here. In addition, this will provide a basis for comparison with the size of the effects in the vocalic and skeleton conditions.

2. Experiment 1: masked priming

Masked priming is an experimental paradigm where the priming item is typically displayed for about 50 ms or less, and is sandwiched between a forward pattern mask and a target item, which serves as a backward mask (Forster & Davis, 1984). This paradigm is generally viewed as being insensitive to semantic effects while being well suited to the study of morphological and form-based effects (Feldman, 2000; Rastle et al., 2000; though see Forster, 1999). More importantly, masked priming seems to be capable of discriminating between orthographic and morphological effects in a variety of languages, including French (Grainger et al., 1991), Dutch (Drews & Zwitserlood, 1995), and English (Feldman, 2000; Rastle et al., 2000). In Semitic languages like Hebrew and Arabic, masked morphological effects have been particularly robust and consistent (Boudelaa & Marslen-Wilson, 2001a,b; Deutsch et al., 1998; Frost et al., 1997), and are obtained even when prime and target pairs share no transparent semantics (Boudelaa & Marslen-Wilson, 2001b; Frost et al., 1997), and minimal form overlap (Boudelaa & Marslen-Wilson, 2001a).

In view of the consistency of masked morphological priming in Semitic languages, Experiment 1 uses this paradigm to examine the role played by the vocalic melody and the CV-Skeleton during the processing of Modern Standard Arabic (MSA) verb forms.

Table 1
Design and sample stimuli for Experiment 1 with Arabic script, IPA transcription and English glosses

	Prime		Target
Condition	control	test	
[+Vowel]	قصاب [qasˤsˤaabun] [CVCCVVCVC] butcher	أشفق [ʔaʃfaqa] [CVCCVCV] pity	ترك [taraka] [CVCVCV] leave
[+Skeleton]	حملة **[ħamlatun]** [CVCCVCVC] raid	فوجئ [fuuʒiʔa] [CVVCVCV] be surprised	شارك [ʃaaraka] [CVVCVCV] participate
[Word Pattern]	وعاء **[wiʕaaʔun]** [CVCVVCVC] vessel	ساند [saanada] [CVVCVCV] support	خالف [xaalafa] [CVVCVCV] disobey

We will compare priming between morphologically related words that share either a vocalic morpheme, a skeletal morpheme, or both (see Table 1).

In Condition 1, the masked prime (e.g. [ʔaʃfaqa] *pity*), where the vocalic melody is {a-a} and the CV-Skeleton is {CVCCVCV}, is paired with a morphologically related visual target (e.g. [taraka] *leave*) where the vocalic melody is {a-a} and the CV-Skeleton is {CVCVCV}. The common morphemic unit between prime and target is the vocalic but not the skeletal morpheme, hence the condition label [+Vowel]. To form a baseline against which priming is measured, the same target [ʔasˤbaħ] *become* is also paired with the unrelated prime [qassaabun] *butcher*, whose vocalic melody and CV-Skeleton are {a-aa} and {CVCCVVCVC}, respectively. In Condition 2, labeled [+Skeleton], with pairs like [fuuʒiʔa]-[ʃaaraka] *be surprised-participate*, the common morphological unit is the skeleton {CVVCVC}, with the vocalic melody being {u-i} in the prime but {a-a} in the target. In the baseline condition the same target [ʃaaraka] is preceded by the unrelated prime [ħamlataun] *raid* where the vocalic morpheme is {a-a}, and the CV-Skeleton is {CVCCVCVC}. In the third condition, labeled [Word Pattern], primes like [saanada] *support* and targets like [xaalafa] *disobey* share both the vocalic melody {a-a} and the skeletal morpheme {CVVCVCV}, which together constitute the word pattern {faaʕal}.

The unrelated prime in the baseline condition again shares neither vocalic melody nor CV-Skeleton. Facilitation in both Condition 1 and Condition 2 will suggest that the two components of the word pattern are both extracted from surface word forms. Alternatively, if reliable facilitation is obtained only in one of these conditions, say for [+Vowel] but not [+Skeleton], this would be an indication that the vocalic morpheme is the unit that underlies word pattern priming, and vice versa.

2.1. Method

2.1.1. Participants

Thirty volunteers, aged 16–20 years old, took part in the experiment. They were pupils at the High School of Tataouine in the South of Tunisia. None of them had any known history of hearing loss or speech disorder. They were native Arabic speakers who had been using MSA on a daily basis at school for the last 10 years. In the current Tunisian educational system almost all subjects are taught in MSA, so that participation in secondary education requires a high degree of proficiency in MSA. Note that MSA is not only the medium of writing in the Arab world, but also dominates the mass media. Arabic children are exposed to MSA via the broadcast media from a very early age, and it is the version of Arabic used in educational settings from nursery school onwards. In additional studies (Boudelaa & Marslen-Wilson, in preparation) we have shown that the primary phenomena observed for MSA (root and word pattern effects) also hold for experiments conducted using the local Southern Tunisian vernacular.

2.1.2. Materials and design

A total of 96 target verb forms, with a mean letter number of 4.04 and a mean syllable length of 3.3, were selected to construct the three conditions outlined in Table 1 (see Appendix A for the full stimulus set), and described in detail above. For each of the 96 prime words, an unrelated baseline word matched as closely as possible on familiarity, number of letters and phonemes was selected. Familiarity was determined on the basis of a pretest where 15 judges who were native speakers of Arabic were asked to rate words on a 1–5 scale with 1 being very unfamiliar and 5 very familiar. All the words used in this experiment had an average rating of 3 or more. Another 15 judges were asked to rate the semantic relatedness of each prime/target pair, using a 9-point scale with 1 being semantically unrelated and 9 highly related. None of the experimental pairs was rated higher than 4 on this scale. Since the stimuli will be used in cross-modal and auditory–auditory priming, we also checked for recognition point (RP) across conditions. RP is the point in a word where it becomes unique (Marslen-Wilson, 1987) and priming effects depending on word identity may vary as a function of RP. Accordingly we computed the RP for each stimulus based on a dictionary analysis of each word's competitor environment. Table 2 summarizes the properties of the stimulus set in terms of number of letters, number of phonemes, familiarity, and RP. Since we are obliged to use a between-word design, there are inevitably small differences across conditions in these counts. The possible contribution of these factors to the observed priming effects will be evaluated for each experiment using regression techniques.

Table 2
Stimulus properties for the test primes, baseline primes, and targets in the [+Vowel], [+Skeleton], and [Word Pattern] conditions (standard deviations in parentheses)

		No. of letters	No. of phonemes	Familiarity	Recognition point
[+Vowel]	Test prime	4.00 (0.76)	7.31 (1.28)	4.08 (0.81)	5.84 (1.51)
	Baseline	4.25 (0.67)	7.66 (1.21)	3.70 (0.97)	4.41 (0.95)
	Target	4.22 (0.91)	7.75 (1.50)	4.32 (0.34)	6.47 (1.46)
[+Skeleton]	Test prime	3.66 (0.48)	5.94 (0.35)	3.70 (0.74)	4.50 (0.80)
	Baseline	3.56 (0.50)	6.72 (0.81)	4.35 (0.70)	4.22 (0.71)
	Target	3.66 (0.48)	5.94 (0.35)	4.49 (0.76)	4.50 (0.72)
[Word Pattern]	Test prime	4.25 (0.98)	7.91 (1.44)	3.85 (0.72)	6.03 (1.47)
	Baseline	4.25 (0.98)	8.16 (1.87)	3.87 (0.76)	4.94 (1.13)
	Target	4.25 (0.98)	7.91 (1.44)	4.56 (0.43)	6.25 (1.37)

Note that the unrelated prime word in the three test conditions is a noun rather than a verb, although the related prime is itself always a verb. The reason for this is that the number of verbal vocalic melodies and CV-Skeletons do not exceed four and eight, respectively.[5] This made it impossible to find sufficient control verb primes that were closely matched to the related primes in terms of familiarity, number of letters and phonemes, and that did not overlap with the targets either at the vocalic or skeletal level, providing unwanted potential morphemic overlap. However, even if the noun/verb shift changes the properties of the baseline, any effect will be constant across the three conditions, and the critical contrasts are between these conditions.

