The time-course of morphological, phonological and semantic processes in reading Modern Standard Arabic

Sami Boudelaa (sami.boudelaa@mrc-cbu.cam.ac.uk)

William Marslen-Wilson (marslen.wilson@mrc-cbu.cam.ac.uk)

MRC Cognition and Brain Sciences Unit
15 Chaucer Road, Cambridge CB2 2EF, UK

Abstract

We investigate deverbal noun and verb morphology in Modern Standard Arabic (MSA), using two masked priming experiments in which the morphological, orthographic and semantic relationship between prime and targets are varied in four SOA conditions (32 ms, 48 ms, 64 ms, and 80 ms). Results show that early in the visual processing of MSA deverbal nouns and verbs, the role played by morphological structure (word patterns and roots), is significantly different from that played by orthographic and semantic factors. Additionally, while word pattern effects are transient and overlap with root morpheme effects only in the early stages of processing, effects of the root are reliably present throughout the recognition process.

Introduction

Unlike Indo-European languages where morphemic units are linearly strung one after the other to create new forms, Semitic languages like Modern Standard Arabic (MSA), or Hebrew draw on a non-linear word building principle whereby at least two abstract morphemes are interlaced one within the other (Holes, 1995, Versteegh, 1997). Reflecting this, surface word forms in such languages are traditionally analyzed into word patterns and roots. Word patterns are CV structures, primarily specifying vowels, that provide phonological structure and convey syntactic meaning, while roots consist solely of consonants and convey the broad semantic properties of the surface form (Wright, 1995). For example, the word [katama] "conceal" comprises the word pattern {fa ala}[1] with the syntactic meaning "perfective, active", and the root {ktm} meaning "concealing". Both of these units recur many times in the language in combination with other units. The word pattern {fa ala} is met in other forms like [sakaba] "pour", [daxala] "enter", [faqada] "miss". Likewise, the root {ktm} appears in such forms as [kattama] "cause to hide", [kaatama] "withhold", and [takattama] "keep mum".

Previous research on the use of word patterns and roots during the processing of Hebrew and MSA has yielded interesting, and largely consistent evidence that these units are actively used during processing (Frost, Forster & Deutsch, et al., 1997, Deutsch, Frost & Forster, 1998, Boudelaa & Marslen-Wilson, 2000). For instance, significant word pattern priming effects were found in Hebrew and MSA, although limited to verb morphology in Hebrew, but applying across syntactic class categories in MSA (Deutsch, et al., 1998, Boudelaa & Marslen-Wilson, 2000). Additionally, reliable root priming was also found in Hebrew and MSA nouns and verbs regardless of semantic transparency (Frost et al., 1997, Boudelaa & Marslen-Wilson, 2000). This research into Semitic morphology has provided some of the most compelling evidence in favour of the view that the role played by morphological structure in lexical processing and representation is distinct from form and meaning effects. Furthermore, the effects of word patterns and roots clearly show that bound and indeed disrupted morphemic units do influence processing.

Here we focus on MSA deverbal nouns and verbs and try to go beyond the research reported so far to examine how the prior presentation of a prime word affects lexical decision to a target as a function of (a) the relationship underlying 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 display durations (or SOA's), of 32, 48, 64, and 80 ms, to assess the effects of priming across these dimensions of similarity. In an earlier masked priming investigation of Arabic morphology, we found reliable word pattern and root priming effects at an SOA of 48 ms. Since both morphemic units seem to be involved in the processing

[1] This is the conventional notation used to describe word patterns, where the letters "f, , l" are place holders indicating where the first, second and third root letters go when this unit is combined with a word pattern, and the vowels ("a, a" here) indicate which vowels are inserted into the surface CV template.

