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Role of Morphology in Visual Word Recognition: A Parafoveal Preview Study in Arabic Using Eye-Tracking

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***Abstract*—Words in Semitic languages such as Arabic and Hebrew are composed of two interwoven morphemes: roots and word patterns (verbal and nominal). Studies exploring the organizing principles of the mental lexicon in Hebrew reported robust priming effects by roots and verbal patterns, but not by nominal patterns. In Arabic, prior studies have produced some inconsistent results. Using the eye-tracking methodology, this study investigated whether the Arabic morphological classes (i.e., root, verbal pattern, nominal pattern) presented parafoveally would facilitate naming of foveally presented words among young native Arabic skilled readers. Results indicate that roots and both word patterns accelerated word naming latencies, suggesting that morphological knowledge contributed to word recognition processes in Arabic. The inclusion of the three morpheme classes into one study represents so far the most comprehensive study of morphological priming effects in Arabic.**

***Index Terms*—Arabic morphology, parafoveal priming, morpheme, mental lexicon, eye-tracking**

I. Introduction

The question of the organization of words in the mental lexicon and the way words' representations are accessed has been debated for decades (Schiff et al., 2011; Velan et al., 2005). The mental lexicon refers to a repository of words, which provides linguistic and conceptual knowledge about language (Ravid, 2004). It contains phonological, orthographical, morphological, semantic and syntactic information about words and deals with how words are activated, stored, processed and retrieved (Jeffrey, 2004). In this regard, the study of morphologically complex words provides a good opportunity to investigate the organization of this lexicon (Juhasz, 2007). However, since complex words in the different languages are composed according to different morphological principles, reading studies seek to take into consideration the specific aspects of the morphological and other linguistic characteristic of the system at hand (Share, 2008; Boudelaa, 2014).

The Arabic language presents several unique features that include more particularly a complex orthographic system and a rich morphology. The Arabic orthographic system, written from right to left, has an "*abjad*" system that consists of 29 consonant letters of which three act also as a long vowel. In addition, short vowels are represented as diacritical marks above or beneath the letters (Saiegh-Haddad & Henkin-Roitfarb, 2014). Depending on the use of the short vowels (that appear as diacritics above or below the words), the Arabic writing system has two orthographic versions: vowelized and unvowelized one (see details in Abu Rabia, 2001; Asadi & Khateb, 2017). When written with short vowels, the orthography is considered transparent and reading relies mainly on sub-lexical processes. When written without short vowels (unvowelized), the orthography is considered deep since words lack part of the phonological information, and reading is said to rely on lexical processes and context cues because many words become homographic (Abu-Rabia, 2001). The children first learn to read with transparent text and start to use the deep orthography around the fourth grade. In this regard, it has been suggested that thanks to morphological structure of Arabic words, the reader can extract phonological information from print even in the unvowelized words (Saiegh-Haddad, 2013, see also Saiegh-Haddad, 2018). Actually, in Indo-European languages such as English, complex words are composed of stems and affixes that are combined linearly, while each individual morpheme can be identified as a unit by itself (Watson, 2002). In these systems, complex words that are morphologically related (e.g., help/help*ful*, dog/dog*s*) are also phonologically, orthographically and semantically related making it difficult to distinguish effects of morphology from other types of relations between words (Boudelaa & Marslen-Wilson, 2001). Words in Arabic are minimally bimorphemic and comprise two unpronounceable bound morphemes: a root and a word pattern (Saiegh-Haddad, 2018). This morphological structure, although nonlinear, is defined by some authors as transparent in the word's orthographic representation and this makes diacritics unnecessary to reading accuracy (Saiegh-Haddad & Schiff, 2016). Roots are composed of three (rarely two or four) consonants while word patterns include vowels or both consonants and vowels. The root usually conveys the core semantic meaning of the word whereas the word patterns usually specify the phonological structure and morpho-syntactic information (Boudelaa & Marslen-Wilson, 2000, 2005; Ryding, 2005b; Watson, 2002). For example, the word <مطبَخ> (/*matˤbaχ*/) for kitchen is a derivation of the root < ط.ب.خ > */tˤ.b.χ/*), which is inserted into the nominal pattern $maC_1C_2aC_3$, with $C_{1\text{-}3}$ representing the three consonants of the root morpheme. The root < ط.ب.خ > refers to anything related to cooking, while the pattern $maC_1C_2aC_3$ is often related to a name of a place. Thus, the combination of this root and word pattern creates the meaning kitchen (i.e., the place where food is cooked). In this manner, the root < ط.ب.خ > can be combined with another pattern, $C_1aC_2C_2a{:}C_3$, to produce the word <طبّاخ> (/*tˤabba:χ*/) meaning cook (Holes, 2004; Watson, 2002; Ryding, 2005b).

