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Root and Pattern Effects in the Processing of Spoken Non-Words in Arabic

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Abstract

Words in Arabic are formed by mapping roots into patterns. Conducting a series of priming experiments, Boudelaa and Marslen-Wilson (2015, p. 955) have concluded that "root and word pattern morphemes function as abstract cognitive entities, operating independently of semantic factors and dissociable from possible phonological confounds" In the present study, plausibility of this conclusion is tested by investigating native Arabic speakers' sensitivity to the presence of roots and patterns when processing spoken *non-words* in Arabic. 50 native Arabic speakers were given a 7-point word-likeness rating task. In this task, participants were asked to rate the word-likeness of 132 auditorily presented non-words in Arabic. 88 of these non-words were created by using real Arabic roots (e.g. /mlk/) that varied in their type and token frequencies and were mapped into two different types of pseudo patterns. Results have shown that native Arabic speakers are sensitive to the presence of roots in the non-words. Specifically, root type frequency had the strongest effect on subjects' ratings of the non-words in both types of patterns. Implications of these findings to theories of the Arabic mental lexicon will be discussed.

Keywords: Arabic, Morphological processing, Roots, Word patterns, Non-words

1. Introduction

Word formation in Arabic is achieved through mapping a root (a number of discontinuous consonants) into a pattern (i.e. a vowel template) (Holes, 1995). Whereas the root determines the semantic meaning of the word, the pattern creates the phonological structure of the word and specifies its morphosyntactic properties. To create a verb, the root is mapped into a verbal pattern and to create a noun the root is mapped into a nominal pattern. For example, the verb /qatala/ “he murdered” is created by mapping the triliteral root {qtl} into the active verbal pattern {faʕala} where the three consonants {fʕl} represent the root consonants (or are “place holders” for the root consonants in Boudelaa and Marslen-Wilson’s (2011) words). On the other hand, the noun /qa:til/ “murderer” is created by mapping the same root consonants {qtl} into the nominal pattern for the active participles {fa:ʕil}.

Studies in Arabic language have found that the root and pattern play a crucial role in word processing. Ample evidence for this role comes from studies conducted by Boudelaa and Marslen-Wilson (e.g. 2005; 2013; 2015). Using priming tasks these studies have maintained that lexical access in Arabic is characterized by a process of morphological decomposition of words into roots and patterns. For example, Boudelaa and Marslen-Wilson (2013) used an auditory priming task and showed that both standard and dialectal Arabic show similar root and pattern priming effects. Similarly Boudelaa and Marslen-Wilson (2015) used cross-modal priming experiments to investigate the processing of complex forms in Arabic. Three major subdivisions were compared: deverbal nouns, verbs and primitive nouns. Their findings were supportive of the view that the Arabic mental lexicon organization is based on the interaction between the root and word pattern. Specifically, they found out that the root and pattern will show priming effects and these are dissociated from any semantic or phonological effects.

However, verbal word patterns and nominal ones do not seem to have the same priming effects in all root-based languages. In other word, whereas both verbal patterns and nominal ones show priming effects in Arabic (e.g. Boudelaa & Marslen-Wilson, 2011), in Hebrew, on the other hand, it had been claimed that the organization and access of verbs is different from that of nouns (Deutsch, Frost, & Forster, 1998). This conclusion is driven by the findings of Deutsch et al. (but see Frost, Froster and Deutsch (1997)) that in visual word recognition whereas words sharing a verbal pattern prime each other those that share a nominal pattern do not. They partly attributed this effect to the relatively higher frequency of verbal patterns as compared to nominal patterns.

More recently, research within the root and pattern framework showed more interest into the role that statistical characteristics of the root play in processing. For instance, Boudelaa and Marslen-Wilson (2011) used masked and cross-modal priming experiments to look into the roles of word pattern and root productivity (family size or type frequency) in generating pattern priming in Arabic deverbal nouns. They found that pattern priming was reliant on the productivity of the root. In other words, for word patterns to prime they would have to appear “in the context of a productive root” (one with a big family or high type frequency). If this occurs, both verbal word patterns and nominal word patterns can prime in a comparable manner.