at such an SOA, we decided to include a shorter SOA of 32 ms, to determine whether word patterns and roots have different processing onsets. We also included the two longer SOA's (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's of 32 ms and 48 ms, participants 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 SOA's (Frost et al., 1997, Forster & Azuma, 2000), and to the investigation of semantic effects at longer SOA's (Perea et al., 1995, Sereno, 1991). Accordingly, apart from minimizing strategic behavior, 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 (Rastle et al., 2000, Feldman, 2000). Our hypothesis is that if morphological structure in MSA is playing a role that is genuinely distinct from that played by orthography and semantics, then this should be reflected in the differential priming effects observed in the morphological, orthographic and semantic conditions across the four SOA's. More specifically, word pattern and root effects should be able to emerge earlier than semantic effects, and should be stronger than orthography-driven effects. Additionally, since root morphemes convey semantic meaning, their effects are predicted to be more long-lived than those of the word patterns, which convey syntactic and phonological information. These predictions are tested in Experiment 1 and 2 using deverbal nouns and verbs respectively.

Experiment 1

While sharing the same stock of root morphemes with verbs, deverbal nouns draw on a specific set of word patterns which distinguishes them not only from verbs but also from the closed class of primitive nouns (Bohas and Guillaume, 1984). The purpose of this experiment is to investigate the time course of word pattern and root effects as opposed to semantic and form effects during the processing of deverbal nouns. To do this we used masked priming with four prime-display durations to assess priming between pairs of deverbal nouns which share either a word pattern, a root, or a non-structural orthographic or semantic relationship.

Method

Participants

A group of 138 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

The prime and target pairs used fell into one of 6 conditions each of which comprised 24 pairs. In Condition 1, which we will refer to as [+WP], the prime and target share a word pattern (e.g., حارس-خالد [xaalid]-[aaris] "eternal"-guardian"). To control for the vocalic and consonantal overlap underlying the prime and target pairs in condition 1, Condition 2, [+Orth1] is an orthographic control condition matching the form overlap (primarily in shared vowels) of the word pattern pairs (e.g., طلاق-سحابة [sa aaba]-[t alaaq] "cloud"-"divorce"). In Condition 3, labeled [+R +S], the prime and target pairs share a root morpheme and a transparent semantic relationship (e.g., رئيس-رئاسة [ri aasa]-[ra iis] "presidency"-"president"). This is in contrast to Condition 4, labeled [+R –S], where the prime and target share a root but their semantic relationship is opaque (e.g., شرطة-شرط [art]-[urt a] "condition"-"police"). Con-dition 5, labeled [+Orth 2], is the orthographic control for the two conditions sharing a root (e.g., ثواب-ثابت [aabit]-[awaab] "firm"-"award"). The difference from [+Orth1] is that whereas the orthographic overlap in the latter relates to the shared vowels between prime and target, here overlap is specified solely in terms of shared consonants. Since vowels are not normally written in MSA (unless long), the form overlap in the [+Orth1] pairs is orthographically implicit, but fully explicit in the [+Orth2] pairs. Condition 6, [-R +S], consists of semantically but not morphologically related pairs (e.g., حرب-قتال [qitaal]-[arb] "fight"-"war"). Each of the related prime words was matched to an unrelated control prime. A similar number of pseudo-word-word pairs was constructed in such a way as to echo the form overlap between the word-word pairs.

Design and Procedure

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. The second event was a prime word written without diacritics in the same font but at 24 points. Four SOA's 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 larger font size of the target was used because MSA does not have the lower-case upper-case distinction. The stimulus words and non-words were written in the usual unvowelled script. Thirty two participants were assigned to the first SOA, forty to the second, thirty six to the third, and thirty to the fourth SOA. Participants were asked to make lexical decision about the target by pressing a "YES" or a "NO" key.

Results and discussion

Figure 1 plots the amount of priming (target RT when preceded by an unrelated prime minus target RT when preceded by a related prime) across condition and SOA.

