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Discontinuous morphology in time: Incremental masked priming in Arabic

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Semitic morphology is based on the combination of two abstract discontinuous morphemes, the word pattern and the root. The word pattern specifies the phonological structure and morpho-syntactic properties of the surface form, while the consonantal root conveys core semantic information. Both units play a crucial role in processing Semitic languages such as Arabic and Hebrew. Here we use incremental masked priming to probe the time-course of word pattern and root activation in reading Arabic deverbal nouns and verbs. The morphological (word pattern and root), orthographic, and semantic relationship between prime and targets is varied over four stimulus onset asynchronies (SOAs) (32, 48, 64, and 80 ms). Results show distinctive patterns of activation for the two morphemic entities. Word pattern effects are transient, and detectable only at SOAs 48 and 64 in deverbal nouns and SOA 48 in verbs. Root effects are strong at all SOAs. This may reflect differences in the timing with which word pattern and root information can be extracted from the orthographic input, as well as differences in the roles of these morphemes in building internal lexical representations. Both types of morphemic effect contrast strongly with the effects of orthographic and semantic primes, where reliable facilitation is only obtained at the longest SOA (80 ms). The general pattern of results is consistent with the view that morphological effects in Semitic languages represent distinct structural characteristics of the language.

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INTRODUCTION

The identification of morphemes in a language is based on the existence of consistent relationships, synchronically and diachronically, between phonological form, semantic meaning, and grammatical function (Aronoff, 1976; Scalise, 1986). A central concern of experimental research into morphology is whether morphemes play a role in the cognitive language system that is separable from phonological, orthographic, and semantic co-occurrence, so that morphological structure is a qualitatively distinct organising property of lexical representation and processing (Caramazza, Laudanna, & Romani, 1988; Clahsen, 1999; Feldman, Frost, & Pnini, 1995; Forster & Azuma, 2000; Marslen-Wilson, Tyler, Waksler, & Older 1994; Rueckl, Mikolinski, Raveh, Miner, & Mars, 1997; Schreuder & Baayen, 1995; Seidenberg & Gonnerman, 2000).

There are two aspects to this question that are not always kept separate. The first is the essentially methodological question of whether, given the likely correlation in a stimulus set between form-based, semantic, and morphological variables, any resulting effects can be safely attributed to morphological factors. In the English prime-target pairs *jumps/jumped* and *darkness/dark*, for example, experimental effects attributed to morphological relatedness can also reflect the other ways these stimuli are related. The second is the more complex question, given that unambiguously morphological effects might be observed, of what this means for the role of morphology in lexical representation and processing. The implications are straightforward for current localist models (Caramazza et al., 1988; Frost, Forster, & Deutsch, 1997; Schreuder & Baayen, 1995), where morphological structure is already an explicit and stipulated property of the model. Such a result would present more of a challenge, however, for connectionist learning models where morphology has no explicit representation (Plaut & Gonnerman, 2000, Seidenberg & Gonnerman, 2000), and has been viewed in the past as simply the interaction of form and meaning-based constraints.

The goal of this paper is to exploit the special properties of Semitic morphology, using the incremental masked priming task (Dominguez, Cuetos, & Segui, 2002; Rastle, Davis, Marslen-Wilson, & Tyler, 2000) to contribute to both these questions. Naturally, there is a great deal of research using other techniques which addresses these issues, and which overall provides substantial evidence for the separability of morphological effects from semantic and form-based factors. However, the advantage of incremental masked priming (and similar tasks) is that it allows us to track the time-course with which different types of processing information become available during visual word-recognition and lexical access, thereby providing an important dynamic perspective on the operations

of the language system. For example, the research on English reported by Rastle et al. (2000) varied the morphological, semantic, and orthographic relationship between primes and targets over three Stimulus Onset Asynchronies (SOA), of 43, 72, and 230 ms. The observed pattern of activation over the three SOAs was clearly distinct for the three types of processing relationship, suggesting different time-courses for morphological, orthographic, and semantic effects, and therefore implying their separability as potential contributors to priming effects between morphologically related items.

There are two main reasons why it is of interest to apply these techniques to Semitic languages. The first is that arguably the strongest evidence for morphology as an organising principle of internal representation and processing comes from Semitic languages like Hebrew and Arabic (Boudelaa & Marslen-Wilson, 2000, 2001; Deutsch, Frost, & Forster, 1998; Deutsch, Frost, Pollatsek, & Rayner, 2000; Frost et al., 1997; Frost, Deutsch, Gilboa, Tannenbaum, & Marslen-Wilson, 2000), so that they should provide a fertile ground for studies of the temporal fine-structure of morphological processing. The second is that these languages separate out morphological functions in a very different way to languages with concatenative morphologies (such as English, French, and Finnish), providing a valuable cross-linguistic contrast. In Arabic, the building of surface word forms is standardly viewed as involving at least two bound morphemic units, a *root* and a *word pattern* (Holes, 1995; Versteegh, 1997; Wright, 1995). Roots and word patterns have a very different phonological make-up and distinct morphological functions. Roots consist solely of consonants and convey semantic meaning, while word patterns consist primarily of vowels but can be comprised of consonants as well, and act as a phonological structure that conveys syntactic information (Wright, 1995). These two units are interleaved and surface in a discontinuous way. For example, in the Modern Standard Arabic (hereafter MSA) verb form [xatama] *seal*, the consonants of the root {xtm}, which conveys the semantic load *sealing*, are discontinuous as a result of being interspersed with the vowels of the word pattern {faʕala},[1] which carries the syntactic meaning *active*, *perfective*.

Both roots and word patterns play a significant cognitive role in the processing of Arabic and Hebrew (Boudelaa & Marslen-Wilson, 2000, 2001; Deutsch et al., 1998; Frost et al., 1997). Importantly, facilitation among word pairs sharing a root morpheme is neither modulated by nor is dependent on the semantic relationships underlying the prime and target

[1] The letters fʕl are traditionally used as place holders indicating where the first, second and third letter of the root are to be inserted.

(Boudelaa & Marslen-Wilson, 2000; 2001; Frost et al., 1997).[2] The Arabic target [kaatibun] *writer* is facilitated by the morphologically and semantically related prime [kitaabun] *book*, where {ktb} has the same semantics in both prime and target, but also by the morphologically related but semantically unrelated prime [katiibatun] *squadron*, where the root {ktb} does not have its dominant writing-related meaning. Furthermore, word patterns, which are intrinsically non-semantic elements, show significant priming in Hebrew verbs (Deutsch et al., 1998), and in Arabic verbs and deverbal nouns (Boudelaa & Marslen-Wilson, 2000).

In the context of such languages, the question of whether morphology, semantics and phonology or orthography have differential time courses can be refined further by asking whether morphology-based effects have the same time course irrespective of the structural and functional characteristics of the morpheme in question. Will root and word pattern effects have the same time course and distribution during on-line processing, or will they differ as a function of the information being conveyed? Additionally, since the consonantal root conveys semantic meaning, and the word pattern conveys phonological information and syntactic meaning, it is possible that root effects over time will have commonalities with semantic effects, whereas word pattern effects may be analogous to form-based effects.

To approach these issues, we focus on Arabic deverbal nouns and verbs and assess how the prior presentation of a masked prime word affects lexical decision to a target as a function of (a) the relationship between prime and target, and (b) prime display duration. As regards (a), we vary morphological, orthographic, and semantic relationships between primes and targets such that the respective contributions of each of these properties can be examined. With respect to (b), we use four prime display durations, of 32, 48, 64, and 80 ms, to assess the dynamics of priming across these dimensions of similarity.

In an earlier masked priming investigations of Arabic morphology, we found reliable word pattern and root priming effects at a 48 ms SOA. Since both morphemic units seem to be active at this SOA, we included a shorter SOA of 32 ms, to determine whether word patterns and roots have different processing onsets. We included the two longer SOAs (64 and 80 ms) to monitor for the life span of the priming likely to be generated by these units. It should be stressed that at SOA 32 ms and 48 ms, participants

[2] This is true of masked priming in Arabic and Hebrew. However, cross-modal priming offers a different picture with a slight increase in the magnitude of priming among transparent pairs in Hebrew (Frost et al., 2000), but not in Arabic (Boudelaa & Marslen-Wilson, 2000).

are not aware of the presence of a prime at all, while at 64 and 80 ms, the presence of a prime may be detectable, though never reliably enough to be reported. This means that masked priming performance is relatively insensitive to episodic and strategic confounds. Furthermore, previous research using this paradigm has shown it to be well suited to the study of morphological and orthographic effects at short SOAs (Forster & Azuma, 2000; Frost et al., 1997; Rastle et al., 2000), and to the investigation of potential semantic effects at longer SOAs (Perea & Gotor, 1997; Sereno, 1991). Accordingly, apart from minimizing strategic behaviour, our choice of a small range of incremental steps in prime durations should allow us to track the dynamics of processing events as they unfold over time, and in a more fine-grained manner than earlier studies using this technique with larger SOAs (Feldman, 2000; Rastle et al., 2000).

If morphological structure in Arabic is playing a role that is genuinely distinct from that played by orthography and semantics, as our work on Arabic (Boudelaa & Marslen-Wilson, 2001) and Frost and colleagues' work on Hebrew suggest, then this should be reflected in differential priming effects in the morphological, orthographic, and semantic conditions across the four SOAs. In particular, word pattern and root effects should be able to emerge earlier than semantic effects, and should be stronger than orthography-driven effects.

EXPERIMENT 1

Arabic deverbal nouns, so called because they derive from the same stock of consonantal roots as verbs, draw on over a hundred different word patterns (Bohas & Guillaume, 1984). More importantly this set of Arabic nouns exhibits a relatively high degree of productivity and systematicity with respect to the word patterns and roots they involve. A root morpheme such as {ksr}, with the semantic field of 'breaking', is recruited many times to construct such deverbal nouns as [kasrun] *breaking*, [kasiirun] *broken*, [taksiirun] *shattering*, and [maksuurun] *fractured*. Similarly, a deverbal noun word pattern like {faaʔilun} meaning *agent noun* participates in the building of numerous forms such as [haaribun] *one who flees*, [kaatimun] *one who hides*, [faatiħun] *one who opens*.

In our previous research, where we found masked priming evidence for deverbal noun word patterns and roots as units subserving the process of mapping orthographic input onto central representations, we co-varied the morphological, orthographic, and semantic relationship between prime and target (Boudelaa & Marslen-Wilson, 2000). Here we follow to the same procedure, focusing on six experimental conditions where the relationship underlying prime and target is either morphological, orthographic, or semantic as illustrated in Table 1.

TABLE 1
Experiment 1: Experimental conditions with example stimulus set

Condition	*Test*	*Prime Baseline*	*Target*
1. **[+WP]**	خالد [xaalidun] *eternal*	نهوض [nuhuudˤun] *getting up*	حارس [ħaarisun] *guard*
2. **[+Orth1]**	طائرة [tˤaaʔiratun] *plane*	فتور [futuurun] *lassitude*	خالص [xaalisˤun] *pure*
3. **[+R +S]**	رئاسة [riʔaasa] *president*	عاقبة [ʕaaqIbatun] *end*	رئيس [raʔiisun] *presidency*
4. **[+R –S]**	ظالم [ðˤalaamun] *oppressor*	حريق [ħariiqun] *fire*	ظلام [ðˤaalimun] *obscurity*
5. **[+Orth2]**	إبريق [ʔibriiqun] *jug*	تأميم [taʔmiimun] *nationalization*	تامّ [taammun] *complete*
6. **[–R +S]**	عمود [ʕamuudun] *post*	حكايه [ħikaajatun] *story*	قصّة [qisˤsˤatun] *novel*

In Condition 1, with pairs like [xaalidun]-[ħaarisun] *eternal-guard*, and [ħaziinun]-[kariimun] *sad-generous*, the prime and target are morphologically related in the sense of sharing a word pattern, which is {faaʕilun} in the first pair and {faʕiilun} in the second. Pairs sharing a word pattern have primarily a vocalic overlap, but may overlap in terms of consonants as well. Note that Arabic noun word patterns, unlike their Hebrew counterparts, do prime successfully provided that they occur in the context of productive roots, and have the same morpho-syntactic meaning in both prime and target (Boudelaa & Marslen-Wilson, 2000,). Priming among [xaalidun]/[ħaarisun]-like pairs will be compared with possible effects in Condition 2, designed to provide an orthographic control – although it should be noted that there is increasing evidence that purely orthographic effects are weak to non-existent in masked priming with Semitic languages (Frost, Kugler, Deutsch, & Forster, 2001). Here we use pairs like [ʃahwatun]-[manðˤarun] *desire-sight*, and [saħaabatun]-[tˤalaaqun] *cloud-divorce*, where primes and targets share an orthographic relationship that mimics as closely as possible the kind of form overlap (chiefly in vowels) found between word pairs sharing a word pattern. If the structural status of the vowels, as parts of a specific word pattern, bears on the mapping of Arabic orthographic

forms onto internal representations, a differential pattern of facilitation should emerge across these two conditions. Note that because only long vowels are written in Arabic script, the overlap here is partly implicit, and has to be inferred from an orthographic input which does not spell out the phonetic properties of the word pattern in full.