Word patterns in Arabic can be further subdivided into verbal and nominal patterns. To create verbs, fifteen possible verbal patterns exists in Arabic (Danks, 2011; Holes, 2004). As for Arabic nouns, most of these are derived from a root that is interwoven into a nominal pattern. Yet, other nouns are constituted of a basic morphologically complex word, such as <مكتب> (/*maktab*/) for office and <مكتبة> (/*maktaba*/ for library), or a solid stem, such as <قمر> (/*qamar*/ for *moon*) which is linearly combined with a suffix to produce <قمري> (/*qamari:*/ for *lunar*) (Ryding, 2005a). There are about one hundred frequent nominal patterns in Arabic, with the most frequent ones being verbal nouns, participles and derivatives (Holes, 2004).

In the Arabic and Hebrew Semitic languages, which share certain morphological similarities, the role of the morphological components in lexical access had been investigated using different priming paradigms (For Arabic see Abu-Rabia & Awwad, 2004; Boudelaa & Marslen-Wilson, 2000, 2005, 2011; Shalhoub-Awwad & Leikin, 2016; Shalhoub-Awwad, 2019) and for Hebrew (Frost et al., 2005; Bentin & Feldman, 1990; Deutsch et al., 1998; Deutsch et al., 2003; Deutsch et al., 2000, 2005; Feldman & Bentin, 1994; Feldman et al., 1995; Frost et al., 1997; Frost et al., 2005; Velan et al., 2005). Studies using the masked priming paradigm in Hebrew reported that robust priming effects were induced by roots (Deutsch et al., 1998; Frost et al., 1997) and verbal patterns (Deutsch et al., 1998) but not by nominal pattern (Frost et al., 1997). In Arabic, a recent study by Shalhoub-Awwad and Leikin (2016) using a cross-modal paradigm in second and fifth grade children and showed that the root induced a priming effect when shared in both verbal and nominal patterns, suggesting that the root plays an important role in the processing and representation of Arabic words. Shalhoub-Awwad (2019) showed also that nominal word patterns facilitated lexical decisions, although in terms of accuracy only but not in response speed. However, in a large series of studies, robust priming effects were reported by the three morphological morphemes: root (Boudelaa & Marslen-Wilson, 2001, 2005; Frost et al., 2005), verbal pattern (Boudelaa & Marslen-Wilson, 2001, 2005) and nominal pattern (Boudelaa & Marslen-Wilson, 2001, 2005, 2011). However, Boudelaa and Marslen-Wilson (2005) have suggested that identification of the consonantal Arabic root occurs earlier than identifying word-pattern. Based on such empirical data stressing the important role morphology plays in the organization of the mental lexicon in Arabic, the model conceptualized by Boudelaa (2014) proposed that all content words in Arabic undergo a process of "obligatory morphological decomposition" (OMD) by which their roots and word patterns are accessed as lexical entries.