Similarly, using both Rapid Serial Visual Presentation and masked priming, Velan and Frost (2011) contrasted the visual word recognition of Semitic root-derived words in Hebrew with other Hebrew words that do not contain a root or have an internal structure (i.e. similar to words in stem-based Indo-European languages like English). They examined the effect of transposed-letter on the processing of these two types of words. They found out that these two types of words are processed and accessed differently. They specifically observed that whereas processing of root-derived word targets was inhibited by primes that contained transposed letters, processing of word targets that have simple structure (i.e. non root-derived) was facilitated by the primes with transposed letters. The authors took this finding as evidence for the availability of two parallel systems of lexical organization and access in Hebrew speakers. That is whereas root-derived words are organized by "neighborhood of root morphemes", words that have simple structure (i.e. non root-derived) are organized by orthographic neighborhoods similar to stem-based languages. Interestingly, when non-productive (pseudo-roots) were used in real word patterns the findings were inconclusive. This result provides further support for Boudelaa and Marslen-Wilson's (2011) suggestion that root productivity is an important factor in determining priming effects.

2. The Current Study

The current study aims to extend previous research by closely examining the role of the morphemic units (i.e. the root and pattern) in the processing of spoken forms in a Semitic language. Previous studies have predominantly used priming tasks using real words as primes and targets. However, research on other languages have shown that native speakers access and utilize different representations (lexical vs. sublexical) differently when processing words vs. non-words in speech recognition (Vitevitch & Luce, 1999). The current study aspires to find out what effects the root and pattern play in the processing of non-words in Arabic ruling out any possible confounds that may be involved in the processing of real words. Specifically, we want to answer the following research questions:

1- Does Arabic root have an effect on processing of spoken non-words in Arabic?

2- Does root frequency have an effect on processing of spoken non-words in Arabic?

3- Which type of root frequency (type frequency or token frequency) has a stronger effect on processing of spoken non-words in Arabic?

4- In which pattern (verbal pattern or nominal pattern) does the Arabic root have a stronger effect on processing of spoken non-words in Arabic?

2.1 Method

A seven-point word-likeness rating task was used in the current experiment to investigate whether there is an effect of root and pattern when processing spoken non-words in Arabic. In this task, subjects listen to auditorily-presented stimuli items (non-word) and they are required to rate the non-words depending on their perceived typicality of Arabic words. A translation into Arabic of the scale in (1) was used.

1- Very non-typical of Arabic 1 2 3 4 5 6 7 Very typical of Arabic

This task has previously been used to investigate the effect of different lexical factors on speech recognition by native speakers. These include the effects of phonotactic probability and syllable stress (Vitevitch, Luce, Charles-Luce, & Kemmerer, 1997), phonotactic probability and neighborhood density (Bailey & Hahn, 2001), and phonotactic probability and non-word length (Frisch, Large, & Pisoni, 2000). Not only has this task been used to investigate the effect of probability but it has also been used to examine the effect of legality on subjective ratings of non-word stimuli (Coleman & Pierrehumbert, 1997). Importantly, this task follows a very clear procedure and it grants subjects a relatively longer time compared to other online tasks such as the Lexical Decision task. Therefore, subjects' responses (i.e. ratings) in this task have been viewed to be predominantly governed by their sensitivity to the typicality of the non-word stimuli (Bailey & Hahn, 2001).

2.2 Participants

51 native Arabic speakers, all students at a Saudi university, took part voluntarily in the experiment. Participants were all male (mean age = 19 years). None of the participants reported a history of speech or hearing problems.

2.3 Stimuli

To answer our research questions, four conditions were created by mapping real roots and nonexistent roots into pseudo verbal and pseudo nominal patterns. Creating the pseudo patterns maintained the same method of manipulation across all conditions and items; that is, replacing the geminated (doubled) second root consonant in the verbal pattern {tafaʕʕal} and in the nominal pattern {tafaʕʕul} (where the three consonants {fʕl} represent the root consonants) with the third consonant (i.e. {tafaʕlal} and {tafaʕlul}, respectively). This produced non-word pairs in Arabic as in /tamalkak/ and /tamalkuk/. The other 44 stimuli were non-words with no real Arabic roots.

In the first condition, 44 Non-word stimuli were created by mapping real Arabic roots into pseudo verbal patterns. For example, the root {ʕlm} was mapped into the pseudo verbal pattern {tafaʕlal} producing the non-word /taʕalmam/; hereafter we refer to this condition as real root in a verbal pattern (RRVP) condition. In the second condition, 44 other non-word stimuli were created by mapping the same roots used in condition 1 into the pseudo nominal pattern {tafaʕlul} (e.g. the root {ʕlm} was mapped into the pseudo nominal pattern {tafaʕlul} producing the non-word /taʕalmum/; hereafter we refer to this condition as real root in a nominal pattern (RRNP) condition.