Conditions 3 and 4 probe the effects of the consonantal root. In Condition 3, the prime and target pairs share a root and a transparent semantic relationship as illustrated by pairs such as [taħqiiqun]-[ħaqiiqatun] *investigation-truth*, and [riʔaasatun]-[raʔiisun]- *presidency-president*. In Condition 4, with pairs like [miʕtˤafun]-[ʕaatˤifatun] *coat-sentiment*, [ʃartˤun]-[ʃurtˤatun] *condition-police* the prime and target share a root, the same structural unit as in Condition 3, but their underlying semantic relationship is opaque (as judged by a panel of native Arabic speakers). One of the critical questions Conditions 3 and 4 are meant to address is whether root morpheme priming will evolve in the same way over time irrespective of the semantic transparency or opacity of the forms involved. Another question relates to whether root and the word pattern priming effects will have comparable profiles over time.

To provide a fuller context for interpreting possible root effects in Conditions 3 and 4, we also included Conditions 5 and 6. Condition 5 consisted of word pairs that are orthographically but not morphologically related, sharing two to three consonants that do not constitute a common root, as in [sulaħfaatun]-[silaaħun] *turtle-weapon*, and [muftin]-[mufattiʃun] *Islamic scholar-inspector*. If the priming effects hypothesised in Conditions 3 and 4 are due to the orthographic overlap necessarily obtaining for any two surface forms sharing a root unit, then the word pairs in Condition 5 should show facilitation effects comparable with those in Conditions 3 and 4. Note that because Arabic script codes all consonants, the form overlap between words sharing a root is fully specified in the orthography. Finally, Condition 6 consists of word pairs like [ʕarabatun]-[sajjaaratun] *vehicle-car*, and [qitaalun]-[ħarbun] *fight-war*, which are strongly semantically related but do not share either roots or word patterns. Such pairs fail to yield any facilitation in masked priming at short SOAs, but can prime at longer SOAs (Rastle et al., 2000). It will be of interest to determine the point at which meaning-based effects start to show, and how this relates to the time-course of word pattern and root effects.

Method

Participants. A group of 139 volunteers aged 16 to 20 took part in the experiment. They were pupils at the high school of Tataouine in South Tunisia, and used MSA on regular basis.

Material. Each of the six conditions described above was made up of 24 prime-target pairs. The target words were chosen to be orthographically unambiguous, as far as possible by including long vowels, which are written in the orthography. In a few cases, where targets were still orthographically ambiguous, we chose targets where the intended alternative was far more frequent than its homograph. In Condition 1, which we will refer to as [+WP], the prime and target share a word pattern (e.g., [xaalidun]-[ħaarisun] *eternal-guard*). These pairs had an average of 1.2 letters in common, computing orthographic units present in the written form of prime and target. To control for the overlap between prime and target pairs, Condition 2, [+Orth1], consisted of primes and targets that had an average of 0.9 letters in common, as illustrated by pairs like [saħaabatun]-[tˁalaaqun] *cloud-divorce*, but which had no morphological or semantic relationship.[3]

In Condition 3, labelled [+R +S], the prime and target pairs share a root morpheme and the root has the same semantically transparent interpretation in both (e.g., [riʔaasatun]-[raʔiisun] *presidency-president)*. This contrasts with Condition 4, labelled [+R −S], where the prime and target share a root (as in [ðˁaalimun]-[ðˁalaamun] *oppressor-obscurity*) but the root does not have the same semantic interpretation in the target as in the prime, where the relationship between the meaning of the root and the meaning of the full form is opaque. Primes and targets shared 3.4 letters in both the [+R +S] condition and the [+R −S] condition.

Condition 5, labelled [+Orth 2], is the orthographic control for the two conditions sharing a root (e.g., [sulaħfaatun]-[silaaħun] *turtle-weapon*). Here the prime and target shared 2.5 letters on average.[4] The difference between [+Orth1] and [+Orth2] is that the orthographic overlap relates to the shared vowels across prime and target in the former, but to the shared consonants in the latter. Because of the nature of Arabic script, the actual orthographic overlap is greater for the consonantal case, underlining the need for different orthographic/form controls for the word patterns and for the roots. Finally Condition 6, [−R +S], consists of semantically but not morphologically related pairs, which share 0.6 letters on average (e.g., [ʕarabatun]-[saʃʃaaratun] *vehicle-car*).

[3] Conditions 1 and 2 were also matched in terms of their underlying phonological overlap (i.e., counting the short vowels not specified in the orthography), which averaged 2.3 and 2.1 phonemes in common, respectively. However, we assume that the critical factor here is orthographic overlap, since this is the overt form dimension directly shared by prime and target.

[4] As is generally the case in research with Semitic scripts, it is not possible to fully match orthographically without introducing morphological confounds. It is hard to find pairs of words that share three consonants that do not share a root as well, especially given the other constraints on the stimuli.

The transparency of the semantic relationship between primes and targets in each condition was determined in a pretest using a large set of potential stimuli where 15 participants were asked to judge the relatedness of the pairs on a 9-point scale, ranging from *very unrelated* (1) to *very related* (9). The mean ratings for the [+R +S] and [−R +S] conditions were equivalent at 7.11 and 7.14 respectively. The ratings for the [+R −S] condition were much lower, at 3.80, though not as low as in the conditions where there was no shared root – for [+WP], [+Orth1], and [+Orth2] the ratings were 1.78, 1.50, and 1.63, respectively. The reason for the intermediate rating in the [+R −S] condition is that Arabic raters treat words sharing a root as having some basic degree of relationship, even if there is no actual semantic overlap.

Each of the 144 test primes was matched as closely as possible in terms of familiarity and of length in letters and syllables to a baseline prime (see Appendix 1 for full list of materials). The mean length of the test primes was 4.43 letters and 3.36 syllables, while the baseline primes were on average 4.29 letters and 3.20 syllables in length. The targets were 4.15 letters and 3.17 syllables long on average. Familiarity was based on a pretest in which native speakers of MSA were asked to rate a list of words on a five-point scale with 1 being *very unfamiliar* and 5 *very familiar*. The target words, the related primes, and the baseline primes were rated 3.88, 4.04, and 4.43 respectively on this scale. The baseline items were neither morphologically, semantically, or orthographically related to the target.

A similar number of word-pseudoword pairs were constructed so as to echo the form overlap between the test pairs. Some of the word-pseudoword pairs used overlapped in vowels only (e.g., [madiinatun]-*[ʔakiibun] *city*),[5] others in consonants only (e.g., [markabun]-*[muruukun] *boat*), and others in neither (e.g., [duxuulun]-*[maħʃafun] *entering*). Two experimental versions were constructed each containing 288 pairs of which 144 were word-word pairs and 144 word-pseudo word pairs, plus 40 practice trials consisting of 20 word-word responses and 20 word-pseudoword responses.

Design and procedure. The two versions were constructed such that all the targets appeared only once in each version, half preceded by a related prime and half by an unrelated prime. 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, displayed for 500 ms. The choice of vertical lines as a mask instead of the more commonly used hash marks was made following a pretest session where we compared

[5] Asterisks indicate a pseudoword throughout.

the two masks and found the former to be more effective. The second event was a prime word written without diacritics in the same font but in 24-point font size. Four SOAs corresponding to a prime display duration of 32, 48, 64, and 80 ms were used. The third event was a target word or non-word written without diacritics in a 34 point font size. The target was displayed until participants responded or 2000 ms had elapsed. The larger font size of the target was used because MSA does not have the lower-case upper-case distinction.

Timing, stimulus display, and data collection were controlled by three laptop PCs running the DMDX package so that up to three participants could be tested simultaneously (Forster & Forster, 2003). Thirty-two participants were assigned to the first SOA, 40 to the second, 36 to the third, and 30 to the fourth SOA. Participants were asked to make as accurate and quick a lexical decision as possible about the target by pressing a YES or a NO key. The experiment started with the practice trials followed by the experimental items. There were two breaks in the test session; one after the practice session and the other halfway through the main test sequence. The experiment lasted about 15 minutes.

Results

Table 2 lists mean RTs and per cent error rate as a function of experimental condition and SOA. The data were pruned in two ways. First, by removing participants with error rates exceeding 30%. Second,

TABLE 2
Experiment 1: Mean RT (ms) and per cent error (in parentheses)

	Stimulus onset asynchrony (SOA)							
	32 ms		*48 ms*		*64 ms*		*80 ms*	
Condition	*Test*	*Control*	*Test*	*Control*	*Test*	*Control*	*Test*	*Control*
1. **[+WP]**	621	624	603	630	586	621	583	594
	(6.25)	(5.99)	(6.04)	(5.73)	(8.59)	(5.73)	(3.06)	(3.06)
2. **[+Orth1]**	610	632	636	634	623	627	599	591
	(5.47)	(5.21)	(2.92)	(4.17)	(4.95)	(5.73)	(3.89)	(5.28)
3. **[+R +S]**	605	626	600	625	595	618	568	591
	(5.99)	(6.77)	(5.63)	(7.81)	(5.47)	(5.99)	(3.89)	(3.61)
4. **[+R –S]**	604	627	617	648	599	630	571	599
	(4.95)	(4.69)	(4.79)	(6.77)	(6.77)	(5.99)	(5.56)	4.17)
5. **[+Orth2]**	638	647	661	671	645	654	586	627
	(7.29)	(7.03)	(6.88)	(7.03)	(7.81)	(7.55)	(5.83)	(6.67)
6. **[–R +S]**	633	636	639	651	628	629	578	610
	(5.99)	(5.99)	(4.59)	(7.55)	(7.03)	(7.03)	(7.22)	(5.28)

by removing data points lying 2 standard deviations above or below the participant's mean. Together the two procedures eliminated one participant from version 1 of SOA 64, and 0.8% of the total data, which were not replaced. The results can best be appreciated by inspecting Figure 1, where the mean priming effects are plotted by condition and SOA.

The data were submitted to mixed-design analyses of variance (ANOVA) with four factors, Condition (six levels, +WP, +Orth1, +R +S, +R −S, +Orth2, −R +S), Prime Type (two levels, test, control), SOA (four levels 32, 48, 64, and 80 ms), and List (two levels), which was included to extract any variance due to counterbalancing. In the participants' analysis (F_1), Condition and Prime Type were treated as repeated factors and SOA and List as unrepeated. In the items' analysis (F_2), Prime Type and SOA were treated as repeated factors and Condition and List as unrepeated. The main effect of Condition was significant by participants and items, $F_1(5, 130) = 36.94$, $p < .001$; $F_2(5, 143) = 10.42$, $p < .001$, and so were the main effects of Prime Type, $F_1(1, 130) = 58.93$, $p < .001$; $F_2(1, 143) = 24.00$, $p < .001$, and SOA, $F_1(3, 130) = 23.50$, $p < .001$; $F_2(3, 143) = 26.93$, $p < .001$. The interaction between Condition and Prime Type was significant in the participants' analysis, $F_1(5, 130) = 4.61$, $p < .05$, but not in the items' analysis ($F_2 < 1$). The two-way interactions between Condition and SOA and between Prime and SOA were not significant

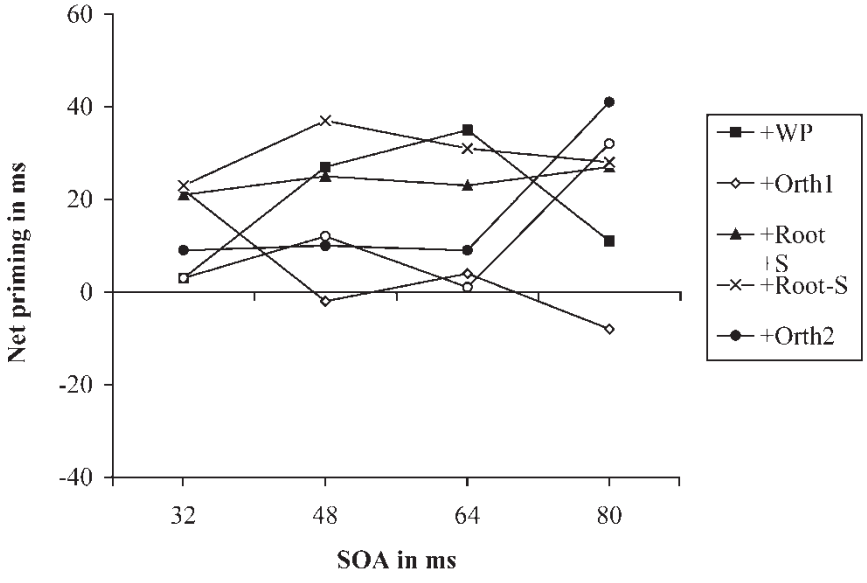

Figure 1. Priming in deverbal nouns as a function of prime-target relationship and stimulus onset asynchrony (SOA).

($F_1 < 1$, $F_2 < 1$). By contrast the three-way interaction between Condition, Prime Type and SOA was significant both by participants and items. $F_1(2, 130) = 2.42$, $p < .05$; $F_2(2, 143) = 4.21$, $p < .05$, suggesting that the amount of priming in the six conditions was not constant across the four SOAs. This three-way interaction was unpacked in a series of Bonferroni-corrected planned comparisons (Keppel, 1982).