In addition to the studies using classical priming paradigms, other investigations relied on eye movement tracking techniques. In particular, eye tracking shows that information a reader can extract is not limited to the fixated word, but extends to the next one or two words. This is because readers can allocate their attention independently from gaze position, so that the process of word recognition often begins before fixating on the foveal word (i.e., in the parafovea). This attention allocation is script-dependent: to the right in English (Rayner & Pollatsek, 1989) and to the left in Hebrew (Pollatsek et al., 1981). Due to the early information extraction from the parafovea and thus the partial activation of the mental lexicon, the integration of the foveal information (i.e., the fixated target word) is facilitated, as evidenced by the "boundary technique" that measures the parafoveal preview benefit effect (Rayner, 2009). Here, the subject fixates a central point while a prime word is simultaneously placed in the parafovea. When the participants' eye passes an invisible boundary, located between the fixation point and the prime word, a target word replaces the prime word. This replacement occurs during saccade execution and is thus not perceived by participants due to saccadic suppression (Rayner, 2009). The advantage here is that in contrast to the masked priming paradigm, which uses a rather "artificial experimental manipulation", the parafoveal preview mimics the processes of word recognition in natural reading conditions (Deutsch et al., 2000). Studies on Hebrew using the parafoveal preview benefit effect reported similar findings to those obtained using the masked priming paradigms (i.e., namely robust priming effects by the root and the verbal pattern but not by the nominal pattern), suggesting that both techniques might tap similar cognitive processes in word recognition (Deutsch et al., 2000, 2003, 2005).

Considering the fact that the parafoveal preview benefit effect is a technique which mimics more natural processes of word recognition, the current research used this technology to examine the extent to which the different morphological classes of Arabic (i.e., root, verbal pattern, and nominal pattern) facilitate word recognition/reading processes. For this purpose, all the three morphological classes were examined within the same participants, allowing thus to compare facilitation effects across the same readers. This design is thought to provide more reliable findings by reducing the impact of interfering factors such as inter-individual differences and by improving comparability of the different morphological structures. Unlike previous studies on Arabic which relied exclusively on lexical decision tasks, the naming task used in the current study implies phonology and pronunciation, two aspects that have yet to be implemented in studies on reading. Given the fact that each type of tasks (i.e., lexical decision and naming) can tap different aspects of reading performance (Katz et al., 2012), both tasks have been used in other languages and were shown to provide complementary results (e.g., Deutsch et al., 1998; Frost et al., 1997). In this regard, this study was predicted to provide new insights into the existing literature on Arabic, and allow strong conclusions concerning the role of the different morphological structures in Arabic word recognition. Based on previous studies, we hypothesized that the presentation of the three morphemic units in the parafovea would facilitate reading of the foveally presented words. This facilitation should appear as priming effect for morphologically related words as compared to unrelated ones.

II. METHODS

A. Participants

A group of 60 native speakers of Arabic participated in the current study. Twelve participants were excluded due to eye tracker related problems (e.g., long eye lashes, insufficient calibration accurateness, or excessive blinks). Hence, 48 participants ($M_{\text{age in years}} = 21.8$, $SD = 2.3$; 25 males) were finally included in the analysis. All of them were right handed (self-declared) students at the University of Haifa and participated for payment (50 NIS) or for course credit. Participants with corrected vision (either with glasses or contact lenses) were not invited to participate. None of the participants suffered from psychiatric or neurological disorders or from any form of learning impairment.

B. Design and Stimuli

Three experiments for three morphological classes (i.e., root, verbal pattern, and nominal pattern) were designed and carried out by each participant. In each experiment, all prime words were length-matched with their corresponding targets words (see Table 1 for examples). Three conditions in each of the experiments were created in which each target word was paired with one of three different prime types. In the Identical Condition (IC) the target word was the same as the prime word. This condition aimed at triggering the maximal expectable priming effect, referred to also as repetition priming. In the Morphologically Related (MR) condition the target word shared the same morphological structure/or root with the prime word. In the unrelated Control Condition (CC) the target word shared no morphological relation with the prime. Only the MR condition varied in each experiment as shown in detail below and illustrated in Table 1.

In the first experiment, Root priming, the target words were nominal forms that shared the same tri-consonantal root with the prime word, but within a different word pattern. In the second experiment, target words were verbs that shared the same Verbal Pattern with the prime word, but with a different root. Here, all targets were conjugated with one of five different verbal patterns that were inflected on the basis of past, singular, masculine form (see Table 1). In the third experiment, the target words were nouns that shared the same Nominal Pattern with the prime word, but with a different root. All targets were declined into one of five different nominal patterns that are common in modern standard Arabic. Since targets and primes appeared without any textual context that would normally provide hints about phonology, all stimuli were partially vowelized. That is, one short vowel was added in order to avoid ambiguity concerning the meaning and/or pronunciation of words.

