# PHONOLOGICAL, SEMANTIC, AND ROOT ACTIVATION IN SPOKEN WORD RECOGNITION IN ARABIC: AN EYETRACKING STUDY

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## 1. Introduction

Spoken word recognition (SWR) is a complex process that includes the activation of word candidates based on the acoustic properties of an input, the selection of the word that best matches these properties, and finally the recognition of the selected word (Dahan and Magnuson 2006, p. 251). Throughout the literature on the SWR, researchers have investigated the nature of spoken word recognition in many languages and theorized different models of SWR, e.g., Marslen-Wilson and Welsh's (1978) Cohort model; McClelland and Elman's (1986) TRACE model; Norris's (1994) Shortlist model; and Luce and Pisoni's (1998) Neighborhood Activation Model (NAM). Despite the fact that these models provide different explanations of the mechanisms involved in the process of SWR, they all agree that the recognition of a spoken word involves activation and competition, and both phonology and semantics.

### 1.1 Spoken word recognition across languages

Previous studies using priming experiments (Marslen-Wilson and Zwitserlood 1989, Meyer and Schvaneveldt 1971, Slowiaczek, Nusbaum, and Pisoni 1987) and eye-tracking experiments (Allopenna, Magnuson, and Tanenhaus 1998, Apfelbaum, Blumstein, and McMurray, 2011, Huettig, Quinlan, McDonald and Altmann 2006, Mirman and Magnuson 2009, Yee and Sedivy 2005) have found evidence of phonological and semantic activation in word recognition. However, these findings have been mainly obtained from studies that have investigated Indo-European languages, which constitute a subset of the languages of the world, and hence might not accommodate all the lexical properties found in other languages. Note that content words in Indo-European languages can be morphologically simple (words consisting of one morpheme only, such as *dog*) or complex (words consisting of more than one morpheme, such as *dogs*). The majority of SWR studies have focused on morphologically simple words which consist of sequences of segments that carry both phonological and semantic contents. This differs from Semitic languages such as Arabic which have a non-linear morphological system. Words are constructed non-linearly by combining a consonantal root that conveys the general thematic meaning (e.g., ktb [writing]) and a pattern that conveys morpho-syntactic information (e.g., the past tense pattern: CaCaC) producing the word *katab* (write-PAST). Therefore, it can be said that Arabic content words are complex by nature and, apart from linearity, are more similar to complex words in Indo-European languages.

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### 1.2 Spoken word recognition of complex words

Complex word recognition has been investigated in many Indo-European languages to explore the influence of word-internal structure and morphology, and several hypotheses and models have been suggested. In other words, this body of research has investigated whether complex words like *teacher* are decomposed into two morphemic units (the stem: *teach* and the suffix *–er*) or processed as a whole word. This line of research has provided several hypotheses and approaches that can be summarized into three types of models. First, whole-word models (e.g., Butterworth 1983, Tyler, Marslen-Wilson, Rentoul, and Hanney 1988) take a continuous, non-decompositional approach to word processing that assumes that words in the mental lexicon are stored and processed as whole-words. Second, decompositional models (e.g., Taft 1981, Taft & Forster 1975) assume that the mental lexicon is morphologically structured and hence complex words are parsed into its morphemic units. Third, dual route models (e.g., Marslen-Wilson, Tyler, Waksler, & Older 1994, Wurm 1997) assume that both a full form route and a full parsing route are combined. However, the latter comes to play only after the first is completed. That is, the parsing route is a backup when a word is rare but morphologically regular and orthographically transparent (Baayen, Dijkstra, & Schreuder 1997, Gwilliams & Marantz 2015, Ussishkin, Dawson, Wedel, & Schluter 2015).

### 1.3 Word recognition in Semitic languages

Despite the fact that previous research on SWR in Arabic is sparse, there is a well-established line of research on VWR in both Arabic and Hebrew. Using a variety of priming experiments, these studies investigated the effect of the Semitic root and pattern as distinct morphemic units in lexical access. Several studies on the visual modality in Hebrew (e.g., Deutsch, Frost, and Forster 1998, Frost, Deutsch, Gilboa, Tannenbaum, and Marslen-Wilson 2000, Frost, Forster, and Deutsch 1997) have investigated the effects for both the consonantal root and word pattern. They found that primes that share a root or a word pattern with a target facilitate lexical access to both nouns and verbs, however, the facilitatory priming effect of the consonantal root was stronger and more robust. Therefore, these authors claim for the important role of the root in lexical access in Hebrew and argue that it must be a part of any model of VWR in Hebrew. Similar results were obtained from a series of studies on VWR in Arabic using masked priming methodologies (Boudelaa and Marslen-Wilson 2011; Boudelaa and Marslen-Wilson 2001, 2004, 2005). These studies provide support for the effect of the consonantal root in lexical access in Arabic nouns and verbs, with stronger effect when primes and targets share the same consonantal root and have a transparent semantic association.