The significant overall priming effect in the [+WP] condition, $F_1(1, 130) = 20.17$, $p < .001$; $F_2(1, 23) = 11.92$, $p < .001$, was exclusively driven by the strong word pattern facilitation at SOA 48, $F_1(1, 39) = 10.15$, $p < .003$; $F_2(1, 23) = 4.58$, $p < .044$, and SOA 64, $F_1(1, 35) = 19.46$, $p < .001$; $F_2(1, 23) = 11.67$, $p < .002$, with no effects at earlier or later SOAs. Priming in the [+Orth1] condition was not significant overall ($F_1 < 1$), $F_2 < 1$. The 22 ms facilitation at SOA 32 was marginally significant, $F_1(1, 31) = 7.10$, $p < .012$; $F_2(1, 23) = 4.084$, $p < .056$, but there was no significant [+Orth1] priming at any of the remaining SOAs.

The overall difference in magnitude of priming between the [+WP] condition and its orthographic control [+Orth1] proved to be significant, $F_1(1, 130) = 6.56$, $p < .05$; $F_2(1, 47) = 4.04$, $p < .046$. Looking at each SOA separately, the difference between [+WP] and [+Orth1] approached significance at SOA 48, $F_1(1, 39) = 6.15$, $p < .018$; $F_2(1, 47) = 1.31$, $p < .25$, and SOA 64, $F_1(1, 35) = 7.26$, $p < .011$; $F_2(1, 47) = 3.58$, $p < .065$, but there were no differences at SOA 32 or SOA 80.

Turning to the root conditions, priming was highly significant overall in the [+R +S] condition, $F_1(1, 130) = 31.20$, $p < .001$; $F_2(1, 23) = 62.86$, $p < .001$, averaging 23 ms, and also proved significant at each individual SOA. Similarly the [+R −S] condition yielded overall significant priming, averaging 28 ms, $F_1(1, 130) = 45.44$, $p < .001$; $F_2(1, 23) = 34.64$, $p < .001$, with significant effects at each SOA. Overall priming in the [+Orth2] condition was not significant ($F_1 < 1$; $F_2 < 1$), with an average priming effect of 9 msec over SOAs 32 to 64, but with an unexpected facilitatory effect at SOA 80, $F_1(1, 130) = 11.41$, $p < .002$; $F_2(1, 23) = 11.44$, $p < .003$. The [−R +S] semantic condition showed a similar pattern, with no significant overall priming, an average effect of 5 ms over the first three SOAs, and significant priming emerging at SOA 80, $F_1(1, 29) = 15.48$, $p < .001$; $F_2(1, 23) = 6.07$, $p < .022$.

There was no difference in the amount of priming between the two root conditions, [+R +S] and [+R −S], with $F_1 < 1$, $F_2 < 1$. Despite the consistent differences between these two conditions and the two control conditions [+Orth2] and [−R +S] across the first three SOAs, we did not obtain robust statistical confirmation of this. Both in overall comparisons collapsing across SOAs, and in individual comparisons at each SOA, we found reliable differences by participants but not by items (under Bonferroni correction).

Given the absence of a clear-cut morphological effect for the root conditions, we conducted additional correlational analyses to check for the possibility of primarily orthographically driven effects in the two [+R] conditions and in the [+Orth2] condition. No correlation between size of priming effect and amount of orthographic overlap was found at any SOA, either for the three conditions individually, or for the three conditions taken together. In a further check, re-running our main analyses of variance with orthographic overlap as a co-variate, we found no modulation of the amount of morphological priming.

We also looked for parallel effects in the semantic domain, checking for possible correlations with semantic relatedness in the two [+R] conditions and in the [−R +S] condition, and again found only weak and inconsistent results. The only significant correlation, in 16 comparisons, was for the combined analysis of all three conditions, at SOA 48 ($r = .235$, $p = .047$), but with no reliable effects at other SOAs . There is little in these two sets of further analyses to support the view that either orthographic or semantic factors are important independent contributors to the priming effects observed here for the prime-target pairs sharing a root.

The error data were analysed in the same way as the RT data. The main effect of Condition was marginally significant by participants, $F_1(5, 130) = 2.14$, $p < .059$, but not by items, $F_2(5, 132) < 1$. The main effect of SOA was unreliable by participants, $F_1(3, 130) = 1.12$, $p < .34$, but reliable by items, $F_2(3, 132) = 12.41$, $p < .001$. None of the remaining effects or interactions reached significance.

Discussion

Experiment 1 asked two questions: whether morphology-based effects are dissociable from form-based and meaning-based effects over time, and whether morphemic units have distinct time signatures as a function of the kind of information they convey.

As regards the first query, the pattern of effects in the three morphological conditions, [+WP], [+R +S], and [+R −S] differs from their matched orthographic and semantic controls, [+Orth1], [+Orth2], and [−R +S]. This contrast is strongest for Conditions 1 and 2, where targets primed by a shared word pattern are significantly facilitated at SOAs 48 and 64 ms, while the matched orthographic control [+Orth1] generates only an early and transient priming effect at SOA 32. This is consistent with previous findings of effective priming by Arabic noun word patterns when these occur in the context of productive roots, and share the same morpho-syntactic interpretation across prime and target (Boudelaa & Marslen-Wilson, 2000). The two root conditions, [+R +S] and [+R −S],

yield consistently robust priming across all four SOAs, contrasting not only with their matched form-based control condition, [+Orth2], which is facilitatory only at SOA 80 ms, but also with the meaning-based matched control condition, [−R +S], whose facilitatory effects are also limited to SOA 80. These contrasts with the root control conditions, however, were not fully statistically robust.

The second outcome of Experiment 1 relates to the differential time course underlying the processing of functionally distinct morphemic entities. Root morphemes, the semantic components of Arabic surface forms, generate priming very early in processing, at SOA 32, and this effect persists over the remaining three SOAs, possibly suggesting a dominant role for this morphemic entity in Arabic visual word recognition. By contrast, word patterns, the means of expressing morpho-syntactic and phonological information about Arabic surface form, seem to affect processing slightly later, and for a noticeably shorter interval of time, with priming being limited to SOAs 48 and 64. Thus, visual word processing in Arabic seems to involve, along with the broad distinction between orthographic, semantic, and morphemic entities, a more fine-grained distinction within the morphological domain, distinguishing word patterns from roots.

A further point relates to the early priming seen in the [+Orth1] vowel overlap condition and the late priming in the [+Orth2] consonant overlap condition. On the basis of our own research (Boudelaa & Marslen-Wilson, 2000, 2001), and research on Hebrew (Frost et al, 2001), where no masked orthographic priming was found at comparably short SOAs (48 ms in Arabic, and 50 ms in Hebrew), the [+Orth1] priming at SOA 32 was not expected. The late priming in the [+Orth2] condition was also not predicted. Since this latter effect (in contrast to the [+Orth1] effect) is replicated in Experiment 2, we will return to it in the later discussion.

In sum, morphological effects seem to dominate over form-driven and meaning-driven effects, and both word pattern and root morphemes are actively used early in processing, but with a temporal precedence for root effects. However, word pattern effects are distinctly transient, yielding facilitation only over two SOAs, while the effects of the root are more durable (Deutsch et al., 2000). This qualitative difference in the effects of word patterns and roots may reflect differences in the processing role of the information conveyed by these two units.

In Experiment 2, we seek to replicate and extend these findings, by asking whether similar patterns emerge from the other major subdivision of Arabic morphology, the Arabic verb.

EXPERIMENT 2

Verb forms are distinguished from deverbal nouns purely by virtue of the word pattern morpheme being used; the underlying root is the same across both syntactic categories. There are only 10 verb word patterns currently in common use. Ordered from 1 to 10 in keeping with the Western tradition, these are: {faʕala}, {faʕʕala}, {faaʕala}, {ʔafʕala}, {tafaʕʕala}, {tafaaʕala}, {ʔinfaʕala}, {ʔiftaʕala}, {ʔifʕalla}, and {ʔistafʕala}. Each of these word patterns has two to three morpho-syntactic interpretations associated with it, such as *causative*, *intensive*, *reciprocal* and so on.[6] To address the issue of when morphology-driven effects come into play as opposed to semantic and orthographic effects, we evaluated priming in six conditions built along exactly the same lines as in the previous experiment.

The first condition is again labelled [+WP] and consists of pairs of verbs sharing a word pattern, such as [laxxasˤa]-[fakkara] *sum up-think*, which share the word pattern [faʕʕala], or [laaħaðˤa]-[saafara] *notice-travel* which share the pattern [faaʕala]. In the [+Orth1] condition, where pairs like [qamarun]-[nasaʒa] *moon-weave*, [qalamun]-taraka] *pen-leave* are used, the prime and target share an orthographic overlap that closely mimics that underlying the pairs in condition 1. In the [+R +S] condition the prime and target share a root and a transparent semantic relationship as in [ʔanzala]-[nazala] *cause to go down-go down*, or [ʔistafaada]-[ʔafaada] *benefit-cause to benefit*, while in [+R −S] they share a root but an opaque semantic relationship as in [xallafa]-[ʔixtalafa] *leave behind-disagree*, or [naafaqa]-[ʔanfaqa] *dissimulate-spend*. In [+Orth2], the orthographic control for the [+R +S] and the [+R −S] conditions, the prime and target pairs are orthographically related. They share two to three consonants as illustrated by pairs such as [muʒaadalatun]-[ʒaada] *discussion-give generously* or [ʕafanun]-[ʕafaa] decomposition-forgive. Finally, the [−R +S] condition is one in which the prime and target share only a semantic relationship as in [ʔalqaa]-[ramaa] *throw-fling* or [ʔixtafaa]-[ɤaaba] *disappear-vanish*.

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[6] A word pattern has a *causative* morpho-syntactic interpretation or meaning when the surface form where it appears is glossable as *cause someone to do X*, where X is the core semantic meaning associated with the root. For example, in the form [ʔaskata], where the root is {skt} *keeping quiet* and the word pattern is {ʔafʕal}, the latter is considered to have a *causative* meaning in the sense that [ʔaskata] is glossable as *cause someone to keep quiet*. Analogously, a word pattern is *intensive* when the surface form of which it is part has to be glossed as *do X with intensity*, and a *reciprocal* word pattern is one which entails a gloss like *X is done mutually by two agents* (Holes, 1995; Wright, 1995).

TABLE 3
Experiment 2: Experimental conditions with example stimulus set

	Prime		
Condition	*Test*	*Control*	*Target*
1. **[+WP]**	لخّص [laxxasˤa] *sum up*	مسحة [musħatun] tinge	فكّر [fakkara] *think*
2. **[+Orth1]**	لجنة [laʒnatun] *committee*	خضوع [xudˤuuʕun] *submission*	أنكر [ʔankara] *deny*
3. **[+R +S]**	احترق [ʔiħtraqa] *burn*	تصديق [tasˤdiiqun] *believing*	أحرق [ʔaħraqa] set ablaze
4. **[+R –S]**	نظّر [naðˤðˤara] *theorize*	مجهول [maʒhuulun] *unknown*	انتظر [(intaðˤtara] *wait for*
5. **[+Orth2]**	بلعوم [bulʕuumun] *pharynx*	مجد [maʒdun] *glory*	بلّل [ballala] *moisten*
6. **[–R +S]**	أيقن [ʔaj̆qana] *ascertain*	تحفة [tuħfatun] *masterpiece*	تأكّد [taʔakkada] *be confirmed*

Method

Participants. Another group of 108 participants from the same age group and linguistic background as those in Experiment 1 took part in this experiment.

Material and design. The design was analogous to that used in Experiment 1. The material consisted of prime and target verb forms which made up six experimental conditions with 24 pairs each as depicted in Table 3.

In Condition 1, [+WP], the prime and target share a word pattern (e.g., [ʔaħraza]-[ʔablaɣa] *acquire-cause to reach*), with orthographic overlap averaging 1.5 letters.[7] Condition 2, [+Orth 1], was again an orthographic

[7] Average underlying phonological overlap was 2.5 phonemes for Condition 1 and 2.0 phonemes for Condition 2.

control for condition 1 (e.g., [laʒnatun]-[ʔankara] *committee-deny*, averaging 0.9 letters overlap.[8]

In condition 3, [+R +S], prime and target share a root morpheme and a transparent semantic relationship (e.g., [ʔiħtaraqa]-[ʔaħraqa] *burn-set ablaze*), while in condition 4, [+R −S], they share a root but have an opaque semantic relationship (e.g., [naðˁðˁara]-[ʔintaðˁara] *theorise-wait for*). The number of shared letters across primes and targets were 3.1 and 3.3 in the [+R +S] and [+R −S] conditions respectively. Condition 5, labelled [+Orth 2], is the orthographic control for conditions 3 and 4 (e.g., [balaʕa]-[ballala]). Here the prime and target pairs share 2.1 letters on average. Condition 6, [−R +S], tests for purely semantic effects (e.g., [ʔayqana]-[taʔakkada] *ascertain-be confirmed*), and the number of letters shared by the prime and target pairs was only 0.4.