TABLE 1
EXAMPLES FOR STIMULI IN THE THREE EXPERIMENTS VARYING THE MORPHOLOGICAL CLASSES AND THE PRIME TYPES

	Target	Prime type		
		CC	**MR**	**IC**
Root	بستان */busta:n/* (garden)	**دخول** */duχu:l/* (entering)	إدخال */ʔidχa:l/* (inserting)	**إدخال** */ʔidχa:l/* (inserting)
Verbal pattern	**تأليف** */taʔli:f/* (composition)	امتنعَ */ʔimtanaʕa/* (prevented)	احترمَ */ʔiħtarama/* (respected)	احترمَ */ʔiħtarama/* (respected)
Nominal pattern	**تقليص** *$/taqlis^{ʕ}/$* (shrinking)	**مزرعة** */mazraʕa/* (farm)	مكتبة */maktaba/* (library)	**مكتبة** */maktaba/* (library)

For the selection of the words and in order to control for words' familiarity, a questionnaire was filled in by 15 native

Arabic speakers. They were asked to rate a list of 900 words on a five-point scale (1 for not familiar and 5 for very familiar). The average familiarity for each word was then computed, and on the basis of items analysis, that allowed removing problematic items (i.e., either items with very low familiarity, or items with large response variance etc.) the final list was constituted with highly familiar words (mean familiarity >4).

Each experiment contained 69 target words associated to one of three prime types (i.e., 23 words per prime type). In order to avoid stimulus repetition (e.g., the same target word primed by an identical word and again by a morphologically related word), three stimulus lists (A, B, and C) were created. These lists contained the same target words, but the prime-target association varied. Participants were allocated to one of the three lists randomly so that 19 participants were tested on list A, 15 participants on list B, and 14 participants on list C. Also, in order to avoid any list effect, stimuli in each list were controlled for the parameters: familiarity, word length, number of phonemes, and number of syllables. There were no significant differences in any of these parameters as indicated by one-way ANOVAs performed on these measures (see Table 2).

TABLE 2
DESCRIPTIVE STATISTICS (MEANS AND SD) FOR THE CHARACTERISTICS OF THE THREE LISTS OF WORDS

Item characteristics	**Lists**				
	A	**B**	**C**	***F***	***p***
Word familiarity	4.7 (0.2)	4.7 (0.2)	4.7 (0.2)	0.01	.98
Word length	4.3 (0.4)	4.3 (0.4)	4.3 (0.4)	0.00	1.00
Number of phonemes	6.2 (1.3)	6.2 (1.3)	6.2 (1.3)	0.00	.99
Number of syllables	2.5 (0.7)	2.5 (0.7)	2.5 (0.7)	0.03	.97

C. Procedure

Before running the experiments, participants were asked to read the instructions presented on the screen in Arabic and to accomplish 18 training trials to ensure a full understanding of the task demands. The order of the three experiments was varied to allow using one of six possible combinations to avoid order effects, while the order of the stimuli was randomized for each participant and list.

Participants were seated at a distance of 50 cm in front of a computer screen (LG Flatron L226WTQ, 22 inch diagonal, screen resolution 1440 x 900 pixels, refresh rate 75 Hz) with their head leaning on a forehead-rest. Since the participant's response demanded oral naming, a chin rest was not used. Eye movements of the right eye were recorded by an SR-Research Ltd. (Canada) EyeLink 1000 tower-mount eye-tracker; however, vision was binocular. The oral response was recorded by a highly sensitive condenser microphone (AKG perception P170, Austria; pre-amplified through a Behringer Xenyx 1002FX, Germany). In addition, a low latency sound card (Creative Soundblaster X-Fi, Singapore) ensured an accurate timing of the sound recording.