Targets preceded by a prime with which they have a common word pattern were significantly facilitated only at SOA's 48 and 64 ms. The orthographic control for the word-pattern pairs [+Orth1] showed signs of priming at SOA 32, but no effects at any later SOA's, indicating that the word-pattern effects at SOA 48 and 64 are unlikely to be form-based. Word pattern priming in MSA deverbal nouns contrasts with the lack of word pattern priming in Hebrew nouns (Frost et al., 1997). This difference may be traced back to the differences underlying the word pairs making up the [+WP] condition in the present study and the Hebrew word pairs used in the same condition by Frost at al., (1997). In this study, as in our original study where we first report word pattern priming in Arabic nominal forms, we made a distinction between the syntactic meaning of the word pattern and its phonological structure (Boudelaa & Marslen-Wilson, 2000). Two surface forms may have a word pattern with the same surface phonological structure but with quite different syntactic meanings. For example, the pair قرود-نزول [quruud]-[nuzuul] ("monkeys"-"going down"), share the phonological structure of the word pattern, which is CVCVVC in both, but diverge with respect to its syntactic meaning. The word pattern has a "plural" meaning in [quruud], but a "singular deverbal noun" meaning in [nuzuul]. When we compared priming between deverbal nouns sharing both the syntactic meaning and the phonological structure of the word pattern with priming between nouns sharing only the phonological structure of the word pattern, it was only the former type of word pairs that yielded significant priming. The word pattern priming in the present experiment replicates our initial finding of reliable facilitation between deverbal nouns sharing the phonological as well as the syntactic meaning of the word pattern.

Turning to the two root conditions, [+R+S] and [+R-S], there was robust priming, at a constant level, across all four SOA's. In the [+Orth2] condition, where the prime and target shared a form overlap that mimicked the consonantal overlap in the root pairs, a facilitatory effect emerges at SOA 80 ms.

Similarly, significant facilitation emerges only at SOA 80 ms in the [-R+S] condition, where there is only a semantic relationship between prime and target. It is interesting to note that while the effects of morphology (here word pattern and root effects) are clearly distinct from orthographic and semantic effects at SOA's 32, 48 and 64 ms, the distinction between morphology-based and form-based and meaning-based effects dissipates at SOA 80. As can be seen in Figure 1 above, at SOA 80 the facilitation observed in the [+R +S] and the [+R-S] conditions is no longer different from that found in the [+Orth2] or the [-R+S] conditions.

A further point relates to the differences in priming between the two orthographic conditions. In [+Orth1], where the form overlap between prime and target is vowel-based, facilitation occurs only at the shortest SOA. In [+Orth2] where form overlap is consonantal in nature, significant priming takes place only at the longest SOA. These differential effects can be

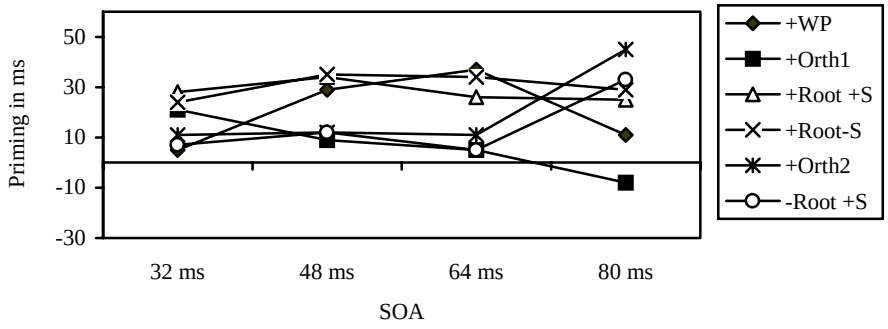

Figure (1): Priming in deverbal nouns as a function of relatedness and SOA

understood in the light of the different functional factors underlying word pattern and root priming – especially, as here, in the written modality, where consonantal information dominates the overt orthographic content of prime and target. The fact that root priming has a more precocious time course than word pattern priming suggests that the language processor monitors for the root consonants in order to access the meaning of the form at hand. Hence word pairs having a non-structural consonantal overlap may act as competitors early on in processing. Conversely, the slightly later onset of word pattern priming suggests that this unit comes into play once a root unit has been converged on. Since a root unit should be successfully extracted very quickly if meaning is to be accessed at all, word pairs sharing vocalic overlap need not compete with each other at the early stages of processing, hence the priming observed in the [+Orth1] condition.