We also computed the average overlap in consonants and vowels for the three main conditions. For [+Vowel] this averaged 2.28 (0.5 consonants, 1.28 vowels), for [+Skeleton] the figure was 0.72 (0.44 consonants, 0.28 vowels), and for [Word Pattern] 3.72 (1.31 consonants, 2.41 vowels). This reflects the properties of the morphological relationships between prime and target in different conditions. Note that the amount of overlap, in terms of shared surface segments, is especially low, as one would expect, in the [+Skeleton] condition. For the baseline primes and targets, the average overlap was uniformly low across all conditions, at 1.16 for [+Vowel], 0.69 for [+Skeleton], and 1.13 for [Word Pattern].

A further 96 words were selected and paired with pseudo-word targets in order to provide 50% "no" responses. The pseudo-words were constructed by combining a non-existing consonantal morpheme with an existing vocalic morpheme and an existing skeletal morpheme. For example, the pseudo-root *{stn} is combined with the existing vocalic melody {a-a} and the existing CV-Skeleton {CVCVC} to derive the non-existing form *[satan]. The amount of form overlap in the word/non-word pairs mimicked as closely as possible that of the experimental word pairs. Additionally, 36 practice trials

[5] The existing four vocalic melodies are {a-a}, {a-u}, {a-i}, {u-i}, and the attested eight CV-Skeletons which combine with three-consonantal roots are {CVCVC}, {CVCCVC}, {CVVCVC}, {CVCVCCVC}, {CVCVVCVC}, {CVCCVCVC}, {CVCCVCC}, {CVCCVCCVC}.

comprising 18 word and 18 non-word responses were constructed in such a way as to be representative of the experimental trials. Two experimental lists were constructed each containing 228 pairs of which 114 were word/word pairs and 114 word/pseudo-word. Subjects were assigned randomly to one of the lists and were not presented with the same prime or target more than once.

2.1.3. Procedure

Each trial consisted of three visual events. The first was a forward pattern mask, in the form of a sequence of 28 vertical lines in a 30-point traditional Arabic font size. This mask was chosen on the basis of pre-testing sessions in which it was compared to the standardly used hash marks. The 28 vertical lines were more effective than the hash marks in masking the prime. The second event was a prime word written in a 24 point using the same font. The prime display duration was 48 ms. The third event was a target word or non-word written without diacritics in a 34-point font size. It was displayed for 2000 ms. Since there is no upper case/lower case contrast in the Arabic script, the targets had a larger font size than the primes to make sure the latter were appropriately masked. Three portable PC monitors were used to test subjects in threes in a quiet room. Stimulus presentation and data collection were controlled by the DMDX software.[6]

All stimuli were presented in white on a blue background, and did not contain any vowel diacritics. These are normally used only in children's reading material or in religious texts. The use of a diacritic-less script usually entails a substantial degree of ambiguity in Arabic orthography. For example, the diacritic-less Arabic form علم exhibits only the root consonants {ʕlm}, and can be read as [ʕalim] *know*, [ʕalam] *flag*, [ʕilm] *science* and [ʕulim] *be known*. To avoid this potential problem, especially since we are interested in priming by vocalic melody, the stimuli used here are either unambiguous, as in the form أصبح ', which is readable only as [ʔasbaħ] *become*, or have one dominant reading such that the alternative interpretation is less frequent. For instance, although the Arabic form ساعد can potentially be read as [saaʕid] *forearm* and [saaʕad] *assist*, the latter was considered to be the more common reading based on the fact that it is one of the 3000 most frequent words of the language, while the former is not (Abdah, 1979). Subjects were asked to make a quick and accurate lexical decision about the target by pressing a YES or NO key. The experiment lasted about 15 minutes and started with 36 practice trials followed by the experimental trials.

2.2. Results

We had six data cells per participant resulting from the combinations of the three prime Conditions (Vowel, Skeleton, Word Pattern) and two Prime Types (related vs. unrelated). The token [ʔaʃaaʕa] *spread rumors* had an error rate of 45% and was discarded from the analysis, as were the data of four participants whose error rates exceeded 20%. Cut-offs were set at 2 standard deviations above or below the mean response of each subject. This procedure, which was applied in the three experiments, eliminated a very small percentage

[6] The DMDX experimental software is made available by K.I. Forster and Jonathan Forster at the University of Arizona, Tucson. For further information see: http://www.u.arizona.edu/~kfortser/dmdx/dmdxhp.htm.

Table 3
Mean lexical decision times and (error rates) in Experiment 1

Condition	Control	Test	Difference
1. [+Vowel]	607 (7.45)	610 (6.49)	−3
2. [+Skeleton]	594 (5.96)	576 (5.46)	18
3. [Word Pattern]	599 (5.26)	578 (6.01)	22

of data (0.05). The mean reaction times and error rates for the remaining data are displayed in Table 3. Overall, we see no priming in the [+Vowel] condition, but comparable facilitation effects for targets sharing only a skeletal morpheme or both a vocalic and a skeletal morpheme.

The data were analyzed in two three-way analyses of variance (ANOVA) with participants (F_1) and items (F_2) as random variables. One factor was Condition with the levels [+Vowel], [+Skeleton] and [Word Pattern], and the second was Prime Type with the two levels related and unrelated. Condition was treated as a repeated factor in the participants' analysis and as an unrepeated factor in the items' analysis, while Prime Type was treated as a repeated factor in both analyses. The third factor was List assignment which was included as a between subject variable in the by-participants ANOVA, and as a between items variable in the items ANOVA. The main effect of Condition was significant both in the participants' and items' analyses [$F_1(2,25) = 7.38$, $P < 0.002$; $F_2(2,94) = 7.88$, $P < 0.001$]. The effect of Prime Type was marginally significant in both participants' and items' analyses [$F_1(2,25) = 4.06$, $P < 0.055$; $F_2(2,94) = 3.73$, $P < 0.057$]. The interaction between Condition and Prime Type was not significant [$F_1 < 1$, $F_2 < 1$].

Planned comparisons revealed the 18 ms priming in the [+Skeleton] condition to be significant by participants [$F_1(1,25) = 4.80$, $P < 0.038$], but not by items [$F_2(1,30) = 2.03$, $P = 0.16$]. The 22 ms priming in the [Word Pattern] condition was significant in both analyses [$F_1(1,25) = 4.48$, $P < 0.044$; $F_2(1,31) = 5.43$, $P < 0.026$]. The effect in the [+Vowel] condition was not significant in either analysis [$F_1 < 1$, $F_2 < 1$]. Comparing conditions, the difference between the amount of priming in the CV-Skeleton condition and the vocalic melody condition was marginally significant by participants [$F_1(1,25) = 3.67$, $P < 0.067$] but non-significant by items [$F_2(1,31) = 1.57$, $P < 0.21$]. There was no difference in priming between the CV-Skeleton condition and the word pattern condition [$F_1 < 1$, $F_2 < 1$], while the difference between the vocalic condition and the word pattern condition was marginally significant [$F_1(1,25) = 4.04$, $P < 0.055$; $F_2(1,31) = 2.86$, $P < 0.095$]. Finally, error analyses did not give rise to any significant effects.