Stimulus presentation was accomplished through the Experiment Builder software (SR-Research, Canada). All stimuli were presented on a grey background (RGB 180, 180, 180). After an initial calibration and validation with a standard nine-point grid, the participants were asked to fixate a point that was placed in the center of the screen (i.e., drift check). When the experimenter observed a stable fixation on the drift check position, the trial start was initiated manually through button press. The sound recording started, the drift check point changed into a plus sign (comprising 0.34 ° visual angle) and simultaneously the prime word (font: regular New Courier, size 12, black, covering on average 1.6 ° visual angle per word, located on the left at a distance of 2.5 degrees between the plus sign and the first character of the prime word) appeared on the screen. One character space to the left of the plus sign an invisible boundary was located. As the participants' eye passed this boundary, a target word replaced the prime word. This replacement occurred during saccade execution and was thus not perceived by participants due to saccadic suppression. Participants were instructed to name the then foveally presented stimulus (i.e., to read aloud the target word; see Figure 1).

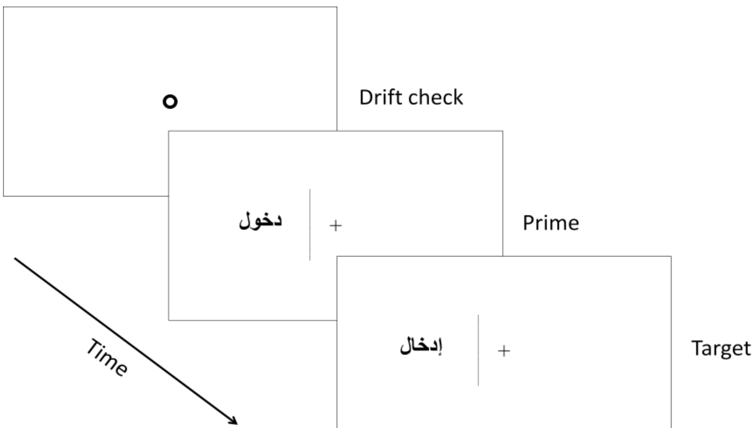

Figure 1. An example for a trial sequence; the grey vertical line represents the invisible boundary and was thus not visible to the participants.

One second after voice onset (detected by the voice trigger of the Experiment Builder), the sound recording stopped; the target word disappeared and a drift check point was presented on the screen, indicating the preparedness for a new trial. Before a new trial was initiated, the quality of calibration was examined and recalibrations were conducted if a deviation from the drift check position by more than one degree was evident.

D. Data Analysis

The DataViewer analysis software (SR-Research, Canada) was used to extract the eye tracking parameters for the time of boundary crossing, fixation durations and blinks. In addition, markers indicating the exact start of the sound recording were extracted, which allowed the alignment of the oral response to the appearance of the visual stimulus. To ensure that participants could benefit from the parafoveally presented prime, trials in which participants crossed the invisible boundary prematurely (i.e., earlier than 10 ms after trial onset) as well as trials containing blinks in the critical period between appearance of the prime and voice onset were discarded. The average of the discarded trials ranged from 21% to 25% of the whole stimuli, with no significant differences between morphological classes, p = .41, or between prime types, p = .73.

Voice onsets were marked and transferred into text files after visual and auditory inspection of the recorded sound files using the PRAAT software package (Boersma & Weenink, 2012). Response accuracy was also verified at this stage and trials containing incorrect responses were not included in further analyses. For each participant, the mean reaction time (RT) for correct responses (i.e., voice onset times from the presentation of the prime in ms) and the percentages of correct responses (accuracy) were computed for each experimental condition. Also, priming effects were determined for each participant as the difference between RTs to CC minus RTs to MR (i.e., morphological priming) and the difference between RTs to CC minus RTs to IC (i.e., repetition priming). The individual RTs and accuracy were then subjected to a repeated measures analysis of variance (ANOVA).

TABLE 3
DESCRIPTIVE STATISTICS (MEANS AND SD) FOR REACTION TIMES IN EACH OF THE MORPHOLOGICAL CLASSES AND PRIMING CONDITIONS TOGETHER WITH MEAN PRIMING EFFECTS

Conditions	**Morphological classes**		
	Root	**NP**	**VP**
IC	766 (88)	766 (83)	790 (80)
MR	777 (83)	785 (87)	797 (76)
CC	797 (95)	797 (82)	822 (82)
Repetition priming	31 (57)	31 (46)	32 (52)
Morphological priming	20 (55)	12 (44)	25 (42)

Abbreviations: NP = nominal pattern; VP = verbal pattern; IC = Identical Condition; MR = Morphologically Related; CC = Control Condition.