The strength of the semantic relationship between primes in targets was again assessed in a pre-test similar to that conducted in Experiment 1. The mean ratings for the [+R +S] and [−R +S] conditions were again equivalent, at 7.21 and 7.33 respectively, with the [+R −S] condition coming in at 3.10. Ratings were uniformly low for [+WP], [+Orth1], and [+Orth2], at 1.62, 1.59, and 1.77, respectively.

As in Experiment 1, each of the related primes was matched as closely as possible on number of letters, number of syllables and familiarity to a baseline prime that shared no relationship with the target (see Appendix 2 for the full stimulus set). The target probes were on average 3.73 letters and 3.08 syllables long, and were chosen to be orthographically unambiguous. The test primes were 4.18 letters and 3.36 syllables long while the baseline primes averaged 3.97 and 3.36 in letter and syllable length respectively. With regard to familiarity, which was determined in a similar pre-test as in Experiment 1, the target words received an average rating of 3.88 on the five-point scale. The test prime and the baseline prime received a rating of 3.97 and 4.46 respectively. A similar number of pseudoword-word pairs was constructed in such a way as to echo the form overlap between the word-word pairs.

Procedure. The procedure was the same as in Experiment 1.

Results

Mean decision latencies and percentage of errors are given in Table 4. About 0.5% of the data were removed as a result of setting cutoffs at 2

[8] Because of the much more restricted range of word patterns in the verbal morphology (10 instead of hundreds), and because of the constraints imposed by the need to use long vowels where possible, it was not possible to fully match Condition 1 in number of overlapping letters without introducing potential morphological confounds.

TABLE 4
Experiment 2: Mean RTs (ms) and per cent error (in parentheses)

	Stimulus onset asynchrony (SOA)							
	32 ms		48 ms		64 ms		80 ms	
Condition	*Test*	*Control*	*Test*	*Control*	*Test*	*Control*	*Test*	*Control*
1. **[+WP]**	635	628	584	616	626	621	595	580
	(5.83)	(5.56)	(6.52)	(4.35)	(6.25)	(4.86)	(6.12)	(5.91)
2. **[+Orth1]**	670	672	654	654	644	657	615	605
	(7.22)	(6.94)	(6.88)	(6.52)	(6.94)	(7.29)	(7.26)	(6.18)
3. **[+R +S]**	588	622	584	623	577	623	544	586
	(5.56)	(5.00)	(7.25)	(6.16)	(3.82)	(5.56)	(3.23)	(6.99)
4. **[+R –S]**	610	638	586	616	595	634	564	592
	(6.94)	(5.83)	6.88)	(5.43)	8.33)	(6.35)	(5.65)	(5.91)
5. **[+Orth2]**	666	645	631	620	642	636	577	606
	(6.67)	(6.83)	(8.33)	(6.16)	(6.60)	(6.25)	(7.27)	(4.84)
6. **[–R +S]**	631	618	631	617	614	616	564	586
	(6.67)	(5.28)	(8.70)	(5.43)	(6.94)	(5.21)	(8.06)	(5.65)

standard deviations above or below the participant's own mean. These were not replaced. The mean priming effects are plotted by condition and SOA in Figure 2.

Latency and error data were submitted to separate mixed design ANOVAs with four factors: Condition, Prime Type, SOA, and List. In the by-participants analysis, Condition and Prime Type were treated as repeated factors, with SOA and List as unrepeated factors. In the by-items analysis, Prime Type and SOA were repeated factors, and Condition and List unrepeated. The results revealed the main effects of Condition, $F_1(5, 107) = 45.23$, $p < .001$; $F_2(5, 143) = 13.99$, $p < .001$, Prime Type, $F_1(1, 107) = 14.00$, $p < .001$; $F_2(1, 143) = 10.46$, $p < .002$, and SOA, $F_1(3, 107) = 3.49$, $p < .019$; $F_2(3, 143) = 16.08$, $p < .001$. Condition interacted significantly with Prime Type, $F_1(5, 107) = 14.39$, $p < .001$; $F_2(5, 143) = 4.05$, $p < .05$, and with SOA, $F_1(5, 107) = 4.97$, $p < .05$; $F_2(5, 143) = 3.51$, $p < .05$. There was no Prime Type by SOA interaction ($F_1 < 1$, $F_2 < 1$). The three-way interaction between Condition, Prime Type, and SOA was significant, $F_1(15, 107) = 2.37$, $p < .05$; $F_{21}(15, 143) = 2.56$; $p < .05$, and we took the same planned comparison approach as in the previous experiment to unpack it.

Overall, priming in the [+WP] condition was not significant ($F_1 < 1$, $F_2 < 1$). However, the 32 ms facilitation for word pairs sharing a word pattern at SOA 48 was significant by participants and items, $F_1(1, 22) = 4.49$, $p < .045$; $F_2(1, 23) = 13.51$; $p < .001$. No significant [+WP] effects were observed at any other SOAs. Priming in [+Orth1] failed to reach significance overall,

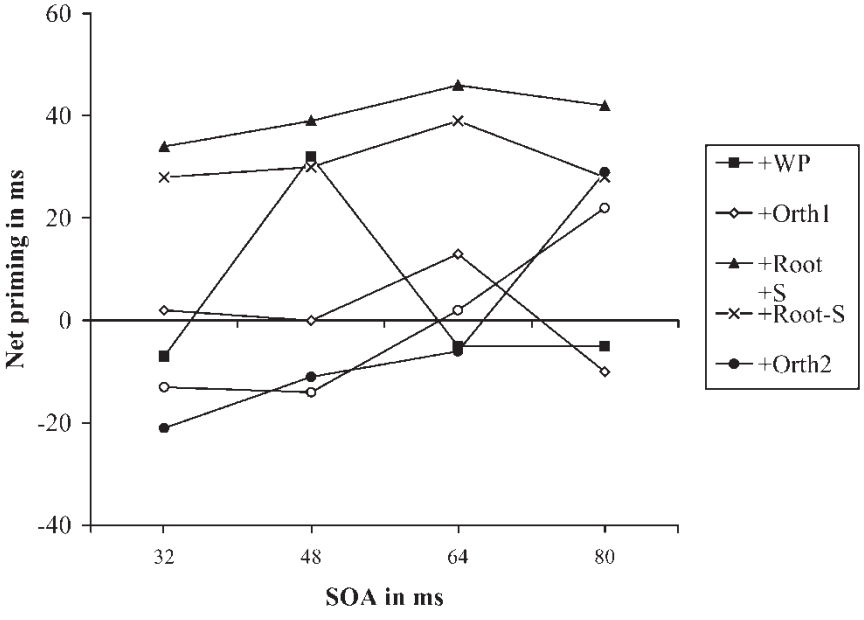

Figure 2. Priming in verbs as a function of prime-target-relationship and stimulus onset asynchrony (SOA).

or at each SOA individually. In particular, there was no sign of the early priming observed at SOA 32 in Experiment 1. The overall difference between the [+WP] and the [+Orth1] condition was not significant ($F_1 < 1$, $F_2 < 1$), but the two conditions did differ at SOA 48, $F_1(1, 29) = 3.64$, $p < .050$; $F_2(1, 23) = 4.67$; $p < .036$.

Turning to the two root conditions, priming in the [+R +S] condition was highly significant, $F_1(1, 107) = 69.83$, $p < .001$; $F_2(1, 23) = 62.86$; $p < .001$, and did not vary across SOA. Averaging 40 ms, the effects are generally stronger than in Experiment 1. A similar pattern held for the [+R −S] condition, $F_1(1, 107) = 28.32$, $p < .001$; $F_2(1, 23) = 34.64$; $p < .001$, with priming overall averaging 31 ms. Conversely, overall priming in the [+Orth2] and the [−R +S] conditions failed to reach significance ($F_1 < 1$, $F_2 < 1$). However, at SOA 80 both [+Orth2], with, $F_1(1, 107) = 28.32$, $p < .001$; $F_2(1, 23) = 4.77$; $p < .040$, and [−R +S], with $F_1(1, 30) = 4.98$, $p < .033$; $F_2(1, 23) = 6.30$; $p < .020$, again showed significant facilitation.

No difference in magnitude of priming was found between the two root conditions, [+R +S] and [+R −S]. In contrast to Experiment 1, there were robust differences with the two root control conditions, both overall and individually, over the first three SOAs. The overall priming for [+R +S] differed significantly from the [Orth2] condition, $F_1(1, 107) = 29.93$, $p < .001$; $F_2(1, 23) = 23.15$; $p < .001$. More specifically, these two conditions

differed at SOA 32, $F_1(1, 29) = 21.72$, $p < .001$; $F_2(1, 23) = 11.05$; $p < .002$, SOA 48, $F_1(1, 22) = 5.75$, $p < .025$; $F_2(1, 23) = 6.84$; $p < .012$, and SOA 64, $F_1(1, 23) = 9.13$, $p < .006$; $F_2(1, 23) = 7.46$; $p < .009$, but not at SOA 80 ($F_1 < 1$, $F_2 < 1$). A similar pattern held for the comparison between [+R −S] and [−R +S], with a significant overall difference, $F_1(1, 107) = 28.43$, $p < .001$; $F_2(1, 23) = 25.66$; $p < .001$, accompanied by significant effects at SOA 32, $F_1(1, 29) = 16.83$, $p < .001$; $F_2(1, 23) = 10.95$; $p < .002$, SOA 48, $F_1(1, 22) = 7.93$, $p < .010$; $F_2(1, 23) = 8.14$; $p < .006$, and SOA 64, $F_1(1, 23) = 3.69$, $p < .050$; $F_2(1, 23) = 5.69$; $p < .021$, but not SOA 80.

Comparing [+R −S] and [+Orth2], an overall difference is also found, $F_1(1, 107) = 16.38$, $p < .001$; $F_2(1, 23) = 14.37$; $p = .001$, accompanied by significant differences at the three shortest SOAs (SOA 32, $F_1(1, 29) = 17.82$, $p < .001$; $F_2(1, 23) = 6.37$; $p < .015$, SOA 48, $F_1(1, 22) = 5.02$, $p < .035$; $F_2(1, 23) = 5.76$; $p < .020$, and SOA 64, $F_1(1, 23) = 6.77$, $p < .016$; $F_2(1, 23) = 5.50$; $p < .023$). Similarly for the overall comparison of [+R −S] and [−R +S], with $F_1(1, 107) = 21.48$, $p < .001$; $F_2(1, 23) = 15.33$; $p = .001$, and differences again observed at SOA 32, $F_1(1, 29) = 11.05$, $p < .002$; $F_2(1, 23) = 5.53$, $p < .023$, SOA 48, $F_1(1, 22) = 7.02$, $p < .015$; $F_2(1, 23) = 7.02$; $p < .011$, and SOA 64, $F_1(1, 23) = 7.29$, $p < .013$; $F_2(1, 23) = 4.83$; $p < .033$.

As in Experiment 1, we also ran correlational analyses to check for possible orthographic overlap effects, focusing on the two root conditions and [+Orth2]. No significant effects were found either for each condition separately or as a group, with the one exception of a correlation of .416 ($p = .043$) for [+Orth2] at SOA 32. Parallel analyses were also run on the same two [+R] conditions and the semantic condition [−R +S] to assess the effects of semantic relatedness. No significant effects were found at any SOA.

The error data were submitted to the same mixed design ANOVA, with SOA emerging as the only significant main effect, $F_1(3, 107) = 5.19$, $p < .002$; $F_2(5, 143) = 6.87$, $p < .05$. Weaker effects were seen for Condition, $F_1(5, 107) = 3.52$, $p < .004$; $F_2(5, 143) = < 1$, and for Prime Type, $F_1(1, 107) = 5.13$, $p < .025$; $F_2(1, 143) = 3.21$ $p < .075$. No other significant effects or interactions were found.

Discussion

The results of this experiment, tapping into the second major domain of Arabic word-formation, confirm the major features of Experiment 1, with a completely new set of materials. We again see a distinct time course for morphology-based effects in contrast to form-based and meaning-based effects, with essentially the same pattern of contrasts between the [+WP] and [+Orth1] conditions on the one hand, and the two root conditions, [+R +S], [+R −S], and their matched orthographic [+Orth2] and

semantic [−R +S] controls on the other. In this second experiment, however, these root effects are now statistically very reliable.

We also replicate the marked differences in the patterns of activation over time for the two different types of morpheme involved. Root priming onsets very early, at SOA 32, at essentially full strength, and carries on through at equivalent levels until SOA 80. Word pattern priming again operates within a narrow temporal window, here restricted to SOA 48. Interestingly, this is similar to the 42 ms SOA at which verb word pattern priming was observed in Hebrew in a single SOA masked priming experiment (Deutsch et al., 1998). No word pattern effects are observed at SOAs earlier or later than 48 ms. This is all the more striking given that the effects of the word pattern in other priming tasks, such as cross-modal and auditory-auditory immediate repetition priming, seem just as durable as root priming effects (Boudelaa & Marslen-Wilson, 2004a).