To check on the possible contribution of stimulus properties such as length in letters and familiarity (phoneme length and RP do not apply here), each of these variables was centered and used as a predictor of priming in separate stepwise multiple regression analyses. Neither length in letters ($R^2 = 0.036$, $F(3,94) = 1.14$, $P = 0.33$) nor familiarity ($R^2 = 0.067$, $F(3,94) = 2.19$, $P = 0.094$) was a significant predictor of priming.

2.3. Discussion

The priming between word pairs sharing both skeletal and vocalic morphemes (i.e. the word pattern) replicates earlier findings in Hebrew (Deutsch et al., 1998; Frost, Deutsch, Gilboa, Tannenbaum, & Marslen-Wilson, 2000) and Arabic (Boudelaa & Marslen-Wilson, 2000). The novel findings in Experiment 1, however, relate to two additional strong trends in the data: first, the larger amount of priming between word pairs sharing a skeletal morpheme as opposed to those sharing a vocalic morpheme, and second, the similarity in the size of the priming effects in the skeleton and the word pattern conditions. The importance of the apparent priming by the CV-Skeleton stems from the fact that the word pairs in this condition share neither orthographic overlap (defined in terms of common letters across prime and target), nor semantic relationships (as reflected in a semantic judgement pretest). All they have in common is the skeleton, the sequence of consonants and vowels, and the syntactic meaning associated with this sequence. The facilitation observed here is suggestive evidence that the CV-Skeleton is actively involved in the mapping of Arabic orthographic forms onto central lexical representations. However, given that the CV-Skeleton effects fell short of full statistical significance, they need validation in further studies.

Unlike the skeleton morphemes, the vocalic morphemes in this study did not yield any suggestion of priming. However, since vocalic morphemes carry important syntactic information such as the passive/active opposition in verbs,[7] this outcome also requires further examination. In particular, the lack of priming may reflect the experimental format we used. In Arabic orthography, information about vocalic morphemes in most Arabic verbs is coded through the use of diacritical marks. As noted earlier, these diacritics are normally only present in works for children and in religious texts. Since the stimuli we used, like most written Arabic, did not contain vowel diacritics, the vocalic morpheme was not directly present in the orthographic input, while the information about the skeleton was explicitly specified in the overall shape of the word. It may be that the vocalic morpheme plays a role that is less easy to detect in masked priming because it is not explicitly specified in the orthography. One way of addressing this possibility is by using a different experimental format where the information about the vocalic morpheme is given directly, by using spoken primes. Experiment 2, accordingly, uses cross-modal priming with the same set of materials.

3. Experiment 2: cross-modal priming

The results of Experiment 1 suggest that the CV-Skeleton but not the vocalic melody affects the processing of Arabic complex forms, as indicated by the trend towards priming in the [+Skeleton] condition and the lack of it in the [+Vowel] condition. Since the prime and target are orthographic events that do not explicitly contain the vocalic morpheme, the failure of this unit to generate priming may be reflecting the insensitivity of masked

[7] Remember, for example, that the members of the active/passive pair [katam]–[kutim] *hide–be hidden* diverge only with respect to their vocalic morphemes {a-a} in the first, and {u-i} in the second.

priming to its effects, rather than the non-involvement of this unit in the word recognition process. To address this issue, we ran the same experiment using cross-modal priming, presenting an auditory prime in which the vocalic morpheme is fully specified, immediately followed by a visual probe. This experimental technique is well suited to the study of morphological effects, and has been extensively used in earlier research (e.g. Frost et al., 2000; Marslen-Wilson et al., 1994).

The second, equally important, purpose of this experiment was to gather converging evidence as to the involvement of the CV-Skeleton in the processing of Arabic surface forms. Since the CV-Skeleton is intrinsically a phonological structure, it is possible that it too will be more strongly activated when the prime is spoken rather than written. This would lead to statistically more robust effects for the [+Skeleton] condition.

3.1. Method

3.1.1. Participants

Another group of 36 volunteers from the same age group and linguistic background as in Experiment 1 were run.

3.1.2. Stimuli and design

The stimuli and design were the same as in Experiment 1 apart from the fact that 80 unrelated pairs were added in order to dilute the proportion of related items and to obscure the relationship in the test items. Of these 40 were word/word pairs and 40 word/non-word pairs. To make sure that participants were not ignoring the auditory prime, they were asked at pseudo-randomly distributed intervals during the course of the experiment to write down the prime word they had just heard. All of these probes were followed by a non-test item. This gave a total of 328 pairs with 164 word responses and an equivalent number of non-word responses. The test items were divided into two balanced versions with all the targets appearing only once in each version, with half preceded by the related prime and half preceded by the control prime.

3.1.3. Procedure

The procedure was also similar to that used in Experiment 1 except that the sequence of stimulus events within each trial was as follows: a 1000 ms silence was followed by an auditory prime. Immediately at its offset a target was displayed on the screen for 2000 ms. A new trial started as soon as the subject responded even if 2000 ms had not elapsed. Timing and response collection were controlled by a laptop PC running the DMDX package. Participants were instructed to make a lexical decision as quickly and as accurately as possible by pressing a YES or NO key. The YES response was always made by the dominant hand. To make sure that participants attended to the auditory prime they were asked at intervals to write down the prime word of the catch trials. The experiment, which lasted about 20 minutes, started with the practice trials followed by the rest of the stimuli.

3.2. Results

The data of seven participants with error rates above 20% were excluded, leaving a total of 29 subjects. Mean decision latencies and accuracy rates for Experiment 2 are shown in Table 4 together with the priming effects for the three experimental conditions. There are no priming effects in the [+Vowel] condition, but clear facilitatory effects in both the [+Skeleton] and the [Word Pattern] conditions.

In ANOVAs similar to those conducted in Experiment 1, the main effect of Condition was not significant [$F_1 < 1, F_2 < 1$]. By contrast, the effect of Prime Type was significant by participants and items [$F_1(2,28) = 6.52$, $P < 0.017$; $F_2(2,95) = 14.33$, $P < 0.001$]. The interaction between Condition and Prime Type was significant by items [$F_2(1,95) = 4.50$, $P < 0.05$] but marginal by participants [$F_1(1,28) = 2.52$, $P < 0.089$]. Planned comparisons revealed the 27 ms priming in the [+Skeleton] condition to be strongly significant [$F_1(1,28) = 12.43$, $P < 0.002$; $F_2(1,31) = 5.93$, $P < 0.021$]. Similarly, the 43 ms priming in the [Word Pattern] condition was significant in both analyses [$F_1(1,28) = 12.43$, $P < 0.001$; $F_2(1,31) = 23.37$, $P < 0.001$]. No significant effects were found in the [+Vowel] condition [$F_1 < 1, F_2 < 1$]. The amount of priming in the [+Skeleton] condition differs significantly from that observed in the [+Vowel] condition [$F_1(1,28) = 10.02$, $P < 0.004$; $F_2(1,31) = 4.39$, $P < 0.05$], but not from that observed in the [Word Pattern] condition [$F_1 < 1$, $F_2 < 1$]. The difference in priming between the [Word Pattern] and the [+Vowel] conditions was significant by items [$F_2(1,31) = 5.89$, $P < 0.001$] and marginally reliable by subjects [$F_1(1,28) = 3.35$, $P < 0.07$].