TABLE 4
DESCRIPTIVE STATISTICS (MEANS AND SD) FOR RESPONSE ACCURACY (%) IN EACH OF THE MORPHOLOGICAL CLASSES AND PRIMING CONDITIONS

Conditions	**Morphological classes**		
	Root	**VP**	**NP**
IC	98.3 (3.4)	98.5 (3.0)	97.6 (3.1)
MR	97.6 (3.4)	98.6 (3.0)	97.6 (3.1)
CC	97.2 (3.4)	98.5 (3.0)	98.2 (2.7)

Abbreviations: NP = nominal pattern; VP = verbal pattern; IC = Identical Condition; MR = Morphologically Related; CC = Control Condition.

III. RESULTS

The descriptive statistics of mean reaction times for each of the morphological classes and priming types are presented together with the mean priming effects in Table 3. A 3 × 3 repeated measures ANOVA was performed on the individual RTs using the morphological classes (root, nominal pattern and verbal pattern) and the prime types (IC, MR, and CC) as within participants' factors. It showed a significant main effect of morphological class (*F(2, 94) = 4.19, p <. 018, η2 = .082*). Bonferroni post-hoc tests showed that this effect was explainable by the fact that on average responses to verbal patterns (*M = 803 ms, SE = 10.7*) were slower than responses to nominal patterns (*M = 783 ms, SE = 11.6, p* = .061) and to roots (*M = 780 ms, p = .029*), with the later two not differing (p = 1). Also, there was a significant main effect of prime type (*F(2, 94) = 25.09, p = .001, η2 = .348*). Bonferroni tests showed that responses to IC were shorter (*M = 774 ms, SE = 10.5*) than to MR (*M = 786 ms, SE = 10. 4. p =.025*) and to the unrelated CC (*M = 806 ms, SE = 10. 8, p = 0.001*). Also, the difference between MR and CC was significant (p < .001, see Figure 2 also for illustration). No significant interaction was found between the morphological class and prime type factors (p = .71).

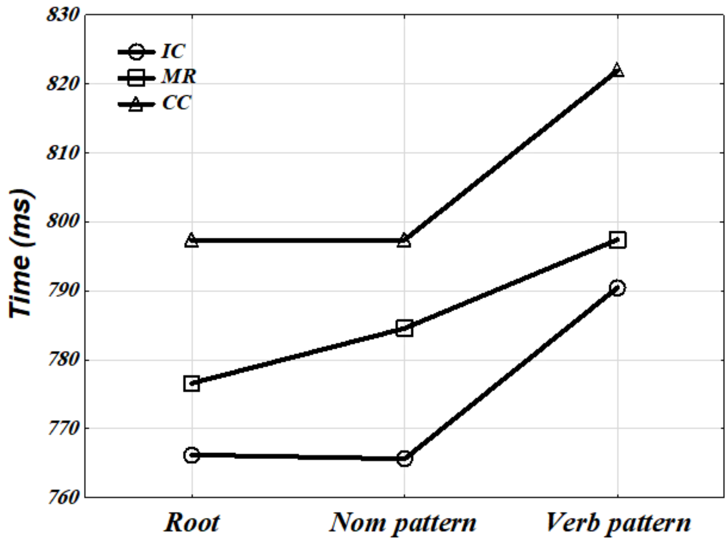

Figure 2. Mean of the participants RTs (in ms) by morphological class and prime type.
IC = Identical Condition; MR = Morphologically Related; CC = Control Condition.

The mean accuracy (percentages of correct responses) over participants and standard deviations for each of the morphological classes and priming conditions are presented in Table 4. The 3 × 3 ANOVA performed on the individual percentages of accuracy using the morphological class (root, verbal pattern and nominal pattern) and the prime type (IC, MR, CC) as within participants' factors showed neither significant main effect of class nor of prime type. Also, no interaction was found between the two factors.