Two other conditions were used for comparison. In the third condition, 22 non-word stimuli were created by mapping nonexistent roots into the same verbal pattern used in condition 1. For example, the nonexistent root {lhr} was mapped into the pseudo verbal pattern {tafaʕlal} producing the non-word /talahrar/; hereafter we refer to this condition as non-root in a verbal pattern (NRVP) condition. Finally, in the fourth condition, 22 non-word stimuli were created by mapping the same nonexistent roots used in condition 3 into the same nominal pattern used in condition 2 (e.g. the nonexistent root {lhr} was mapped into the pseudo nominal pattern {tafaʕlul} producing the non-word /talahrur/); hereafter we refer to this condition as non-root in a nominal pattern (NRNP) condition.

Type and token frequencies for real roots were calculated using Aralex database www.mrc-cbu.cam.ac.uk:8081/aralex .online/login.jsp (Boudelaa & Marslen-Wilson, 2010).

In addition, positional and biophone phonotactic probability of the non-words were calculated using the online phonotactic probability calculator for Arabic (Aljasser & Vitevitch, 2018).

This method of stimuli creation enabled us to control different variables which have been shown to affect non-word processing. These include the number of phonemes and syllables. Specifically, all non-words in all conditions had eight phonemes and three syllables. Moreover, due to the pattern chosen, the initial phoneme /t/ is held constant across conditions.

The stimuli items were spoken in isolation and recorded by a male native Arabic speaker in an anechoic chamber using a high-quality microphone on to digital-audio-tape at a sampling rate of 44.1 kHz. The recordings were then saved as digital 16- bit files on a computer disk.

2.4 Procedure

The total of 132 non-word stimuli items were put in three randomized lists with all 132 items in each. The participants were divided into three equal groups each taking one of the three randomized lists. A language computer lab was used for the experiment presentation. Each group was tested one at a time. Each participant was seated in a computer booth equipped with headphones. Participants were instructed that they will listen to non-words and that their task is to rate how similar (typical) these are to Arabic words. All participants' inquiries were answered prior to the start of the experiment. Prior to the stimuli presentation, each participant received five practice trials. These trials were used to familiarize the participants with the task and were not included in the final data analysis. Two 3-minute breaks were provided for each group.

2.5 Results

Recall that we had four different conditions:

1- Real root in a verbal pattern (RRVP).

2- Real root in a nominal pattern (RRNP).

3- Non-root in a verbal pattern (NRVP).

4- Non-root in a nominal pattern (NRNP).

Table 1. Mean ratings and standard deviations (SD) for the four conditions

Condition	Mean rating	SD
RRVP	4.31	0.54
RRNP	4.37	0.63
NRVP	3.11	0.49
NRNP	3.23	0.57

Analysis of Variance (ANOVA) showed that between conditions' ratings were significantly different $p < .0001$. Six separate t-tests were then conducted between each two conditions. These showed that ratings for RRVP and RRNP conditions were not statistically different $p > .05$. Similarly, NRVP and NRNP conditions were not statistically different $p > .05$.

However, t-tests showed that both RRVP and RRNP ratings were significantly higher than NRVP and NRNP ratings.

Regression analysis was conducted on the three independent variables: type frequency, token frequency and phonotactic probability to find out the variable that had the strongest effect on ratings. This showed that root type frequency had the strongest significant effect in both verbal patterns $p = 0.011$ and nominal ones $p = 0.008$

2.6 Discussion

In the current study, we set out to explore the effect of the root and pattern on the processing of spoken Arabic. However, unlike previous studies that predominantly used priming tasks with real words as primes and targets, the current study explored this effect on the processing of non-words. The choice of non-words was mainly motivated by two reasons: Firstly, in the processing of real words other semantic or phonological confounds might be involved. Those can either inflate or reduce the effect of the root and pattern. Secondly, it has been shown that in the processing of words and non-words the lexical and sub-lexical representations are accessed and used differently (Vitevitch & Luce, 1999). We therefore aimed to test whether the effect of root and pattern would remain in the processing of non-words. Four research questions were formulated which for the sake of convenience are repeated here:

1- Does Arabic root have an effect on processing of spoken non-words in Arabic?