Experiment 2 also replicates two features of the priming responses for the control conditions. Both the root orthographic control [+Orth2] and the purely semantic condition [−R +S] again show significant facilitatory effects at the longest SOA (80 ms), but no significant effects at shorter SOAs. The third control effect observed in Experiment 1, the significant priming at SOA 32 for the word pattern orthographic control [+Orth1], showed no signs of replication here, indicating that this is not a robust finding. We now turn to a discussion of the overall results for the two experiments.

GENERAL DISCUSSION

This study addressed two questions – whether morphological effects have a different time course from form-based and meaning-based effects, and whether functionally distinct morphemic entities have different effects over time. To do this we focused on the processing of discontinuous morphemes in Arabic deverbal nouns and verbs, using the incremental masked priming paradigm in combination with lexical decision. The combined results of the two experiments give a clear and consistent picture of the dynamics of morphological effects in Arabic visual word recognition. What are the implications of these results?

Are morphological effects separable from orthographic and semantic effects?

Semitic languages such as Arabic already provide some of the strongest evidence for separable morphological effects in psycholinguistic tasks. The experiments here, contrasting morphological, orthographic, and semantic relationships in the incremental masked priming task, reinforce this view.

There are two aspects of the results that contribute to this conclusion. These are the marked differences in the temporal patterning of the priming effects attributable to different sources, and, second, the apparent irrelevance of form-based and semantic factors to the presence or absence of a priming effect between words in Arabic sharing a morpheme.

Words sharing a root morpheme show reliable priming across all four SOAs, with little change from SOA 32 to SOA 80. This pattern of effects cannot be due to a confound with semantic factors. First, priming is equally strong regardless of whether primes and targets share a transparent (e.g., [taħqiiqun]-[ħaqiiqatun] *investigation-truth*) or an opaque semantic relationship (e.g., [miʔtˤafun]-[ʔaatˤifatun] *coat-sentiment*), at all SOAs. Second, significant priming effects for pairs that share a semantic relationship [−R +S] but no morphological relationship emerge only at SOA 80, and are undetectable at earlier SOAs, for both experiments. This is consistent with most earlier studies that have looked at semantic effects in masked priming at short SOAs. Third, there is no correlation for either root condition with degree of semantic relatedness.

Similar arguments hold for orthographic factors. Orthographically related words in [+Orth2], sharing two or more consonants that do not belong to the same root (e.g., [sulaħfaatun]-[silaaħun] *turtle-weapon*), generate reliable priming only at the longest SOA (80 ms). Correlational analyses for the two [+R] conditions together with [+Orth2], as well as analyses of covariance with orthographic overlap as a co-variate, consistently show no effects of orthographic factors on priming. The late effect for [+Orth2] may itself not be a purely orthographic effect – in scripts like English such effects are typically found at the shortest SOAs (e.g., Rastle et al, 2000). Instead, it may reflect a late interaction between the root consonants signalled in the target and the partial overlap with these in the prime. However, this is an effect that itself requires further research.

Turning to the word pattern results, with their distinctive transient effects peaking at the middle SOAs, it is even clearer that these are morphologically driven rather than reflecting semantic or orthographic confounds. Where semantics is concerned, words sharing just a word-pattern are viewed by native speakers as being wholly semantically unrelated (with the same low ratings as baseline unrelated prime-target pairs in pre-tests of semantic relatedness). In terms of conventional views of the conditions under which semantic priming occurs, there is simply no basis for such effects in the [+WP] pairs. For orthography, there is similarly very little basis for an effect based just on form overlap. Because of the nature of Arabic script, with most vowels not written, and with the surface phonetic content of word patterns being predominantly in the form of vowels, direct orthographic overlap was very low in the [+WP]

conditions, averaging 1.3 letters for targets 4 letters long. Even if an orthographic priming effect could be generated on this minimal basis, there would be no grounds for expecting it to show the same pattern over SOAs as the [+WP] conditions – especially since neither the [+Orth1] condition, nor the [+Orth2] condition, with twice as much overlap in terms of letters, showed anything like this pattern.

More generally, orthographic effects in Semitic languages seem to be difficult to obtain (Frost et al., 2001), while morphological effects are robust and consistent even in cases of minimal form overlap (Boudelaa & Marslen-Wilson, 2001) and of allomorphic variation (Boudelaa & Marslen-Wilson, 2004b). Indeed, in a recent study (Boudelaa & Marslen-Wilson, 2004a), we found evidence for morphological priming between Arabic verbs with no orthographic overlap at all. These were prime-target pairs sharing the same CV-Skeleton, or abstract consonant-vowel (CV) sequence. The CV-Skeleton, viewed as a component of the word pattern, is an abstract prosodic morpheme which specifies the overall phonological structure of the surface word, as well as critical morpho-syntactic properties, but does not specify the exact phonological or orthographic identity of the consonants and vowels in the word (McCarthy, 1981, 1982). The prime-target pair [fuuʒiʔa]-[ʃaaraka] *be surprised-participate*, for example, share the reciprocal CV-Skeleton {CVVCVCV}, but have no orthographic content in common. Such pairs, nonetheless, prime consistently across a variety of tasks, including masked priming at an SOA of 48 ms (Boudelaa & Marslen-Wilson, 2004b).

Overall, these results demonstrate that morphological effects in Arabic visual word-recognition and lexical access can be conclusively separated from potential effects of form or meaning overlap. Priming for pairs sharing roots and word-patterns is robust, occurs at short SOAs, and is likely to reflect repeated access to the same underlying sub-lexical units in prime and target. There is little evidence at all for consistent orthographic priming, and semantic priming seems to reflect late effects, possibly based on the spread of activation between separate lexical representations.

Why is morphology different from orthography and semantics?

Morphology, orthography, and semantics are three distinct domains of knowledge. Each of them provides a different and independent type of information about lexical items, and exerts differential effects on the way words are processed and organised in lexical space. Since the lexical system seeks out patterns in the environment in order to acquire, store, and access linguistic knowledge in an efficient way, it is the domain of knowledge that

is most consistent and regular that will gain more weight in determining the way the mental lexicon is organised. This will vary cross-linguistically since speakers of different languages make differential choices of the way they encode meaning. In Semitic languages the most consistent and recurrent patterns are those provided by the morphological domain.

Consider for example the notion of *causativity*. In Indo-European languages like English, causativity is encoded either lexically as in 'teach' *cause to learn*, or syntactically as in *make someone happy*, and occasionally through derivational morphology as in 'widen' *cause to become wide*. By contrast, in Semitic languages like Arabic, the idea of causativity is almost exclusively encoded morphologically by using such word patterns as {ʔafʕala} or {faʕʕala} to create causative verbs like [ʔaʕlama] *cause to know*, or [farraħa] *cause to become happy*. Now consider the following Arabic forms: [kataba], [kaataba], [kitaabun], [maktabun], and [kaatibun] and their respective English equivalents *write*, *correspond*, *book*, *office*, *author*. The broad meaning of *writing* inherent in all the Arabic forms above, is conveyed by the root {ktb}, which occurs in all the forms. The same general meaning of *writing* or *having to do with writing* is also present in the English translation. However, there is no clearly recurring element across all the English forms. In other words, the Arabic linguistic environment offers a generally more consistent relationship between the form of a word and its meaning than its English counterpart; and the crucial elements in this consistency are roots and word patterns. Every time a causative meaning is encountered, the pattern {ʔafʕala} or {faʕʕala} is more likely than not to be present, and every time the meaning of *writing* is encountered, the root {ktb} has a high probability of being present. Thus as language learning progresses a coherent system evolving around roots and word patterns emerges, and the extraction of these elements becomes the primary task of the language processor.

However if Arabic, and indeed Semitic, morphology derives its weight from the fact that it is the means of choice for expressing meaning, why is there no difference between [+R +S] and [+R −S]? What would the justification be for parsing a complex form like [katiibatun] *squadron* when its meaning is not the sum of its component morphemes? One suggestion is that the search for regular patterns that the lexical system undertakes is guided by consistency between form and meaning only at the outset. Later on in development the system would be looking for and using consistency wherever it can be found. The form commonality between [katiibatun], *squadron* [maktabun] *office*, [kitaabun] *book* and [kataba] *write* would be enough to build a morphological family around the root {ktb}. The end-state lexical processor in Semitic languages would thus be looking for morphological structure provided by roots and word patterns regardless of meaning.

Why do roots and word patterns have differential priming profiles?

This study demonstrates that the root morpheme has an earlier and more long-lived effect than the word pattern in the masked priming task. The earlier onset of root effects compared with word pattern effects may derive at least in part from the consonantal nature of Arabic orthography, where consonants but not vowels are fully specified. In other words, while the visual event presents fully specified information about the consonantal root, it presents only partial information about the word pattern. This means that while accessing the meaning of an orthographically presented root can be direct, the mapping of a visually presented word pattern onto its morpho-syntactic meaning is indirect and may require mediation through access to phonology. If this is correct, then it is phonological mediation that results in word pattern priming kicking in after root priming. Another factor underlying the differential priming onsets of word patterns and roots may be simply the nature of information conveyed by the two units. In particular, the meaning conveyed by the root is arguably more constraining than that conveyed by the word pattern. Surface forms sharing a root make up a more coherent morphological family than those sharing a word pattern, and this may also facilitate access (for evidence on morphological family size effects in Semitic languages, see Moscoso del Prado Martín, Bertram, Schreuder, & Baayen, in press). The emergence of root effects prior to word pattern effects is perhaps paralleled by Hebrew developmental data showing that the ability to identify and manipulate root morphemes (in offline tasks) is present even in 3- to 4-year-olds, while word pattern identification and manipulation takes place only after the child is 10 years old or more (Ravid & Malenky, 2001).

What is less straightforward to account for is why roots and word patterns have differential priming offsets. If priming by these two units is subserved by the same underlying mechanism, namely by access to a common morpheme in prime and target, why does word pattern priming have transient effects in this task, whereas in other priming tasks such as cross-modal and auditory-auditory priming, it has effects that seem as long-lasting as those of roots?

The transient effects may reflect the timing with which word pattern information is used in the dynamic processes of early visual word recognition and lexical access. At SOA 32, as sketched above, word pattern information about the prime may not yet be available to influence processing of the target. Twenty milliseconds later, at around SOA 48, prime word pattern information is available and interacts strongly with word pattern extraction processes in the analysis of the target. This window seems quite narrow, however, since by SOA 80 there is no longer

any priming effect. This may reflect the genuine transience of word pattern activation for briefly exposed masked primes, or it may reflect transfer of information about word patterns to levels of the system that are not engaged by masked priming. An important issue for further research is to begin to probe the basis of these timing differences—whether they reflect differences in activation rate for different morpheme-types, for example, or whether they reflect specific properties of lexical architecture.

Theoretical implications

While previous investigations of Semitic languages (Boudelaa & Marslen-Wilson, 2001, 2004b; Frost et al., 1997) have established the importance of morphology in processing and representation, the current findings constitute a substantial step forward in understanding not only the dynamic unfolding of morphological, orthographic, and semantic effects over time, but also the more fine-grained unfolding of word pattern and root effects. Morphological effects, including root and word pattern effects, take precedence over orthographic and semantic effects, because morphological structure offers a more salient and consistent domain of analysis and processing in lexical access.

At this point, there are two possible directions one can take. The first is the class of dual route models such as the one put forward by Frost and his colleagues (Frost et al., 1997, 1998, 2000) for Hebrew. On this account, lexical units (words) and sub-lexical units (morphemes) are both represented, and processing of printed stimuli consists of a lexical retrieval process in which lexical units are located at the word level, and a morphological parsing process in which morphemic units are extracted and located at the sub-lexical level. The difference between word pattern priming in Hebrew verbs and nouns, where significant facilitation was observed for the former but not the latter is captured by allowing verb word patterns to be represented at the sub-lexical level and the lexical level, while the nominal word pattern is represented only at the lexical level (Deutsch et al., 1998; Frost et al., 1997). An Arabic version of such a model would thus need to feature deverbal noun word patterns, verb word patterns and roots, since they all prime successfully in this language. With this done, we can proceed to assess how such an architecture may accommodate the differential morphological, orthographic, and semantic effects on the one hand, and the differential effects of roots and word patterns on the other.

The earlier onset of morphological priming compared with orthographic and semantic effects can be modelled by assuming that the parsing route and the full form access route run in parallel and the fastest route wins the

race. The time required to recognise a word via either route would be a stochastic variable with some overlap in the temporal distribution of the two routes. Thus under some circumstances both routes have a chance of winning. However, since most Arabic words are clearly made up of an identifiable root and an identifiable word pattern, the parsing route will often win the race and produce a successful parse as evidenced by the earliness and durability of root priming. Orthographic and semantic effects, may emerge at longer SOAs because the direct access route will have had enough time to deliver an output. As regards the differential onset of word pattern and root priming, it may be argued to derive, as mentioned above, from the consonantal nature of Arabic orthography which provides full information about roots but partial information at best about word patterns. An orthographically presented word pattern may need to be mapped onto a phonological representation before its morpho-syntactic interpretation can be contacted. This is not the case for the root, which can in principle be directly accessed from print without need for phonological mediation, hence its earlier priming effects. Finally, with respect to the different offsets of word pattern and root priming, one possibility is to model these in terms of differential decay functions.