In order to assess the extent to which the parafoveal preview influenced priming, a measure of the central fixation duration (i.e., the time participants spent fixating the cross and consequently perceived the prime parafoveally) was computed for each individual participant. A correlation analysis was then conducted between this measure (mean fixation time of each participant) with the individual size of the two priming effects, that is, repetition priming (*M* = 31.44, *SD* = 31.41) and morphological priming (*M* = 19.36, *SD* = 31.75, see Table 3). As illustrated in Figure 3, positive correlation was found between the fixation duration measure and the size of the priming effect both for repetition priming ($r = 0.349$, $p < 0.05$; A) and for morphological priming ($r = 0.314$, $p < 0.05$; B) showing that longer fixations were associated with stronger priming effects.

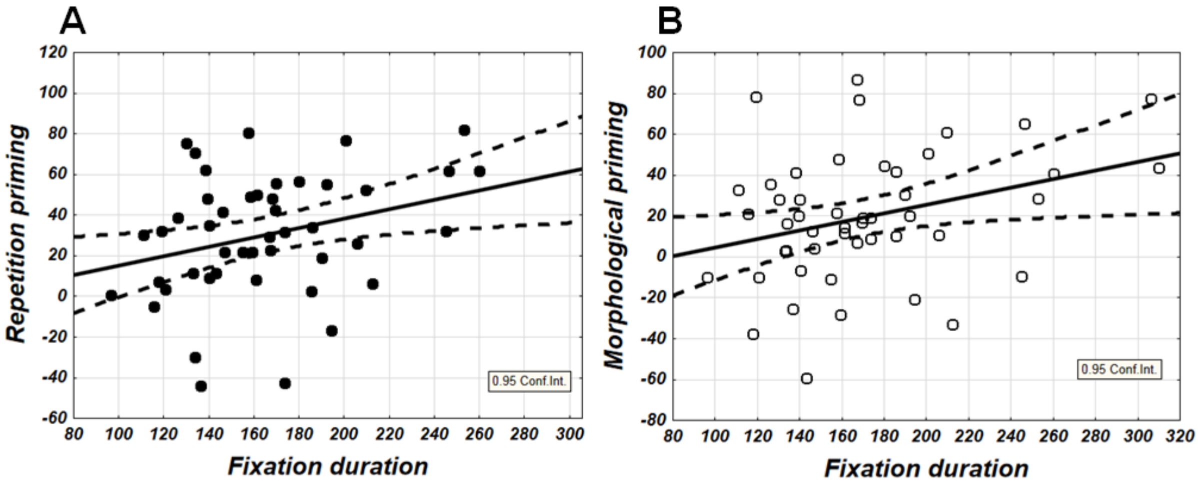

Figure 3. Scatter plot showing the correlation of fixation duration with A) repetition priming effect and B) with morphological priming effect in three experimental conditions.

IV. Discussion

The current study investigated how morphological structures affect visual word recognition in Arabic. For this purpose, we used the parafoveal preview method that closely mimics the natural reading process, and a word naming task. We assessed the effects of morphologically related prime words (in contrast to unrelated and identical words), presented parafoveally, on the identification of the foveally presented target words. Unlike earlier findings from Hebrew, the other Semitic language, these results clearly indicate that all three morphological classes contribute to word identification in Arabic.

A significant facilitation was obtained when a prime word shared the root letters with a target word. This finding is consistent with previous studies in Arabic using masked priming (Frost et al., 2005), incremental masked priming (Boudelaa & Marslen-Wilson, 2001, 2005) and cross-modal priming paradigms (Boudelaa & Marslen-Wilson, 2000, 2004; Shalhoub-Awwad & Leikin, 2016) and quite similar to findings obtained in Hebrew (e.g., Deutsch et al., 1998; Deutsch et al., 2000, 2005; Deutsch et al., 2003; Frost et al., 1997). This finding contradicts the earlier results in Arabic by Abu-Rabia and Awwad (2004) where priming effects were neither observed for roots nor for nominal patterns using the masked priming technique. Possible methodological differences between the current and the above-mentioned study might explain the discrepancy between these observations. These results are however in line with recent observations from a recent study using cross-modal paradigm by Shalhoub-Awwad and Leikin (2016) suggesting a central role for roots in both verbal and nominal patterns. All together our results strengthen the claim that in Semitic languages, root priming occurs even when the prime and the target belong to different syntactic categories, indicating that this morpheme functions as an abstract organizing unit of the lexicon.