In sum, the results of this experiment suggest that morphological effects take precedence over form driven and meaning driven effects. More importantly perhaps, from the perspective of Semitic morphology, both word pattern and root morphemes are actively used very early in processing. However, the effects of word patterns are rather transient yielding facilitation only over two SOA's, while the effects of the root are more durable (Deutsch et al., 2000). Arguably the qualitative difference underlying the effects of word patterns and roots reflects the difference between the information conveyed by these two units. Word patterns convey information that is syntactic and phonological in nature (Holes, 1995), whereas roots convey semantic information. The more consistent effects of roots by contrast to word patterns suggest that the information conveyed by the root is critically used throughout processing while that conveyed by the word pattern is only transiently salient.

Experiment 2

As we noted earlier, a primary division in Arabic morphology is between the sets of deverbal nouns and the verbs themselves. While roots are the same across deverbal nouns and verbs, word patterns are the unit that distinguishes these two syntactic categories. Accordingly, Experiment 2 was designed to ask three questions: First, will word patterns have similar transient priming effects in verbs as they do in nouns? Second, will root morphemes yield the same consistent priming effects in verbs? Third, are the effects of these two morphological units distinct from the effects produced by orthography and semantics?

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 Experiment1. The material consisted of prime and target verb forms which made up 6 experimental conditions with 24 pairs each. In Condition 1, [+WP], the prime and target share a word pattern (e.g., أبلغ-أحرز [a raza]-[abla a] "obtain"-"inform"). Condition 2, [+Orth 1], was an orthographic control for the form overlap in condition 1 (e.g., أنكر-لجنة [la natun]-[ankara] "committee"-"deny"). In condition 3, [+R +S], prime and target share a root morpheme and a transparent semantic relationship (e.g., أحرق-احترق [i taraqa]-[a raqa] "get burned"-"burn"), while in condition 4, [+R –S], they share a root but have an opaque semantic relationship (e.g., تقدم-تقادم [taqaadama]-[taqaddama] "get old"-"progress"). As in Experiment 1, Condition 5, [+Orth 2], is the orthographic control for conditions 3 and 4 (e.g., بلل-بلع [bala a]-[ballala] "swallow"-"soak"). Condition 6, [-R +S], tests for purely semantic effects (e.g., تأكد -أيقن [ayqana]-[ta akkada] "ascertain"-"make sure"). Each of the related primes, across the 6 conditions, was matched as closely as possible to a control prime that shared no relationship with the target. A similar number of pseudo-word-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 and discussion

Figure 2 shows net priming effects for the six experimental conditions across the four SOA's.

The results are even more clear cut than for the deverbal nouns. The effects of word pattern morphemes is again strong but highly transient, yielding significant priming at SOA 48 only. Its matched orthographic

control, [+Orth1] condition shows a marginal 12 ms facilitation at SOA 32 ms but no effects thereafter, suggesting that word pattern effects are genuine morphological effects that are not amenable to a form-based account. As regards roots, significant priming effects are observed across all four SOA's in both the [+R+S] and the [+R-S] conditions. Orthographic and semantic effects, as illustrated by the [+Orth2] and the [-R+S] conditions, again emerge only at SOA 80. This confirms that root morpheme effects and form-driven and meaning-driven effects have different time courses, the latter two effects taking more time to build up.

These results suggest that in MSA, morphological processing has a different locus from form-based and meaning-based processing. Moreover, verb word patterns, like deverbal noun word patterns, play a highly significant, though transient role during processing. Roots, by contrast, give rise to an evenly distributed pattern of facilitation across SOA's. The different time courses of word pattern and root processing observed in this experiment and in the previous one, suggest that the language processor uses the information conveyed by these two units in different ways and at different points in the internal process of linguistically interpreting a written form.