As regards the error data, there was a main effect of Prime Type [$F_1(1,28) = 6.04$, $P < 0.07$; $F_2(1,31) = 4.87$, $P < 0.03$], due mainly to the increased error rate in the [+Skeleton] control condition, as reflected in the interaction between Condition and Prime Type [$F_1(1,28) = 7.89$, $P < 0.001$; $F_2(1,95) = 3.50$, $P < 0.034$]. It is not clear why error rate is increased here. These are the same visual targets as in Experiment 1, where error rates were very similar across all conditions.

Finally, we checked on the possible contribution of the relevant stimulus properties (length in phonemes, familiarity, and RP). As before, each variable was centered and used in a separate stepwise regression analysis. None of the three variables significantly predicted priming (length in phonemes: $R^2 = 0.040$, $F(3,95) = 1.26$, $P = 0.29$; familiarity: $R^2 = 0.036$, $F(3,95) = 1.13$, $P = 0.34$; RP: $R^2 = 0.024$, $F(3,95) = 0.76$, $P = 0.51$).

Table 4
Mean lexical decision times and (error rates) in Experiment 2

Condition	Control	Test	Difference
1. [+Vowel]	592 (6.03)	593 (5.82)	−1
2. [+Skeleton]	600 (11.85)	573 (4.31)	27
3. [Word Pattern]	620 (5.82)	577 (5.17)	43

3.3. Discussion

The cross-modal priming paradigm used in Experiment 2 provides a clear replication and strengthening of the pattern of effects in Experiment 1. Strong priming effects emerge in the CV-Skeleton and the word pattern conditions, but not in the vocalic melody condition. The absence of any difference between the word pattern and the CV-Skeleton conditions raises the possibility that the word pattern priming effects obtained here and in earlier studies primarily reflect skeleton morpheme effects. Furthermore, the emergence of skeleton priming effects in cross-modal priming, where the prime is auditory and the target is visual, suggests that the skeleton morpheme is playing a role at an abstract level of representation, onto which auditory as well as visual input can be mapped (Marslen-Wilson et al., 1994).

Unlike skeleton morphemes, vocalic morphemes fail to yield any cross-modal priming effects. This suggests that the lack of vocalic morpheme priming in Experiment 1 cannot be attributed to the use of a diacritic-less written prime. The fact remains, however, that the target in the cross-modal priming format used here is still a vowel-less visual probe. In other words, any potential facilitation resulting from prior exposure to the vocalic morpheme in the auditory prime may be offset by the need to recover this morphemic unit from a visual target that conveys it only implicitly. To assess this possibility, we ran a third experiment using the auditory–auditory priming task, where both prime and target are auditorily presented.

4. Experiment 3: auditory–auditory priming

The auditory–auditory immediate priming format used in this third experiment has two features of interest. First, the prime and target are auditory events in which the vocalic morpheme is fully specified. Second, priming effects tend to be stronger in the auditory–auditory format than in the cross-modal or masked priming procedures (Marslen-Wilson & Zhou, 1999). These two factors should maximize the chances of observing priming by vocalic morphemes, and provide further evidence about the involvement of the CV-Skeleton in lexical processing.

4.1. Method

4.1.1. Participants

These were 30 pupils from the same age group and linguistic background as Experiment 1.

4.1.2. Stimuli and design

These were the same as in Experiment 2, with the exception that visually presented targets were replaced by spoken targets.

4.1.3. Procedure

All the prime and target words were recorded by a native speaker of Arabic and digitized with a sampling rate of 44 kHz, then down-sampled to 22 kHz using the CoolEdit program and stored on a portable PC. The items were recorded over different sessions in a random sequence but with members of prime/probe pairs well separated to avoid their having more similar voice qualities than any other two items chosen randomly from the set of material. Three portable PC monitors were used to test subjects in threes in a quiet room. They heard the stimuli at a comfortable level through HD 250 Sennheiser headphones. The sequence of stimulus events within each trial was as follows: the prime word was played and around 50 ms after its offset the target was presented. The time out period was 2 s, and the inter-trial interval was 1 s.

Timing and response collection were controlled by a laptop PC running the DMDX package. Latencies were measured from the target word's acoustic onset. The mean duration of the target words was 769 ms in the [+Vowel] condition, 687 ms in the [+Skeleton] condition, and 747 ms in the [Word Pattern]. Since the materials had originally been designed for visual presentation, some variation in auditory duration was to be expected. Since all prime/target comparisons with baseline are within-word, this should not affect the interpretation of the results. Participants were instructed to make a lexical decision as quickly and accurately as possible by pressing a YES or NO key. The YES response was always made by the dominant hand. The experiment, which lasted about 35 minutes, started with the practice trials followed by the rest of the stimuli. This was a significantly longer running time than either Experiment 1 (15 minutes) or Experiment 2 (20 minutes), and some subjects had difficulty maintaining focus, leading to erratic responding.

4.2. Results

Eight subjects had an error rate well over 20%, and their data were discarded from the analysis, leaving a total of 22 participants. Table 5 gives the mean response latencies (for correct responses only) and the average error scores, together with the priming effects for each condition.

In analyses similar to those conducted in Experiments 1 and 2, the main effect of Condition was significant [$F_1(2, 1) = 54.97$, $P < 0.001$; $F_2(2, 95) = 8.38$, $P < 0.001$], as was the effect of Prime Type [$F_1(2, 21) = 22.01$, $P < 0.001$; $F_2(2, 95) = 6.55$, $P < 0.012$]. The interaction between Condition and Prime Type was significant by participants [$F_1(1, 21) = 5.35$, $P < 0.05$] but not by items [$F_2(1, 95) = 1.50$, $P < 0.27$]. Planned comparisons showed the 36 ms facilitation in the [+Skeleton] condition to be significant [$F_1(1, 21) = 10.75$, $P < 0.003$; $F_2(1, 31) = 5.60$, $P < 0.024$]. The 34 ms effect

Table 5
Mean lexical decision times and (error rates) in Experiment 3

Condition	Control	Test	Difference
1. [+Vowel]	997 (7.39)	996 (7.10)	−9
2. [+Skeleton]	950 (7.95)	914 (6.53)	36
3. [Word Pattern]	967 (5.11)	933 (3.98)	34

in the [Word Pattern] condition was significant by participants [$F_1(1,21) = 14.13$, $P < 0.001$] and nearly reliable by items [$F_2(1,31) = 3.43$, $P < 0.074$]. No significant effects were found in the [+Vowel] condition [$F_1 < 1$, $F_2 < 1$]. The difference between the amount of priming in the [+Skeleton] and the [+Vowel] conditions was significant by subjects [$F_1(1,21) = 4.80$, $P < 0.037$] but marginal by items [$F_2(1,31) = 2.80$, $P < 0.09$]. As before there was no difference between the amount of priming in the [+Skeleton] and the [Word Pattern] conditions [$F_1 < 1$, $F_2 < 1$]. The amount of facilitation in the [Word Pattern] and the [+Vowel] conditions was significantly different by subjects but marginal by items [$F_1(1,21) = 7.84$, $P < 0.009$; $F_2(1,31) = 2.80$, $P < 0.09$].