2- Does root frequency have an effect on processing of spoken non-words in Arabic?

3- Which type of root frequency (type frequency or token frequency) has a stronger effect on processing of spoken non-words in Arabic?

4- In which pattern (verbal pattern or nominal pattern) does Arabic root have a stronger effect on processing of spoken non-words in Arabic?

Our findings indicate that the answers for the first two research questions are affirmative. Non-words with real roots embedded had higher ratings than non-words with pseudo-roots. Not only were our Arabic speakers sensitive to the presence of real roots in the non-words but they additionally showed sensitivity to the frequency of the root. Specifically, root type frequency had the strongest effect on word-likeness ratings. These findings suggest that root effects in Arabic spoken word recognition are very robust and are beyond any other phonological or semantic factors that are involved in the processing of real words. This converges very closely with the findings from other studies on Arabic that used real word stimuli mainly utilizing priming experiments (e.g. Boudelaa & Marslen-Wilson, 2011; 2015).

For example, Boudelaa and Marslen-Wilson (2011) found that prime and target sharing a root strongly primed each other. This was evident in both visual and auditory presentations of the stimuli. This was interpreted by the authors as reflecting a decompositional process whereby the root shared is identified and accessed. The current findings provide further support for this conclusion. That is, even when roots were embedded in non-words, clearly ruling out any semantic factors, the auditorily-presented stimulus was decomposed and the roots were accurately identified and accessed.

Interestingly, our Arabic speakers were particularly sensitive to the type frequency of the root. In other words, productive roots (i.e. those that appear in more words in Arabic) had the strongest effect on rating. This is in line with previous research using real word stimuli in Arabic. For instance, Boudelaa and Marslen-Wilson (2011) showed in both visual and auditory word processing that root productivity was the determining factor for word-pattern priming. In other words, word-pattern priming does not show unless the embedded root is productive. Similar to the current finding, their result particularly from the auditory prime, as Boudelaa and Marslen-Wilson observed provides strong evidence that lexical processing in Arabic revolves around the root.

Arguably, this is not specific to Arabic but seems to be characteristic of other Semitic languages. Letter-transposition priming studies on Arabic (e.g. Perea, Mallouh, & Carreiras, 2010) and Hebrew (Velan & Frost, 2007) show that keeping the root intact is a prerequisite for lexical access. Therefore, it seems safe to agree with the proposal that in Semitic languages "lexical space is structured according to the morphological roots, so that all words derived from a given root are clustered together" (Velan & Frost, 2007, p. 916).

This may provide a plausible explanation for the absence of pattern type effect in the current study. Recall that real roots were embedded in two different types of patterns: a pseudo verbal pattern and a pseudo nominal one. We found no difference between the ratings of these two different conditions. This is not unexpected given the findings of priming studies on Arabic. Unlike in Hebrew where only verbal word patterns can prime (Deutsch et al., 1998), in Arabic both verbal and nominal word patterns show priming effects provided that they appear in the context of a productive root (Boudelaa & Marslen-Wilson, 2011). In the current study, the same roots were used across the two pattern type conditions thus ruling out the effects that may arise as a result of the use of different roots. This again provides further evidence that our subjects were capable of detecting the real roots in the non-words. Obviously, this is not a mere root consonants' slots detection but rather a correct identification of the real root morpheme. That is because non-words where non-roots were embedded had lower ratings than those with real roots.

3. Conclusion

The current study provided further evidence that recognition of spoken forms in Arabic involves a process of decomposition of the form and identification of its morphemes. Obviously, this is beyond any phonological or semantic factors. This process revolves around the root morpheme and is guided by its distributional features. A theoretical description of Arabic mental lexicon capturing this process is needed. This account as Boudelaa and Marslen-Wilson's (2015, p. 977) conclude "needs to be able to represent underlying lexical elements as abstract morphemic units, where these representations abstract away both from the phonological features of their surface realisation as spoken forms and from the specific semantic properties of these forms .."

A final note of caution needs to be made about the nature of the methodology adopted in the current study and the implication of the results. The current study shows that when granted enough time (i.e. in the word-likeness rating task) native speakers managed to detect the roots embedded in the non-words. Future research needs to investigate whether such ability can be replicated when online tasks (e.g. Lexical Decision) are used.

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Note

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