The alternative direction to this dual route approach is to look at connectionist models (Plaut & Gonnerman, 2000; Rueckl et al., 1997; Rueckl & Raveh, 1999). On this account, morphological effects derive from the learned sensitivity of the language processor to the systematic relationships among the surface forms of words and their meanings, just as phonological representations themselves may derive from learned relationships among acoustic, semantic, and articulatory information (Plaut & Kello, 1998). Recently, Plaut and Gonnerman (2000) carried out a simulation in which a set of morphologically related words varying in semantic transparency were embedded either in a morphologically rich language (intended to simulate Hebrew), or a morphologically impoverished language (intended to simulate English). The network showed more priming as a function of semantic transparency in both languages, which is inconsistent with a number of masked priming experiments in Hebrew and Arabic where no difference in magnitude of priming between [+R +S] and [+R −S]-type pairs was found (Boudelaa & Marslen-Wilson, 2000, 2004a, 2004b; Frost et al., 1997). Furthermore, the network extended priming to the semantically opaque words (i.e., [+R −S]) only in the morphologically rich language. This, however, seems inconsistent with recent masked priming data showing equivalent priming among semantically transparent (e.g., driver/DRIVE) and semantically opaque forms (e.g., corner/CORN) in morphologically less rich languages such as English (Feldman & Soltano, 1999; Rastle et al., 2000), and French (Longtin, Segui, & Halle, 2003). Another challenge, although outside the scope of the Plaut and

Gonnerman network, would be to explain how cross-modal priming, with overt, auditorily presented primes, shows equivalent priming between morphologically related words regardless of semantics in Semitic languages (e.g., Boudelaa & Marslen-Wilson, 2000), but not in Indo-European languages (e.g., Marslen-Wilson et al., 1994).

The empirical weaknesses of the Plaut & Gonnerman's (2000) network do not, of course, entail the failure of the entire distributed connectionist approach. Networks trained on a more naturalistic input, and embodying more realistic assumptions about the impact of morphological factors on lexical organisation and lexical processing, may well show results more consistent with what natural language users do. Such a system should treat Arabic and English differently because regularities in the two types of languages lie in different places, as well as reflecting further differences in the functional and distributional properties of Arabic word pattern and root morphemes.

Conclusion

The present work presents new information on how the dynamics of the language processor are influenced by morphology, orthography, and semantics. Across languages, these three domains of knowledge have different impacts on the way visual input is mapped onto internal representations of lexical forms. The existing models of language processing and representation are mainly guided by what we know about Indo-European languages, and in particular English. If we are to build a viable theory of language processing that captures the universal properties of language without failing to acknowledge the idiosyncratic characteristics of different languages, we need to sample typologically different languages. The present study is a step in this direction.

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Appendix 1

Test items used in Experiment 1. For every item, the Arabic script, an IPA transcription and an English gloss are given.

Prime		
+WP	**Unrelated**	**Target**
خالد [xaalidun] eternal	نهوض [nuhuudˤun] getting up	حارس [ħaarisun] guard
نشيط [naʃiitˤun] active	جنون [ʒunuunun] insanity	صغير [sˤaʁiirun] small
ضعيف [dˤaʕiifun] weak	نقطة [nuqtˤatun] point	أخير [ʔaxiirun] final
تجارة [tiʒaaratun] trade	حمولة [ħumuulatun] burden	كتابة [kitaabatun] writing
فقير [faqiirun] poor	شهرة [ʃuhratun] fame	بعيد [baʕiidun] remote
فاسد [faasidun] corrupt	هدنة [hudnatun] truce	قادم [qaadimun] coming
حزين [ħaziinun] unhappy	لعبة [luʕbatun] game	كريم [kariimun] generous
ثورة [θawratun] rebellion	حفرة [ħufratun] hole	دعوة [daʕwatun] invitation
كشّاف [kaʃʃaafun] scout	غياب [ʁiʒaabun] absence	فلاّح [fallaaħun] farmer
تهمة [tuhmatun] allegation	فرار [firaarun] departure	سلطة [sultˤatun] authority
وضوح [wudˤuuħun] clarity	بلاغ [balaaʁun] bulletin	جلوس [ʒuluusun] sitting
خلافة [xilaafatun] succession	صعوبة [sˤuʕuubatun] difficulty	دراسة [diraasatun] study

Prime		
+WP	**Unrelated**	**Target**
وقوع [wuquuʕun] happening	رقيق [raqiiqun] delicate	دخول [duxuulun] entering
سلوك [suluukun] behavior	شبكة [ʃabakatun] net	حصول [ħusˤuulun] coming about
خبيث [xabiiθun] malicious	زينة [ziinatun] decoration	سريع [sariiʕun] fast
عاقل [ʕaaqilun] rational	بؤس [buʔsun] wretchedness	خادم [xaadimun] servant
صامت [sˤaamitun] quiet	ممكن [mumkinun] possible	لاجئ [laaʒiʔun] refugee
خطيب [xatˤiibun] orator	مبدع [mubdiʕun] innovator	شريف [ʃariifun] noble
سقوط [suquutˤun] falling down	دهشة [dahʃatun] astonishment	خروج [xuruuʒun] coming out
سرور [suruurun] happiness	خليّة [xaliʤatun] cell	هجوم [huʒuumun] attack
ثمين [θamiinun] valuable	فرصة [fursˤatun] opportunity	عجيب [ʕaʒiibun] wonderful
جريح [ʒariiħun] wounded	رؤية [ruʔʤatun] vision	نظيف [naðˤiifun] clean
غليظ [ɣaliiðˤun] thick	مربّع [murabbaʕun] square	عميق [ʕamiiqun] profound
رحيل [raħiilun] departure	ندرة [nudratun] scarceness	نصيب [nasˤiibun] share

Prime		
+Orth1	**Unrelated**	**Target**
ثروة [θarwatun] fortune	عبور [ʕubuurun] crossing	مذهب [maðhabun] ideology
رياضة [riʒaadˤatun] sport	خمود [xumuudun] abatement	كفاح [kifaaħun] struggle
بطالة [bitˤaalatun] unemployment	نشوء [nuʃuuʔun] emergence	حصار [ħisˤaarun] embargo
شماتة [ʃamaatatun] gloating over others' grief	نبوغ [nubuʁuun] genius	جبان [ʒabaanun] coward
قسوة [qaswatun] hardness	هدوء [huduuʔun] quietude	مركب [markabun] boat
مائدة [maaʔidatun] dining table	سكون [sukuunun] inactivity	ضابط [dˤaabitˤun] officer
نقابة [naqaabatun] trade union	رابطة [raabitˤatun] bond	حنان [ħanaanun] compassion
غنيمة [ʁaniimatun] spoils	هبوط [hubuutˤun] landing	عديد [ʕadiidun] numerous
سباحة [sibaaħatun] swimming	شرود [ʃuruudun] roaming	صراع [sˤiraaʔun] conflict
سماحة [samaaħatun] kindness	شروق [ʃuruuqun] sun rise	ذهاب [ðahaabun] going away
دامية [daamiʒatun] bloody	بروز [buruuzun] protrusion	رائع [raaʔiʕun] marvelous
بضاعة [bidˤaaʕatun] commodity	سكوت [sukuutun] silence	جهاد [ʒihaadun] fight

Prime		
+Orth1	**Unrelated**	**Target**
شهوة [ʃahwatun] desire	مرور [muruurun] passing by	منظر [manðˤarun] sight
سحابة [saħaabatun] cloud	عصفور [ʕusˤfuurun] bird	طلاق [tˤalaaqun] divorce
تفاهة [tafaahatun] triviality	شروع [ʃuruuʕun] beginning	عناء [ʕanaaʔun] toil
حديقة [ħadiiqatun] garden	شحرور [ʃuħruurun] blackbird	عريض [ʕariidˤun] large
صرامة [sˤaraamatun] strictness	نزوح [nuzuuħun] exodus	جواد [ʒawaadun] horse
حماقة [ħamaaqatun] foolishness	صعود [sˤuʕuudun] going up	سماع [samaaʕun] hearing
زاوية [zaawiʝatun] corner	بلوغ [buluuɣun] reaching	قادر [qaadirun] capable of
طازجة [tˤaaziʒatun] fresh	خضوع [xudˤuuʕun] submission	ماهر [maahirun] skillful
طائرة [tˤaaʔiratun] plane	فتور [futuurun] tepidity	خالص [xaalisˤun] pure
ذريعة [ðariiʕatun] pretext	سهولة [suhuulatun] ease	خبير [xabiirun] expert
قبيلة [qabiilatun] tribe	ليونة [luʝuunatun] softness	عريق [ʕariiqun] deep rooted
عزيمة [ʕaziimatun] determination	مرونة [muruunatun] flexibility	شقيق [ʃaqiiqun] brother

Prime		
+R+S	**Unrelated**	**Target**
رئاسة [riʔaasatun] presidency	عاقبة [ʕaaqibatun] upshot	رئيس [raʔiisun] president
جماعة [ʒamaaʕatun] company	وسيلة [wasiilatun] means	اجتماع [ʔiʒtimaaʕun] gathering
مشترك [muʃtarikun] participant	بنيان [bunjaanun] edifice	شركة [ʃarikatun] partnership
أديب [ʔadiibun] author	لسان [lisaanun] tongue	أدب [ʔadabun] literature
تحقيق [taħqiiqun] investigation	موضوع [mawdˤuuʕun] subject	حقيقة [ħaqiiqatun] truth
تحرير [taħriirun] emancipation	أسبوع [ʔusbuuʕun] week	متحرّر [mutaħarrirun] emancipated
وظيفة [waðˤiifatun] function	إلغاء [ʔilɣaaʔun] cancellation	موظّف [muwaðˤðˤafun] functionary
سليم [saliimun] safe	جدير [ʒadiirun] worthy of	سلام [salaamun] safety
احتفال [ʔiħtifaalun] celebration	انتداب [ʔintidaabun] assignment	حفل [ħaaflun] party
مشاورة [maʃaawaratun] consultation	إقامة [ʔiqaamatun] sojourn	مشورة [maʃuuratun] counsel
وحدة [wiħdatun] union	سؤال [suʔaalun] question	توحيد [tawħiidun] unification
مستعمر [mustaʕmirun] coloniser	مفاجأة [mufaaʒaʔatun] surprise	استعمار [ʔistiʕmaarun] colonisation

Prime		
+R+S	**Unrelated**	**Target**
رسول [rasuulun] messenger	حصان [ħisʔaanun] horse	رسالة [risaalatun] message
سعيد [saʔiidun] happy	وكيل [wakiilun] representative	سعادة [saʔaadatun] happiness
تصحيح [tasħiiħun] correction	فرق [farqun] difference	صحيح [saħiiħun] correct
محبّة [maħabbatun] love	تيّار [taʤʤaarun] current	حبيب [ħabiibun] darling
ارتياح [ʔirtiʤaaħun] comfort	ابتزاز [ʔibtizaazun] extortion	مريح [muriiħun] comfortable
رحيم [raħiimun] pitiful	كيان [kiʤaanun] entity	رحمة [raħmatun] pity
شاهد [ʃaahidun] witness	كامل [kaamilun] complete	شهادة [ʃahaadatun] testimony
شجاع [ʃuʒaaʔun] courageous	خاتم [xaatimun] ring	شجاعة [ʃaʒaaʔatun] courage
توجيه [tawʒiihun] directing	توزيع [tawziiʔun] distribution	وجهة [wiʒhatun] direction
مهاجر [muhaʒirun] immigrant	عدالة [ʔadaalatun] justice	هجرة [hiʒratun] immigration
مبتدأ [mubtadiʔun] beginner	تعزيز [taʔziizun] consolidation	ابتداء [ʔibtidaaʔun] beginning
محسن [muħsinun] beneficent	مظهر [maðʕharun] appearance	إحسان [ʔiħsaanun] beneficence

Prime		
+R-S	**Unrelated**	**Target**
حكمة [ħikmatun] wisdom	شراء [ʃiraaʔun] purchasing	حكومة [ħukuumatun] government
مطرقة [mitˤraqatun] hammer	حافلة [ħaafilatun] coach	طريق [tˤariiqun] road
حدوث [ħuduuθun] happening	جفاء [ʒafaaʔun] repulsion	محادثة [muħaadaθatun] discussion
تقديم [taqdiimun] introduction	واسطة [waasitˤatun] mediator	قديم [qadiimun] old
طباعة [tˤibaaʕatun] printing	رقابة [raqaabatun] surveillance	طبيعة [tˤabiiʕatun] nature
سفير [safiirun] ambassador	بريد [bariidun] mail	سفر [safarun] travel
منطق [mantˤiqun] logic	يتيم [ʝatiimun] orphan	منطقة [mintˤaqatun] zone
منحرف [munħarifun] perverted	هذيان [haðaʝaanun] hallucination	حريف [ħariifun] customer
علامة [ʕalaamatun] mark	جارية [ʒariʝatun] bond-maid	تعليم [taʕliimun] education
غروب [ɣuruubun] sun set	كتلة [kutlatun] lump	غريب [ɣariibun] foreign
سكون [sukuunun] tranquility	شمول [ʃumuulun] exhaustion	مسكين [miskiinun] needy
قناع [qinaaʕun] mask	حائط [ħaaʔitˤun] wall	قناعة [qanaaʕatun] satisfaction