Turning to the error data, the main effect of Condition was significant by participants [$F_1(1,21) = 3.37$, $P < 0.044$] but not by items [$F_2(1,95) = 1.77$, $P = 0.17$]. Neither the main effect of Prime Type nor its interaction with Condition reached significance in any of the analyses [$F_1 < 1$, $F_2 < 1$]. Note that there was no sign here of the increased error rate for the [+Skeleton] controls seen in Experiment 2.

Finally, we checked as before for the possible contribution of relevant stimulus properties (familiarity, RP). We used acoustic duration of the target words rather than the more indirect measure of length in phonemes. None of these variables was a significant predictor of priming effects: RP ($R^2 = 0.068$, $F(3,95) = 2.23$, $P = 0.090$), familiarity ($R^2 = 0.036$, $F(3,95) = 1.13$, $P = 0.34$), and acoustic duration ($R^2 = 0.048$, $F(3,95) = 1.53$, $P = 0.211$).

4.3. Discussion

Despite the very different mode of presentation of the target word in this experiment, as a fully specified auditory sequence rather than an orthographic image, the overall pattern of results is the same as in the previous two experiments. Word pairs sharing only a skeleton morpheme, or a skeleton and vocalic morpheme at the same time, facilitate each other reliably. Furthermore, the amount of priming generated by the word pattern as a whole is not significantly different from that produced by the skeleton alone. In contrast, the vocalic morpheme again failed to generate any facilitatory effects, despite the overall increase in the amount of facilitation in auditory–auditory priming. This shows that the lack of overt coding of this potential morphemic unit in the previous two experiments was not the reason why no priming had been observed in the [+Vowel] condition.

5. General discussion

In these experiments we set out to explore whether vocalic melodies and CV-Skeletons could be shown to be separable cognitive entities, along the lines suggested by McCarthy (1981, 1982), in contrast to the traditional analysis in terms of the single mono-morphemic entity called the word pattern (Holes, 1995; Versteegh, 1997; Wright, 1995), and, in particular, whether priming could be observed for the CV-Skeleton, an abstract prosodic morpheme with no surface phonetic content. In Experiment 1, using masked priming, there was a strong trend towards facilitation for the CV-Skeleton but no sign of priming by the vocalic melody alone. Experiment 2 used cross-modal immediate repetition priming to probe further for evidence of the involvement of the skeleton in lexical processing, and to determine whether the absence of vocalic morpheme priming in Experiment 1 was a task-specific effect. Strong cross-modal priming effects by the skeleton were observed, while the vocalic morpheme failed to show any such effects, despite the overt marking of the vocalic melody in the prime. In Experiment 3, where auditory–auditory priming was used, the skeleton morpheme, but not the vocalic melody, again generated significant priming.

As shown in Fig. 2, the pattern of results was very stable across the three experiments. We confirmed this in a further overall analysis of the three experiments, with Experiment entered as a three-level factor (masked, cross-modal, and auditory–auditory priming) along with the three factors Condition, Prime Type, and List that were used in the earlier analyses of each experiment individually. The main effect of Condition was strongly significant [$F_1(2,74) = 12.82$, $P < 0.000$; $F_2(2,284) = 10.84$, $P < 0.000$], as were those of Prime Type [$F_1(1,74) = 22.25$, $P < 0.000$; $F_2(2,284) = 21.60$, $P < 0.000$], and Experiment [$F_1(2,74) = 259.81$, $P < 0.000$; $F_2(2,284) = 201.22$, $P < 0.000$]. Most importantly, while Condition interacted significantly with Prime Type [$F_1(1,74) = 9.67$, $P < 0.000$; $F_2(1,284) = 6.14$, $P < 0.002$], there were no significant interactions between Prime Type and Experiment or between Condition, Prime Type and Experiment [F_1 and $F_2 < 1$ throughout].

Collapsing across the three experiments, we see a robust pattern of similarities and differences between conditions. The [+Vowel] condition failed to yield any significant effects [$F_1 < 1$, $F_2 < 1$], with an average overall effect of -4 ms. In contrast, the [+Skeleton] condition gave rise to significant priming, averaging 27 ms [$F_1(1,74) = 26.51$, $P < 0.000$; $F_2(1,92) = 12.84$, $P < 0.001$], as did the [Word Pattern] condition, at 33 ms [$F_1(1,74) = 14.70$, $P < 0.000$; $F_2(1,96) = 19.27$, $P < 0.000$]. There was a significant difference between the magnitude of priming in the [+Vowel] and [+Skeleton] conditions [$F_1(1,74) = 18.37$, $P < 0.000$; $F_2(1,61) = 7.84$, $P < 0.006$] and between the [+Vowel] and [Word Pattern] conditions [$F_1(1,74) = 13.82$, $P < 0.000$; $F_2(1,92) = 11.046$, $P < 0.001$], but no difference between [+Skeleton] and [Word

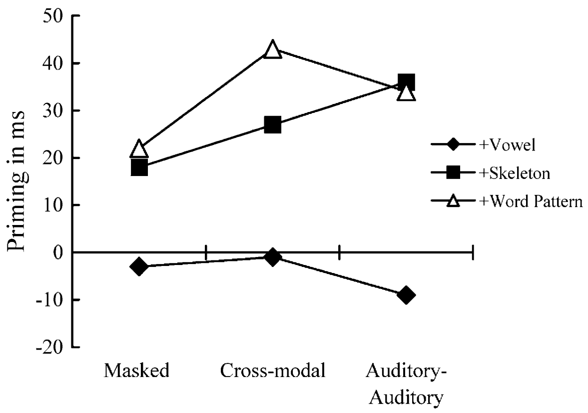

Fig. 2. Averaged priming effects across conditions in the three experiments.

Pattern]. This confirms the cognitive effectiveness of the CV-Skeleton in generating priming, the absence of any parallel effects for the vocalic melody, and the apparent equivalence between word pattern effects and CV-Skeleton effects.

These CV-Skeleton effects cannot be accounted for in terms of segmental overlap, since the primes and targets in the [+Skeleton] condition essentially have no consonants or vowels in common. Form overlap is much larger in the [+Vowel] condition, which consistently fails to prime. More generally, we have evidence from other experiments that extensive form overlap per se, whether segmental or prosodic (in the form of shared stress patterns), is not enough to produce priming in Arabic. The form relationship has to coincide with a morphological relationship for priming to occur. Similarly in Hebrew, a Semitic language which has many features in common with Arabic, no form-based effects seem to be found (Frost, Kugler, Deutsch, & Forster, 2001).

The clearest evidence against an account in terms of suprasegmental form factors such as stress comes from earlier experiments where primes and targets share homophonic word patterns (and therefore also CV-Skeletons) that correspond to different underlying morphemes (Boudelaa & Marslen-Wilson, 2000). Prime/target pairs like [quruud]–[nuzuul] *monkeys–descending* share the phonological characteristics of the word pattern {fuʕuul} but are not morphologically related, in the sense that the morpho-syntactic meaning of the word pattern is *plural* in the prime but *deverbal noun singular* in the target. Under these conditions, no priming is obtained, even though prime and target share the same CV-Skeleton, the same vocalic melody, and the same stress pattern. Significant priming was only found when the prime and target shared the word pattern not only at the level of form but also at the level of morphological function, as in pairs like [duxuul]–[nuzuul] *entering–descending*, where the shared word pattern has the same morpho-syntactic meaning across prime and target of *singular deverbal noun*. In addition, when form overlap is in terms of the consonantal content of the prime/target pair, so that there is partial overlap in the specification of the root (as in pairs like [mukatiʔibun]–[kaatib] *sad–writer*), we reliably see interference effects rather than facilitation effects (e.g. Boudelaa & Marslen-Wilson, 2000).