The present findings demonstrated also that both nominal and verbal word patterns contribute significantly to Arabic word recognition. These results are also consistent with previous studies in Arabic using masked priming (Boudelaa & Marslen-Wilson, 2011), incremental masked priming (Boudelaa & Marslen-Wilson, 2001, 2005) and cross modal paradigms (Boudelaa & Marslen-Wilson, 2000, 2004). In line with previous observations, the present findings suggest that the word pattern morpheme constitutes an independent lexical entity that plays a crucial role in the processing of Arabic words. This finding highlights the difference between the two Semitic languages, since only verbal pattern (but not nominal pattern) seems to serve as an organizing principle of the lexicon in Hebrew (Frost et al., 1997). The strong role of the verbal system in Arabic and Hebrew is explainable through its relatively small size as compared to the nominal system. Its patterns form a grammatically closed system in the sense that no new members can be added to the group, and any verbal form in the language must be adapted in form to one of the existing patterns.

However, the question remains as to why nominal patterns act as an organized entity in the process of word recognition in Arabic but not in Hebrew? The word pattern is thought to convey the phonological structure and morpho-syntactic information but does not supply semantic information. Our findings however, challenge this view and suggest that the word patterns in Arabic supply semantic characteristics, since there is often a good deal of overlapping of meaning between the forms (Muhammad, 2006). Indeed, each of the verbal patterns in Arabic can be distinguished semantically from one another (Watson, 2002). Moreover, the semantic relations between the various patterns are much more restricted in the verbal than the nominal system in Hebrew but not in Arabic. In Arabic, although the group of the nominal patterns is huge, it seems that most nominal patterns are semantically transparent so that words that are derived from a given nominal pattern are semantically related to other words that share this nominal pattern. For example, the words <شارب> (/*ʃa:rib*/ for drinker, the one who drinks) and <كاتب> (/*ka:tib*/ for writer, the one who writes) belong to the same nominal pattern $C_1a{:}C_2iC_3$ that means "the doer of the action". Thus, beside the semantic information the root supplies, the nominal pattern seems to supply additional information about semantics. These effects should be ascribed to the productive character of nominal morphology in Arabic, and this result would constitute a genuine cross-linguistic difference between Arabic and Hebrew.

Since this is the first investigation in Arabic that used the parafoveal preview technique, it seemed necessary to demonstrate that the observed acceleration of word identification in the fovea can unequivocally be attributed to the presentation of a prime word outside of the fovea. When correlating the size of each priming effect (i.e., repetition priming and morphological priming) with the fixation duration on the fixation cross before crossing the invisible boundary, positive correlations were observed. These results indicate that prolonged parafoveal exposure to the prime resulted in stronger preview benefits. Accordingly, the parafoveal preview technique represents a valid technique for assessing priming effects also for studies using Arabic words.

However, our results also call for further investigations of individual differences in priming effect size. As shown in the correlation graphs, some participants clearly profited from parafoveal preview while others exhibited even prolonged reaction times albeit comparable fixation durations. Hence, the size of the preview effect was only partially explained by individual differences in fixation duration. Since parafoveal information extraction is considered crucial in natural text reading, future investigations of parafoveal benefit might uncover possible sources for reading impairments such as dyslexia.

Several unique and innovative aspects of this study should be emphasized. The first one is the level of comprehensiveness of the study design which examined the three morphological classes within the same participants, improving thus the comparability of the different morphological structures. The second aspect is related to the naming task used in the current study which implies the articulation aspect of reading. Given that each type of task can tap different aspects of reading performance, the results presented shed new lights on the existing literature on Arabic and allow for strong conclusions concerning the role of morphological structures in Arabic word recognition.

To summarize, the findings presented in this study demonstrated that the three morphological structures in Arabic could contribute to word recognition and thus support previous conclusions regarding the organization principles of morphologically complex words in the Arabic mental lexicon. In line with recent literature on the matter (Saiegh-Haddad, 2018), this study provided further evidence about the role morphology plays in reading Arabic.

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