Prime		
+R-S	**Unrelated**	**Target**
سلبيّ	نحوي	أسلوب
[salbiʤʤun]	[naħwiʤʤun]	[ʔusluubun]
negative	grammatical	style
حرام	جماد	احترام
[ħaraamun]	[ʒamaadun]	[ʔiħtiraamun]
illicit	inanimate	respect
أغنية	حقيقة	غنيّ
[ʔuɣniʤatun]	[ħaqiiqatun]	[ɣaniʤʤun]
song	truth	rich
ظالم	حريق	ظلام
[ðˤaalimun]	[ħariiqun]	[ðˤalaamun]
oppressor	fire	obscurity
عقدة	محنة	اعتقاد
[ʕuqdatun]	[miħnatun]	[ʔiʕtiqaadun]
knot	affliction	belief
عذاب	فداء	عذب
[ʕaðaabun]	[fidaaʔun]	[ʕaðbun]
torture	sacrifice	sweet
منبسط	منحرط	بسيط
[munbasitˤun]	[munxaritˤun]	[basiitˤun]
cheerful	affiliated	simple
غيرة	سطوة	تغيير
[ɣiiratun]	[satˤwatun]	[taɣʤiirun]
envy	influence	change
مجاوزة	نخاع	جواز
[muʒawaazatun]	[nuxaaʕun]	[ʒawaazun]
overtaking	spinal cord	admissibility
معطف	ملفوف	عاطفة
[miʕtˤafun]	[malfuufun]	[ʕaatˤifatun]
overcoat	wrapped up	sentiment
مراجعة	محافظة	رجوع
[muraaʒaʕatun]	[muħaafaðˤatun]	[ruʒuuʕun]
revision	preservation	coming back
شرط	خطأ	شرطة
[ʃartˤun]	[xatˤaʔun]	[ʃurtˤatun]
condition	error	police

Prime		
+Orth2	**Unrelated**	**Target**
محايد [muħaaʝidun] neutral	مدافع [mudaafiʔun] defender	حياة [ħaʝaatun] life
مستبدّ [mustabiddun] tyrant	تصوير [tasʕwiirun] portrayal	سبب [sababun] reason
تمساح [timsaaħun] crocodile	تجربة [taʒribatun] experience	مساء [massaʔun] evening
مدير [mudiirun] director	كثيف [kaθiifun] dense	دين [diinun] religion
تحدّ [taħaddin] challenge	تقريب [taqriibun] approximation	حدّ [ħaddun] frontier
مصافحة [musʕaafaħatun] hand shake	معالجة [muʕaalaʒatun] treatment	صفة [sʕifatun] attribute
تأميم [taʔmiimn] nationalisation	إبريق [ʔibriiqun] jug	تامّ [taammun] complete
مسرح [masraħun] theatre	مصحف [musʕħafun] Koran	سرّ [sirrun] secret
ثابت [θaabitun] firm	شارع [ʃaariʔun] avenue	ثواب [θawaabun] reward
سلحفاة [sulaħfaatun] turtle	انتهاء [ʔintihaaʔun] radio	سلاح [silaaħun] weapons
معبد [maʕbadun] place of worship	موسم [mawsimun] season	تعبير [taʕbiirun] expression
محراث [miħraaθun] plow	مذياع [miðʝaaʔun] radio	حرارة [ħaraaratun] heat

Prime		
+Orth2	**Unrelated**	**Target**
مقعد [maqʔadun] seat	مهنة [mihnatun] profession	قاعة [qaaʔatun] room
موجب [muuʒibun] motive	مطرب [mutˤribun] singer	موجة [mawʒatun] wave
مفت [muftin] casuist	لقب [laqabun] title	مفتّش [mufattiʃun] inspector
تأجيل [taʔʒiilun] postponement	إقليم [ʔiqliimun] province	تاج [taaʒun] crown
ميلاد [miilaadun] birth	بطاقة [bitˤaaqatun] card	ميل [maʝlun] inclination
فضاء [fadˤaaʔun] space	يسار [ʝasaarun] left	فضيلة [fadˤiilatun] virtue
إمضاء [ʔimdˤaaʔun] signature	إحساس [ʔiħsaasun] feeling	ضئيل [dˤaʔiilun] scanty
إعراب [ʔiʔraabun] inflection	إفلاس [ʔiflaasun] bankruptcy	معركة [maʔrakatun] battle
ناجع [naaʒiʔun] efficient	خاشع [xaaʃiʔun] earnest	منجد [munʒidun] dictionary
لجة [lumʒatun] snack	غرفة [ʁurfatun] chamber	مجرم [muʒrimun] criminal
دينار [diinaarun] monetary unit	إغراء [ʔiʁraaʔun] seduction	مدينة [madiinatun] metal
منتعل [muntaʔilun] shod	قوّة [quwwatun] power	نعيم [naʔiimun] amenity

Prime		
-R+S	**Unrelated**	**Target**
أزمة [ʔazmatun] crisis	قنصل [qunsˤulun] consul	مشكلة [muʃkilatun] problem
غوث [ɣawθun] rescue	صاف [sˤaafin] crystal	معونة [maʔuunatun] help
إضافة [ʔidˤaafatun] addition	قافلة [qaafilatun] caravan	زيادة [ziʤaadatun] increase
داء [daaʔun] disease	كأس [kaʔsun] cup	مرض [maradˤun] illness
عربة [ʕarabatun] vehicle	إلقاء [ʔilqaaʔun] addition	سيّارة [saʤʤaaratun] car
شبّاك [ʃubbaakun] window	مرشّح [muraʃʃaħun] candidate	نافذة [naafiðatun] window
غذاء [ɣiðaaʔun] nutrition	إبرة [ʔibratun] needle	طعام [tˤaʕaamun] food
فوز [fawzun] victory	شخص [ʃaxsˤun] individual	نجاح [naaʒaaħun] success
حكاية [ħikaaʤatun] story	عمود [ʕamuudun] post	قصّة [qisˤsˤatun] novel
زعيم [zaʕiimun] leader	كثرة [kaθratun] abundance	قيادة [qiʤaadatun] leadership
حلف [ħilfun] pact	تنظيم [tanðˤiimun] organisation	معاهدة [muʕaahadatun] treaty
عروس [ʕaruusun] bride	قوت [quutun] nutriment	زواج [zawaaʒun] marriage

Prime		
-R+S	**Unrelated**	**Target**
علوّ [ʕuluwwun] rising	موز [mawzun] banana	ارتفاع [ʔirtifaaʕun] going up
وفاة [wafaatun] death	قلعة [qalʕatun] tower	موت [mawtun] death
عائلة [ʕaaʔilatun] family	نصيحة [nasˁiiħatun] advice	أسرة [ʔusratun] family
أمانة [ʔamaantun] trustworthiness	تدريب [tadriibun] training	ثقة [θiqatun] trust
جولة [ʒawlatun] excursion	قصّاب [qasˁsˁaabun] butcher	نزهة [nuzhatun] promenade
قتال [qitaalun] fight	خيال [xaʃaalun] imagination	حرب [ħarbun] war
حجّة [ħuʒʒatun] evidence	صلة [sˁilatun] link	دليل [daliilun] proof
متعسف [mutaʕassifun] despot	تقسيم [taqsiimun] dividing	جبّار [ʒabbaarun] tyrant
متعب [mutʕibun] tiring	مخيّم [muxaʃʃamun] camp	شقاء [ʃaqaaʔun] toil
خير [xaʃrun] fortune	جهد [ʒuhdun] effort	بركة [barakatun] fortune
بيت [baʃtun] house	وعي [waʕʃun] consciousness	حجرة [ħuʒratun] room
عجوز [ʕaʒuuzun] old woman	سرير [sariirun] bed	شيخ [ʃajxun] old man

Appendix 2

Test items used in Experiment 2. For every item, the Arabic script, an IPA transcription and an English gloss are given.

Prime		
+WP	**Unrelated**	**Target**
لخّص [laxxasˤa] sum up	مسحة [musħatun] tinge	فكّر [fakkara] think
تخلّص [taxallasˤa] get rid of	منطفئ [muntˤafiʔun] extinguished	تعرّض [taʔarradˤa] deal with
لاحظ [laaħaðˤa] notice	منتج [muntiʒun] produces	سافر [saafara] travel
أحرز [ʔaħraza] acquire	برود [buruudun] frigidity	أبلغ [ʔablaɣa] cause to reach
ابتسم [ʔibtasama] smile	مغفّل [muɣaffalun] silly	التفت [ʔiltafata] look back
استأجر [ʔistaʔʒara] hire	مغازلة [muɣaazalatun] flirting	استغرق [ʔistaɣraqa] engross
حصل [ħasˤala] happen	دين [diinun] religion	جلس [ʒalasa] sit down
انهمر [ʔinhamara] pour down	تحافت [tahaafutun] follow in succession	انقطع [ʔinqatˤaʔa] be cut
رتّب [rattaba] tidy up	كسب [kasbun] earning	مثّل [maθθala] act
تضمّن [tadˤammana] include	واجب [waaʒibun] duty	تذكّر [taðakkara] remember
ناقش [naaqaʃa] discuss	إكرام [ʔikraamun] deference	ساعد [saaʔada] help
أبصر [ʔabsˤara] see	رفيق [rafiiqun] companion	أغلق [ʔaɣlaqa] close

Prime		
+WP	**Unrelated**	**Target**
احتقر [ʔiħtaqara] despise	نيابة [niʒaabatun] representation	اجتمع [ʔiʒtamaʕa] meet
استأذن [ʔitaʔðana] seek permission	دحرجة [daħraʒatun] rolling	استخدم [ʔistaxdama] use
لمع [lamaʕa] glimmer	تامّ [taammun] complete	صرخ [sˤaraxa] shout
انفجر [ʔinfaʒara] explode	تلقيح [talqiiħun] vaccination	انصرف [ʔinsˤarafa] depart
بارك [baaraka] congratulate	مريض [mariidˤun] ill	خالف [xaalafa] disagree
أقفل [ʔaqfala] close	مخطئ [muxtˤiʔun] erroneous	أصدر [ʔasˤdara] issue
استخرج [ʔistaxraʒa] extract	مقاومة [muqaawamatun] fight	استعمل [ʔistaʕmala] utilize
تفضّل [tafadˤdˤala] oblige	مزمن [muzminun] chronic	تعلّق [taʕallaqa] stick to
أطعم [ʔatˤʕama] feed	واسع [waasiʕun] wide	أخبر [ʔaxbara] tell
استأنف [ʔistaʔnafa] resume	متأرجح [mutaʔarʒiħun] swinging	استقبل [ʔistaqbala] receive
انفرد [ʔinfarada] isolate oneself	متخصّص [mutaxasˤsˤisˤun] specialist	انقلب [ʔinqalaba] be overturned
تأخّر [taʔaxxara] be late	قلعة [qalʕatun] tower	تمكّن [tamakkana] manage to

Prime		
+Orth1	**Unrelated**	**Target**
غاية [ɣaaʤatun] purpose	شهوة [ʃahwatun] desire	ثابر [θaabara] persevere
بطّة [batˤtˤatun] duck	نور [nuurun] light	نصّب [nasˤsˤaba] appoint
راية [raaʤatun] banner	بروز [buruuzun] appearing	عالج [ʕaalaʒa] treat
بدعة [bidʕatun] novelty	هدوء [huduuʔun] quiet	احترم [ʔiħtarama] respect
مرق [maraqun] broth	كوخ [kuuxun] hut	ذبح [ðabaħa] slay
محنة [miħnatun] ordeal	وضوء [wudˤuuʔun] ablution	اندثر [ʔindaθara] become extinct
طلقة [tˤalqatun] shot	سوء [suuʔun] evil	صرّح [sˤarraħa] declare
مجلّة [maʒallatun] magazine	سرور [sururun] happiness	تحرّك [taħarraka] move
نادم [naadimun] repentant	غروب [ɣuruubun] sun set	دافع [daafaʕa] defend
عدد [ʕadadun] number	ثبوت [θubuutun] stability	لمس [lamasa] touch
عالة [ʕaalatun] dependent	طموح [tˤumuuħun] aspiration	صاهر [sˤaahara] become related by marriage
سهر [saharun] staying up	صوف [sˤuufun] wool	خلع [xalaʕa] remove