What seems to be required for priming to occur in Arabic is structural morphemic overlap. Anything short of that, whether segmental or suprasegmental overlap (or, indeed, both), will fail to be effective. This is consistent with our general assumption here that priming effects in morphologically related pairs are the result of accessing the same underlying structural unit during the processing of prime and target.

5.1. CV-Skeletons as cognitive units

One motivation for the research reported here was to assess the extent to which lexical processing is influenced by a purely structure-based morphological entity, the CV-Skeleton. The word pairs used to evaluate the effects of the CV-Skeleton have neither consonants nor vowels in common, and yet they facilitate each other successfully across three priming paradigms. These priming effects are quite predictable in the context of Semitic non-concatenative morphology, where the CV-Skeleton is arguably a structural unit that conveys syntactic information such as transitivity and reciprocity. It also conveys information about the metrical structure of the surface form, and determines the morphological category to which it belongs (Kenstowicz, 1996; McCarthy, 1982; Wright, 1995). If the language processor is to carry out effectively its task of mapping surface forms onto internal representations, then it cannot disregard the constraining information inherent in the skeleton. The cognitive morphemic status of a given linguistic entity must be influenced by its processing significance as an information-carrying unit.

In this context it is surprising not to find any priming by the vocalic melody, which in theory also conveys necessary syntactic information (McCarthy, 1981, 1982). One possibility is that the analysis of the vocalic morpheme has a time-course that is delayed relative to the CV-Skeleton. Research on reading Arabic orthography (e.g. Courrieu & Do, 1987; Roman & Pavard, 1987) suggests that vowels may not be used immediately as they are read, but only after the root consonants have been determined. However, this would not explain the absence of priming in Experiment 3, where both prime and target are presented auditorily. An alternative possibility is that the weakness of the vocalic melody effects is the result of influences from the native Southern Tunisian dialect of the participants. These participants were fluent users of MSA, in which the vocalic melody is indeed consistently used to convey syntactic contrasts such as voice (active/passive). However, in Southern Tunisian Arabic the active/passive distinction is no longer conveyed by the vocalic melody but rather by an additional CV-Skeleton opposition. This may have had the effect of weakening the salience of the MSA vocalic melody contrasts for these speakers, so that it was less effective in the priming situation, which depends on highly automatized rapid processing of linguistic inputs. An interesting further possibility is that the MSA vocalic morpheme would surface more strongly in tests on MSA speakers from more conservative dialects of Arabic, such as Saudi Arabian Hijaazi, where the vocalic melody is still used to encode syntactic distinctions such as that between the indicative and the imperative mood.[8]

Whatever the reason for the vocalic melody results, the striking positive finding in this research is the consistent facilitatory effect for the CV-Skeleton. This pattern of results is difficult to explain in terms of either phonetic or semantic overlap. In terms of phonetic form the CV-Skeleton is an abstract and underspecified unit which conveys only the information that a segment, consonant or vowel, is present. It says nothing about the identity of the segment itself. In terms of meaning, as conventionally defined, the pairs used in these experiments were judged by native speakers to be completely unrelated. The relative consistency of skeleton priming across visual, cross-modal and auditory presentation formats strongly suggests that the CV-Skeleton is a modality independent lexical entity. Furthermore, the absence of a significant difference between priming by CV-Skeletons and priming by word patterns suggests that the primary processing force of the word pattern, in both phonological and morpho-syntactic domains, may be carried by the skeleton.

The morphological nature of the CV-Skeleton effects in Arabic contrasts with the results of research into this element in several non-Semitic languages. Earlier reports on the effects of the CV-Skeleton in English, Dutch, French, and Spanish have produced mixed results, and have either failed to replicate the effects of this unit from one experiment to the next (Meijer, 1996; Romani, 1992), found relatively weak effects associated with this unit (Costa & Sebastian-Galles, 1998), or found no effects altogether

[8] We thank J. McCarthy for drawing our attention to the fact that the active/passive distinction is still coded in the vocalic melody in some Saudi Arabian Bedouin dialect (McCarthy, February 2001, personal communication).

(Ferrand & Segui, 1998, Experiment 1; Roelofs & Meyer, 1998; but see Floccia, Kolinsky, Dodane, & Morais, 2003). Furthermore, the direction of the CV-Skeleton effects are sometimes inhibitory rather than facilitatory (Berent, Bouissa, & Tuller, 2001).

The reason for these weak and inconsistent effects of the CV-Skeleton, compared to the strong effects for a Semitic language like Arabic, is likely to be a consequence of the different linguistic status of this unit across these different language families. The CV-Skeleton is purely a phonological structure in languages like English or Dutch, but a distinct and productive morphemic entity in Arabic. A speaker of Arabic presented with a CV-Skeleton is likely to converge on at least a general syntactic meaning, a syntactic category, and a stress pattern. This is the result of the relatively consistent mapping between the CV structure of words and these properties of surface word forms (Kenstowicz, 1996; McCarthy, 1981). Thus, for example, Arabic words with the CV-Skeleton {CVCCVC} are typically verb forms, with an *intensive* meaning, and are invariably stressed on the first syllable [CVC]. CV-Skeletons in languages like English simply do not exhibit the same correlation with lexical category and syntactic meaning.

5.2. Morphological units in Arabic

As mentioned earlier, our previous investigations of the Arabic mental lexicon have uncovered several properties of the underlying cognitive units for this language. More specifically, we found priming by word patterns and roots whether these were semantically transparent or opaque. We also reported priming by a new unit, the *etymon* (Boudelaa & Marslen-Wilson, 2001a), which is a two-consonantal unit that conveys semantic meaning and is viewed by some as incompatible with the three-consonantal approach (e.g. Bentin & Frost, 2001; Bohas, 1997). In the current research we have described what we take to be a genuine morphological effect of the CV-Skeleton, an abstract prosodic morpheme. Assuming priming is a good diagnostic of the cognitive relevance of a given linguistic unit, our research suggests that four lexical units govern lexical representation and processing in Arabic: the etymon and the root on the one hand, and the word pattern and the CV-Skeleton on the other.

One way of modeling a system with these properties is in the kind of dual route localist framework proposed by Frost et al. (1997) and Deutsch et al. (1998) for Hebrew. On this view the lexicon is thought to consist of a level of lexical units (i.e. words) and a level of sub-word units (i.e. roots for Hebrew nouns, and roots and word patterns for Hebrew verbs). These two levels of representations are interconnected such that a morphemic unit can be accessed either through a whole-word search route, or a morphological decomposition route. In the context of Arabic, the sub-word level of representation would have to include not only word patterns and roots as is the case in Hebrew, but also CV-Skeletons and etymons since this account assigns an independent representation to any unit that affects on-line processing. These sub-lexical levels of representations would further have to be interconnected with the lexical level of representation in order to allow for the simultaneous extraction of morphemic units on the one hand, and the whole-word search on the other. Priming among Arabic words sharing a morpheme, whether this was a word pattern, a CV-Skeleton, a root, or an etymon, would thus be the consequence of the same underlying morphemic entity being extracted from prime and target. Note that the adoption of this approach to account for the range of morphological priming data in Arabic requires a complex and elaborated architecture with multiple levels of representations.