Conclusion

We have reported two experiments aimed at assessing the time course of morphological, orthographic and semantic effects. In so far as Semitic languages are concerned, there are at least three ways in which morphological effects can be said to be clearly distinct from orthographic and semantic effects:
First, word pattern morphemes, which are non-semantic in nature, yield significant priming, while their matched orthographic controls either do not yield any priming at all, as in Experiment 2, or do so much less reliably, as in Experiment 1. Second, root morphemes play a role irrespective of semantic transparency, with surface forms giving rise to reliable and significant priming as long as they share a morphemic unit. Third, morphological effects occur prior to orthographic and semantic effects and have a longer time-course - at least as far as the root is concerned. In the context of Semitic morphology, this is the first demonstration that word pattern and root morphemes have overlapping but different processing time courses. This state of affairs is a direct consequence of the kind of information that word patterns and roots convey. The reliable and long-lived root priming effects reflect the fact that lexical interpretation and integration of Arabic surface forms relies primarily on this unit. The transient word pattern priming effects point to the fact that this unit is the focus of the lexical mapping process only in so far as a consonantal root unit can be successfully extracted. Evidence supporting this comes from the finding that no word pattern priming is found with pseudowords consisting of existing word patterns and a non-existing root, while root priming is found in pseudo words consisting of an illegal combination of an existing word pattern and an existing root (Frost et al., 1997). Functionally, the results point to the conclusion that morphemic units that are non-linear and abstract are able to govern lexical access and lexical representation.

Turning to the orthographic effects observed in this study, it seems that in MSA, and arguably in other Semitic languages as well, vowels and consonants have a different status. This is clear from the differential priming yielded by word patterns and consonants on the one hand, and by the different loci of orthographic priming in the [+Orth1] and [+Orth2] on the other. Remember that when
orthographic overlap is defined in terms of shared vowels across primes and targets as in the [+Orth1] condition, facilitation is early and transient. By contrast, when it is defined in terms of the consonants shared by prime and target as in the [+Orth2] condition, facilitation is late and robust. Taken together, these results suggest that proximity in the Arabic lexical space is sensitive to similarity in vowels and to similarity in consonants, and that early on in processing lexical competition is initiated on the basis of the consonantal component of the surface form but not its vocalic component.

It is worth noting that in English, where the vowel-consonant distinction is not morphemic, and under experimental conditions that are most similar to ours, that is at 32 ms SOA (Feldman, 2000) and at 43 ms (Rastle et al., 2000), no orthographic effects are obtained. Nonetheless, overall orthographic effects in English tend to be facilitatory early in processing and inhibitory later on. In other words, English orthographic priming is more in keeping with the priming profile we observe in our [+Orth1] condition, and the mirror image of what we observe in our [+Orth2] condition. The emergence of relatively late form effects as evidenced by the priming in [+Orth2] at SOA 80 can perhaps be accommodated within a model where knowledge about the semantic and formal attributes of the input, be they phonological or orthographic, are at the same level in the perceptual system and are computed in parallel, rather than having the form computed prior to accessing the lexicon (Gaskell & Marslen-Wilson, 1998).

From the perspective of a general theory of morphological processing and representation, the current results put new constraints on how to account for morphological effects. For example, while connectionist models, as they now stand, may be able to account for morphological priming in the absence of synchronic semantic links between prime and target (Plaut & Gonnerman, 2000), it is less clear how word patterns, which are non-semantic units in essence, would be predicted to generate priming within such a framework. Nevertheless, it remains important to persevere with models which offer explicit and quantitative predictions about behavior.

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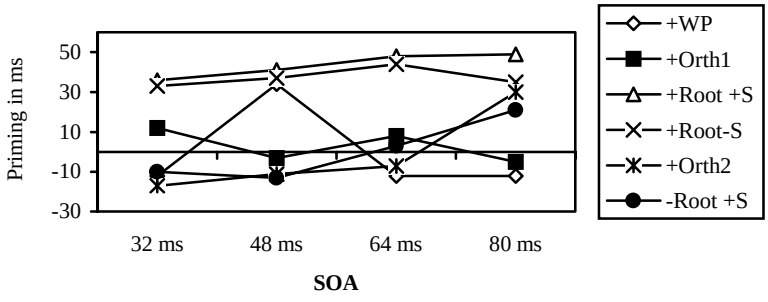

Figure (2): Priming in verbs as a function of relatedness and SOA