Prime		
+Orth1	**Unrelated**	**Target**
خلسة [xilsatun] furtively	وجوب [wuʒuubun] necessity	انتصر [ʔintasˤara] conquer
أسد [ʔasadun] lion	سور [suurun] fence	كفل [kafala] sponsor
شمعة [ʃamʕatun] candle	عزوف [ʕuzuufun] turning away	أقلق [ʔaqlaqa] pester
لجنة [laʒnatun] committee	خضوع [xudˤuuʕun] submission	أنكر [ʔankara] deny
بعثة [biʕθatun] delegation	شرود [ʃuruudun] straying	انخدع [ʔinxadaʕa] be deceived
صخرة [sˤaxratun] rock	جمود [ʒumuudun] solidity	كلّف [kallafa] entrust
سلّة [sallatun] basket	عضو [ʕudˤwun] limb	ضمّد [dˤammada] bandage
قامة [qaamatun] stature	بزوغ [buzuuɤun] emergence	جامل [ʒaamala] compliment
قمر [qamarun] moon	قوت [quutun] subsistence	نسج [nasaʒa] weave
رجّة [raʒʒatun] shock	فول [fuulun] beans	حصّن [ħasˤsˤana] fortify
بدن [badanun] body	غول [ɤuulun] ogre	نقم [naqama] begrudge
قلم [qalamun] pen	حوت [ħuutun] fish	ترك [taraka] leave behind

Prime		
+R+S	**Unrelated**	**Target**
تكوّن [takawwana] form	معلّم [muʔallimun] teacher	كوّن [kawwana] form
احترق [ʔiħtaraqa] burn	تصديق [tasˀdiiqun] believing	أحرق [ʔaħraqa] set ablaze
خالط [xaalatˀa] mix with	غدير [ɣadiirun] brook	اختلط [ʔixtalatˀa] be mixed with
أنزل [ʔanzala] lower	جرأة [ʒurʔatun] boldness	نزل [nazala] come down
انتقل [ʔintaqala] move	توديع [tawdiiʔun] leave taking	نقل [naqala] cause to move
ابتعد [ʔibtaʔada] move away	مصيبة [musˀiibatun] calamity	أبعد [ʔabʔada] put aside
استفاد [ʔistafaada] benefit	معاناة [muʔaanaatun] endurance	أفاد [ʔafaada] cause to benefit
ابتدأ [ʔibtadaʔa] begin	ممتاز [mumtaazun] excellent	بدأ [badaʔa] begin
ارتفع [ʔirtafaʔa] rise	مجتهد [muʒtahidun] diligent	رفع [rafaʔa] raise
أوجد [ʔawʒada] create	نزيف [naziifun] hemorrhage	وجد [waʒada] find
استمع [ʔistamaʔa] listen	تأليف [taʔliifun] composition	سمع [samiʔa] hear
تغلّب [taɣallaba] overcome	شروع [ʃuruuʔun] starting	غلب [ɣalaba] defeat

Prime		
+R+S	**Unrelated**	**Target**
استمتع [ʔistamtaʕa] enjoy	ازدهار [ʔizdihaarun] prosperity	تمتّع [tamattaʕa] savor
انتفع [ʔintafaʕa] profit	تدبير [tadbiirun] arrangement	نفع [nafaʕa] be beneficial
استحسن [ʔistaħsana] find something to be good	مبادلة [mubaadalatun] exchange	أحسن [ʔaħsana] do well
التقى [ʔiltaqaa] meet	متشبّث [mutaʃabbiθun] adhering	لقي [laqiɟa] find
تفرّق [tafarraaqa] become separated	مهذّب [muhaððabun] well-mannered	فارق [faaraqa] leave
تشارك [taʃaaraka] take part	مناسب [munaasibun] convenient	اشترك [ʔiʃtaraka] participate
تعذّر [taʕaððara] be beneficial	منقذ [munqiðun] rescuer	اعتذر [ʔiʕtaðara] apologize
اكتشف [ʔiktaʃafa] discover	واسطة [waasʕitʕatun] mediator	كشف [kaʃafa] uncover
تعجّب [taʕaʒʒaba] marvel at	قصير [qasʕiirun] short	أعجب [ʔaʕʒaba] admire
أدخل [ʔadxala] insert	زواج [zawaaʒun] marriage	دخل [daxala] enter
عاون [ʕaawana] help	صدفة [sʕudfatun] coincidence	تعاون [taʕaawana] help each other
هاجم [haaʒama] raid	وقوف [wuquufun] stopping	هجم [haʒama] attack

Prime		
+R-S	**Unrelated**	**Target**
ناهض [naahadˤa] oppose	مصلح [musˤliħun] reformer	نهض [nahadˤa] stand up
تفرّس [tafarrasa] stare	مهمل [muhmilun] negligent	افترس [ʔiftarasa] devour
غامر [ɣaamara] venture	ناقد [naaqidun] critic	غمر [ɣamara] overwhelm
استعمر [ʔistaʕmara] colonize	لوم [lawmun] blame	اعتمر [ʔiʕtamara] visit
تعارف [taʕaarafa] become acquainted	رخصة [ruxsˤatun] license	اعترف [ʔiʕtarafa] admit
عقّد [ʕaqqada] complicate	صبح [sˤubħun] morning	اعتقد [ʔiʕtaqada] believe
تحوّل [taħawwala] become	عتاب [ʕitaabun] admonition	حاول [ħaawala] try
واجه [waaʒaha] confront	مطبخ [matˤbaxun] kitchen	توجّه [tawaʒʒaha] head for
تقرّر [taqarrara] be decided	سكوت [sukuutun] silence	استقرّ [ʔistaqarra] settle
وقّع [waqqaʕa] sign	سند [sanadun] support	توقّع [tawaqqaʕa] expect
نافق [naafaqa] dissimulate	ممثل [mumaθθilun] actor	أنفق [ʔanfaqa] spend
تقاسم [taqaasama] share	إعارة [ʔiʕaaratun] loan	أقسم [ʔaqsama] take an oath

Prime		
+R-S	**Unrelated**	**Target**
نظّر [naðˤðˤara] theorise	هبة [hibatun] gift	انتظر [ʔintaðˤara] wait for
تقاعد [taqaaʕada] resign	شتيمة [ʃatiimatun] insult	قعد [qaʕada] sit down
استأثر [ʔistaʔθara] appropriate	مجازفة [muʒaazafatun] hazard	أثّر [ʔaθθara] influence
أضرب [ʔadˤraba] go on strike	متعب [mutʕibun] tiring	اضطرب [ʔidˤtˤraba] be disturbed
أحدث [ʔaħdaθa] cause to happen	طاعة [tˤaaʕatun] obedience	تحدّث [taħaddaaθa] talk
تشرّف [taʃarrafa] be honored	كفاح [kifaaħun] struggle	أشرف [ʔaʃarafa] supervise
احتضر [ʔiħtadˤara] be in the throes of death	مفاجئ [mufaaʒiʔun] surprising	أحضر [ʔaħadˤara] bring
ابتذل [ʔibtaðala] make trite	مراقب [muraaqibun] supervisor	بذل [baðala] sacrifice
خلّف [xallafa] leave behind	جريح [ʒariiħun] wounded	اختلف [ʔixtalafa] disagree
تقادم [taqaadama] become old	مجهول [maʒhuulun] unknown	تقدّم [taqaddama] advance
قبّل [qabbala] kiss	شروق [ʃuruuqun] sun rise	تقابل [taqaabala] meet
تنافس [tanaafasa] compete	ثمرة [θamratun] fruit	تنفّس [tanaffasa] breath

Prime		
+Orth2	**Unrelated**	**Target**
متراجع [mutaraaʒiʔun] retreating	انحناء [ʔinħinaaʔun] bending	ترجم [tarʒama] translate
اشمئزاز [ʔiʃmiʔzaazun] disgust	استفسار [ʔistifsaarun] inquiry	شمّ [ʃamma] smell
تكسير [taksiirun] breaking	تقليص [taqliisˁun] shrinking	كسا [kasaa] clothe
مربض [marbadˁun] fold	خفيف [xafiifun] light	ربّى [rabbaa] raise
حنق [ħanaqun] anger	يأس [jaʔsun] despair	حان [ħaana] be imminent
جرعة [ʒrʔatun] mouthful	وتر [watarun] string	جاع [ʒaaʔa] feel hungry
مفتوح [maftuuħun] open	منسحب [munsaħibun] withdrawing	فات [faata] elapse
مفروض [maafruudˁun] imposed	موضوع [mawdˁuuʔun] subject	فرّ [farra] flee
مطلع [matˁlaʔun] beginning	مسبح [masbaħun] swimming pool	طال [tˁaala] become long
إسقاط [ʔisqaatˁun] tumbling	إخلاص [ʔixlaasˁun] faithfulness	سقى [saqaa] water
هبوط [hubuutˁun] landing	عيش [ʔaʃun] way of life	هبّ [habba] blow
تقليد [taqliidun] imitation	تسمية [tasmiʒatun] nomination	قلّ [qalla] diminish

Prime		
+Orth2	**Unrelated**	**Target**
متلهّف	مطمئنّ	تلا
[mutalahhifun]	[mutˤmaʔinnun]	[talaa]
yearning for	serene	succeed
سعال	ذنب	سعى
[suʔaalun]	[ðanbun]	[saʔaa]
sneezing	wrong-doing	endeavor
إبعاد	إرسال	باع
[ʔibʔaadun]	[ʔirsaalun]	[baaʔa]
removal	sending	sell
بلعوم	مجد	بلّل
[bulʔuumun]	[maʒadun]	[ballala]
pharynx	glory	moisten
مجادلة	انصراف	جاد
[muʒaadalatun]	[ʔinsˤiraafun]	[ʒaada]
discussion	departure	give generously
مجلّد	مربّع	جال
[muʒalladun]	[murabbaʔun]	[ʒaala]
hardbound book	square	walk
مضحك	مسعف	ضحّى
[mudˤħikun]	[musaʔifun]	[dˤaħħaa]
humorous	rescuer	sacrifice
عفن	درج	عفا
[ʔafanun]	[daraʒun]	[ʔafaa]
decomposition	stairs	forgive
متشابه	متألّم	شبّ
[mutaʃaabihun]	[mutaʔallimun]	[ʃabba]
similar	suffering	grow up
تجريد	تخطيط	جرّ
[taʒriidun]	[taxtˤiitˤun]	[ʒarra]
dispossessing	planning	pull
صفعة	طور	صفا
[sˤafʔatun]	[tˤawrun]	[sˤafaa]
smack	period	become clear
مخبأ	معدن	خاب
[maxbaʔun]	[maʔdanun]	[xaaba]
hiding place	metal	fail

Prime		
-R+S	**Unrelated**	**Target**
أيقن	تحفة	تأكّد
[ʔaɟqana]	[tuħfatun]	[taʔakkada]
ascertain	masterpiece	be confirmed
هاج	نيّة	أغضب
[haaʒa]	[niɟɟatun]	[ʔaʏdˤaba]
become agitated	intention	cause to become angry
حذف	طيّب	ألغى
[ħaðafa]	[tˤaɟɟibun]	[ʔalʏaa]
omit	good	cancel
أنجز	جبهة	وفى
[ʔanʒaza]	[ʒabhatun]	[wafaa]
carry out	front	fulfill
رحم	مزعج	أشفق
[raħima]	[muzʔiʒun]	[ʔaʃfaqa]
have mercy	annoying	pity
استغلّ	طريقة	انتهز
[ʔistaʏalla]	[tˤariiqatun]	[ʔintahaza]
exploit	method	seize the opportunity
اقتنص	مشاكس	اصطاد
[ʔiqtanasˤa]	[muʃaakisun]	[ʔisˤtˤaada]
hunt	quarrelsome	hunt
اقتفى	سيطرة	اتّبع
[ʔiqtafaa]	[saɟtˤaratun]	[ʔittabaʔa]
track	dominion	follow
نظّف	ميز	غسل
[naðˤðˤafa]	[maɟzun]	[ʏasala]
clean	segregation	wash
اختفى	صيانة	غاب
[ʔixtafaa]	[sˤiɟaanatun]	[ʏaaba]
hide	upkeep	vanish
دنا	نيل	اقترب
[danaa]	[naɟlun]	[ʔiqtaraba]
become nearer	obtainment	draw closer
أنشد	واضح	غنّى
[ʔanʃada]	[waadˤiħun]	[ʏannaa]
chant	clear	sing

Prime		
-R+S	**Unrelated**	**Target**
صوّر [sˤawwara] draw	بيت [baʝtun] house	رسم [rasama] paint
نما [namaa] grow	شهر [ʃahrun] month	ازداد [ʔizdaada] increase
ارتدى [ʔirtadaa] wear	ولاية [wilaaʝatun] state	لبس [labisa] wear
امتنع [ʔimtanaʕa] abstain	منتشر [muntaʃirun] widespread	رفض [rafadˤa] refuse
بيّن [baʝʝana] show	سجلّ [siʒillun] register	أظهر [ʔaðˤhara] display
قبض [qabadˤa] grasp	خير [xaʝrun] good	أمسك [ʔamsaka] seize
استدعى [ʔistadʕaa] invite	ارتجال [ʔirtiʒaalun] improvisation	نادى [naada] call
شيّد [ʃaʝʝada] establish	مشي [maʃʝun] walk	بنى [banaa] build
أجمع [ʔaʒmaʕa] concur	منحة [minħatun] grant	اتّفق [ʔittafaqa] agree
ألقى [ʔlqaa] fling	ضياع [dˤaʝaaʕun] loss	رمى [ramaa] throw
أدرك [ʔadraka] understand	ثقيل [θaqiilun] heavy	فهم [fahima] understand
رقد [raqada] slumber	سير [saʝrun] marching	نام [naama] sleep