An alternative view of lexical architecture is provided by distributed connectionist models (Gaskell & Marslen-Wilson, 1997, 2002; Plaut & Frost, 2001; Plaut & Gonnerman, 2000; Rueckl, Mikolinski, Raveh, Miner, & Mars, 1997; Seidenberg, 1987; Seidenberg & McClelland, 1989). Here lexical elements are thought of in terms of distributed representations where a unique pattern of activation across a set of units is involved in the representation of different items. For example, the internal representation of a word like [batar] *cut off* will not be factored out into a root {btr}, an etymon {bt}, a word pattern {faʕal}, and a CV-Skeleton {CVCVC}, instead it will consist of a pattern of activation over several units or nodes. The units recruited upon the processing of the root {btr} in the surface form [batar], for example, will also be recruited upon the processing of the form [mabtuur] *cut off*, which features the same root. In addition, some units involved in the representation of the root {btr} will also be involved in the representation of the root {btt} in forms such as [batta] *sever*. The obvious semantic link between [batar] and [batta], despite their not sharing a root (as classically defined), will be picked up by the system given a sufficient number of forms sharing only two consonants but mapping onto closely related semantics. In principle, this could deliver the observed etymon effects. The same holds for word patterns and CV-Skeletons. The units activated upon the processing of, for example, the word pattern {faʕal} in [batar] will also be activated when processing the same unit in a form like [kaman] *hide*. A subset of these units will in turn be recruited when processing a form like [qubil] *be accepted*, which shares the skeleton {CVCVC} with [batar].

At present, however, the available data do not discriminate between a connectionist model of the type outlined here, and the localist multi-route model described above. In both cases, full computational implementation seems some way off, making it difficult to evaluate in detail the possible differential predictions of the two approaches.

In conclusion, the research reported here shows that morphemic units can be highly abstract, to the extent of having no segmental specification, and yet prove to be important cognitive units in language processing and representation. But for this to happen, the linguistic environment must provide the appropriate backdrop.

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Appendix A. Test items in Arabic script, with their IPA transcription and English glosses

+Vowel		
Control	**Test**	**Target**
دكّان	جازف	اندثر
[dukkaan]	[ʒaazaf]	[ʔindaθar]
shop	act blindly	be wiped out
زاوية	تجاهل	أقسم
[zaawiɟa]	[taʒaahal]	[ʔaqsam]
corner	ignore	take an oath
صوف	عاتب	اجتاز
[sˤuuf]	[ʕaatab]	[ʔiʒtaaz]
wool	blame	be wiped out
قصّاب	أشفق	ترك
[qasˤaab]	[ʔaʃfaq]	[tarak]
butcher	be merciful	leave
كيان	تطوّع	استقرّ
[kiɟaan]	[tˤatawwaʕ]	[ʔistaqarr]
essence	to volunteer	settle down
مظهر	استرخص	التهم
[maðˤhar]	[ʔistarxasˤ]	[ʔiltaham]
appearance	ask for permission	devour
قبيح	تأنّى	اعترف
[qabiiħ]	[taʔanna]	[ʔiʕtaraf]
ugly	be patient	confess
بيئة	أثمر	اضطرب
[biiʔa]	[ʔaθmar]	[ʔidˤtˤarab]
environment	confess	shake
حريق	امتنع	اعتقل
[ħariiq]	[ʔimtanaʕ]	[ʔiʕtaqal]
fire	refrain	imprison
وكيل	رتع	أصبح
[wakiil]	[rataʕ]	[ʔasˤbaħ]
deputy	graze	become
انتداب	غمر	اضطرّ
[ʔintidaab]	[ɣamar]	[ʔidˤtˤarr]
assignment	overwhelm	be forced
تعزيز	دغدغ	افترس
[taʕziiz]	[daɣdaɣ]	[ʔiftaras]
consolidation	tickle	eat ferociously
هزل	دفن	استحق
[hazl]	[dafan]	[ʔistaħaqq]
joking	bury	deserve
أديب	شتم	اعتقد
[ʔadiib]	[ʃatam]	[ʔiʕtaqad]
writer	deserve	believe
جواد	طبخ	اعتدى
[ʒawaad]	[tˤabax]	[ʔiʕtadaa]
horse	cook	attack
توزيع	وهب	انتظر
[tawziiʕ]	[wahab]	[ʔintaðˤar]
distribution	offer	wait for

(*continued on next page*)

Appendix A (*continued*)

	+Vowel	
Control	**Test**	**Target**
سراح	أتعب	فاق
[saraaħ]	[ʔatʕab]	[faaqa]
release	tire	excel
تيّار	استوى	تقدّم
[taɟɟaar]	[ʔistawaa]	[taaqaddam]
draught	be even	move forward
خاتم	زمّر	استدعى
[xaatam]	[zammar]	[ʔistadʕaa]
ring	whistle	invite
حليب	أصلح	نهض
[ħaliib]	[ʔas^{ʕ}laħ]	[nahad^{ʕ}]
milk	tire	be even
عدالة	راوغ	أنفق
[ʕadaala]	[raawaɣ]	[ʔanfaq]
justice	dribble	spend
جدير	ضمّد	توقّع
[ʒadiir]	[d^{ʕ}ammad]	[tawaqqaʕ]
worthy	bandage	anticipate
ابتزاز	تصاهر	أحضر
[ʔibtizaaz]	[tas^{ʕ}aahar]	[ʔaħd^{ʕ}ar]
steel	melt	spend
بنيان	أشرق	تحدّث
[bunɟaan]	[ʔaʃraq]	[taħddaθ]
edifice	rise	speak to
عنز	أهمل	حجب
[ʕanz]	[ʔahmal]	[ħaʒab]
goat	overlook	veil
صورة	توتّر	حاول
[s^{ʕ}uura]	[tawattar]	[ħaawal]
picture	become strained	try
فؤاد	تضرّع	بذل
[fuʔaad]	[tad^{ʕ}arraʕ]	[baðal]
heart	beseech	endeavour
مملكة	تطوّر	أشرف
[mamlaka]	[tat^{ʕ}awwar]	[ʔaʃraf]
kingdom	progress	oversee
قلعة	كافح	توجّه
[qalʕa]	[kaafaħ]	[tawʒʒah]
fortress	progress	go towards
إلغاء	استعار	أثّر
[ʔilɣaa]	[ʔistaʕaar]	[ʔaθθar]
cancellation	borrow	influence
كامل	جرح	استعدّ
[kaamil]	[ʒaraħ]	[ʔistaʕadd]
perfect	wound	be ready
معركة	اختلس	قعد
[maʕraka]	[ʔixtalas]	[qaʕad]
battle	pilfer	borrow

(*continued on next page*)

Appendix A (*continued*)

+Skeleton

Control	Test	Target
مصير	نوقش	ساعد
[masˤiir]	[nuuqiʃ]	[saaʕad]
outcome	be discussed	help
جنون	خوطب	بارك
[ʒunuun]	[xuutˤib]	[baarak]
foolishness	be talked to	help
أصل	قيل	جاع
[ʔasˤl]	[qiil]	[ʒaaʕ]
origin	be said	get hungry
بئر	يئس	ربط
[biʔr]	[ɟaʔis]	[rabatˤ]
well	despair	tie
حيلة	كوفئ	لازم
[ħiila]	[kuufiʔ]	[laazam]
cunning	be awarded	adhere
عمود	هوجم	واصل
[ʕamuud]	[huuʒim]	[waasˤal
post	be assaulted	continue
سلوك	طولب	دافع
[suluuk]	[tˤuulib]	[daafaʕ]
behaviour	be asked for	defend
ذرّة	نبت	لعب
[ðarra]	[nabat]	[laʕib]
atom	grow	play
ثور	سئل	ثبت
[θawr]	[suʕil]	[θabat]
ox	be asked	be firm
عروس	أطيل	أشاع
[ʕaruus]	[ʔutˤiil]	[ʔaʃaaʕ]
bride	play	spread rumours
عجوز	لوحظ	غادر
[ʕaʒuuz]	[luuħiðˤ]	[ɣaadar]
bride	be remarked	leave
خيمة	عولج	صادف
[xaɟma]	[ʕuuliʒ]	[sˤaadaf]
tent	be treated	coincide
خوف	كشف	ركب
[xawf]	[kaʃaf]	[rakib]
fear	uncover	mount
تاج	خدع	رضي
[taaʒ]	[xadaʕ]	[radˤiya]
crown	deceive	be content
جبين	فورق	قاوم
[ʒabiin]	[fuuriq	[qaawam]
forehead	be left	resist
ثروة	راجع	حوفظ
[θarwa]	[raaʒaʕ]	[ħuufiðˤ]
fortune	revise	be preserved

(*continued on next page*)

Appendix A (*continued*)

+Skeleton		
Control	**Test**	**Target**
دهر	غسل	فهم
[dahr]	[ɣasal]	[fahim]
epoch	wash	understand
مذاق	أسيل	أعاد
[maðaaq]	[ʔusiil]	[ʔaʕaad]
taste	be made to flow	repeat
ثلج	أقيل	أضاع
[θalʒ]	[ʔuqiil]	[ʔadˤaaʕ]
snow	be discharged	waist
سرور	أحاط	أزيل
[suruur]	[ʔaħaatˤ]	[ʔuziil]
happiness	surround	be abolished
آية	رغب	سكن
[ʔaaɟa]	[raɣib]	[sakan]
verse	dsire	subside
سيرة	أهين	أعان
[siira]	[ʔuhiin]	[ʔaʕaan]
course of life	be humiliated	help out
غروب	قوتل	ناسب
[ɣuruub]	[quutil]	[naasab]
sun set	be fought	be convenient
نكبة	دوهم	جاور
[nakba]	[duuhim]	[ʒaawaz]
calamity	be taken by surprise	overtake
برق	ركض	نسي
[barq]	[rakadˤ]	[nasiɟa]
lightning	gallop	forget
بطن	مكث	خشي
[batˤn]	[makaθ]	[xaʃiɟa]
belly	stay	fear
سقوط	أطيع	أضاف
[suquutˤ]	[ʔutˤiiʕ]	[ʔadˤaaf]
falling	be obeyed	add
حملة	فوجئ	شارك
[ħamla]	[fuuʒiʔ]	[ʃaarak]
campaign	be taken aback	participate
وضوح	أسيء	أتاح
[wudˤuuħ]	[ʔusiiʔ]	[ʔataaħ]
add	be wronged	vouchsafe
ثوب	فتح	لقي
[θawb]	[fataħ]	[laqiɟa]
garment	open	encounter
ثغر	أشير	أصاب
[θaɣr]	[ʔuʃiir]	[ʔaasˤab]
mouth	be hinted to	hit the target
غليظ	نودي	لاءم
[ɣaliiðˤ]	[nuudiɟ]	[laaʔam]
rough	be called	suit

(*continued on next page*)

Appendix A (*continued*)

	+Word Pattern	
Control	**Test**	**Target**
وعاء [wiʕaaʔ] container	ساند [saanad] support	خالف [xaalaf] disobey
حادّ [ħaadd] sharp	جرّب [ʒarrab] try	كلّف [kallaf] charge with
غوث [ɣawɵ] assistance	خلع [xalaʕ] remove	حصل [ħasˤal] occur
مناقصة [munaaqasˤa] submit a bid	استأذن [ʔistaʔðan] ask for permission	استخدم [ʔistaxdam] use
وليد [waliid] new born	أبصر [ʔabsˤar] see	أغلق [ʔaɣlaq] shut down
يتيم [ɟatiim] orphan	زاحم [zaaħam] crowd	وافق [waafaq] agree with
شبكة [ʃabaka] net	تضمّن [tadˤamman] involve	تذكّر [taðakkar] remember
مبادلة [mubaadala] exchange	انجذب [ʔinʒaðab] be attracted to	انطلق [ʔintˤalaq] be free
مفاوضة [mufaawadˤa] negotiation	استخرج [ʔistaxraʒ] extract	استعمل [ʔistaʕmal] make use of
شخصية [ʃaxsˤiɟɟa] make use of	ابتسم [ʔibtasam] smile	التفت [ʔiltafat] look back
ضئيل [dˤaʔiil] tiny	راقب [raaqab] keep an on	سافر [saafar] travel
لهجة [lahʒa] dialect	تخلّص [taxallasˤ] get rid of	تعرّض [taʕarradˤ] oppose
أغنية [ʔuɣniɟa] song	انفجر [ʔinfaʒar] explode	انصرف [ʔinsˤaraf] go away
بندقية [bunduqiɟɟa] rifle	استأجر [ʔistaʔʒar] rent	استغرق [ʔistaɣraq] last
منطق [mantˤiq] logic	أحرز [ʔaħraz] obtain	أبلغ [ʔablaɣ] tell
نسيم [nasiim] breeze	تأخّر [taʔaxxar] be late	تمكّن [tamakkan] manage

(*continued on next page*)

Appendix A (*continued*)

+Word Pattern		
Control	**Test**	**Target**
تهنئة [tahniʔa] congratulation	انفرد [ʔinfarad] stand alone	انقلب [ʔinqalab] be overturned
مؤامرة [muʔaamara] conspiracy	استأنف [ʔistaʔnaf] resume	استقبل [ʔistaqbal] receive
كنيسة [kaniisa] church	ابتلع [ʔibtalaʕ] swallow	احترم [ʔiħtaram] respect
مفت [muftin] expounder of religious law	لخص [laxxasˤ] look back	فكر [fakkar] think
عود [ʕuud] rod	لمع [lamaʕ] shine	صرخ [sˤarax] look back
ميزان [mizaan] balance	احتقر [ʔiħtaqar] despise	اجتمع [ʔiʒtamaʕ] gather
نشأة [naʃʔa] upgrowth	راهن [raahan] bet	رافق [raafaq] accompany
صلة [sˤila] link	غرد [ɣarrad] twitter	سجل [saʒʒal] record
إحساس [ʔiħsaas] feeling	انهمر [ʔinhamar] pour	انقطع [ʔinqatˤaʕ] be severed
ألم [ʔalam] pain	هدأ [hadaʔ] abate	جلس [ʒalas] sit down
دواة [dawaat] ink bottle	أطعم [ʔatˤaʕam] feed	أخبر [ʔaxbar] inform
فرار [firaar] flight	تفضل [tafadˤdˤal] condescend	تعلق [taʕallaq] be attracted to
جزء [ʒuzʔ] part	رتب [rattab] tidy up	مثل [maθθal] represent
قبة [qubba] dome	خضع [xadˤaʕ] surrender	سكت [sakat] be quiet
كارثة [kaariθa] disaster	احتفل [ʔiħtafal] celebrate	اجتهد [ʔiʒtahad] make an effort
عظمة [ʕadˤama] greatness	أقفل [ʔqfal] lock up	أصدر [ʔasˤdar] issue

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