Turning to auditory processing in Semitic languages, Boudelaa and Marslen-Wilson (2000) and Ussishkin, et al. (2015) are the only known studies that have investigated phonological, morphological, and semantic activation in Arabic and Maltese, respectively. The results of these studies highlight the importance of the consonantal root as a distinct morphological unit in Arabic and Maltese, and they confirm previous findings from the visual modality in both Arabic and Hebrew. They also provide further support for models of morphological processing that allow morphological decomposition (Marslen-Wilson et al. 1994, Taft 1981, Taft and Forster 1975, Wurm 1997).

As a group, the studies reviewed above show that there is ample evidence for the consonantal root in both visual and auditory processing and lexical access in Semitic languages. To further investigate the effect of the consonantal root, the current study aims to use the VWP with eye-tracking to explore SWR in Arabic. The VWP is a valuable methodology to investigate phonological, semantic and morphological effects in lexical access (Allopenna, et al. 1998, Apfelbaum et al. 2011, Huettig et al. 2006, Mirman and Magnuson 2009, Yee and Sedivy 2005). One advantage of VWP is that it does not require metalinguistic decisions from participants. It is also a valuable methodology to explore the timecourse of subtle competitor effects in SWR and hence can provide insights into the mental processes involved in language comprehension, including the earliest processes (Allopenna et al. 1998, Tanenhaus, Spivey-Kowlton, Eberhard and Sedivy 1995).

The main goal of this study was to investigate whether Arabic words derived from the same consonantal root are linked in the mental lexicon and hence are co-activated in SWR. However, as Arabic words derived from the same root share both phonological and semantic properties, it is difficult to determine whether the effect comes from the root as an independent morphemic unit or whether the effect come from the phonological and semantic overlap between these words. Therefore, it is important to also examine phonological and semantic overlaps in SWR in words that do not belong to the same root.

## 2. The Experiment

### 2.1 Participants

Participants were 31 adult native speakers of Arabic who were recruited from the Saudi Students Club in Ottawa (3 females, mean age = 23 years) All participants had Arabic as their L1 and English as their L2. All participants reported having normal or corrected-to-normal vision, normal hearing, and no reading issues. Three additional participants were tested, but the data was not included due to poor calibration measurements. All participants were compensated with $10.

### 2.2 Stimuli

Stimuli were fifteen quadruplets of Saudi Arabic nouns comprised of 15 target words, 15 phonological competitors (also called cohort competitor, which were words that start with the same two segments of the target words, but did not belong to the same root and were not semantically related to the target words), 15 semantically competitors (not phonologically related to the target), and 15 root competitors (words that belong to the same consonantal root and share the same onset). An additional 30 unrelated words were selected. Stimuli were recorded by a male native speaker of Saudi Arabic.

### 2.2.1 Familiarity ratings as a measure of word frequency

Due to the unavailability of a word frequency counts for Saudi Arabic, a familiarity rating task was developed and completed on-line by 30 participants recruited from the Saudi Students Club in Ottawa which is affiliated to the Cultural Bureau of the Embassy of Saudi Arabia (9 females, mean age = 28 years). None of these participants completed the actual experiment. Participants rated the words based on how often they hear and/or read the words. The rating scale was as follows: (1) I do not know this word, (2) I know this word but never encountered it, (3) I know this word but rarely encounter it, (4) I know this word and sometimes encounter it, (5) I know this word and I usually encounter it. Only words that were rated 3.5 or above were used in the study.

### 2.2.2 Visual stimuli rating

The visual stimuli were cliparts taken from free commercial clipart databases and online image banks. Images were selected to be as prototypical as possible, based on Saudi Arabian norms. All images were presented to 5 native speakers of Arabic also recruited from the Saudi Students Club. These participants also did not complete the experimental study. They were shown the images and asked to describe each image with one word. They were also instructed to write the first two names that came to mind, if an image could be described by two names. Images were used in the study if they were named correctly by 3 out of 5 individuals. In fact, all images were named correctly by at least 4 out of the 5 individuals, except for two images. These two images were replaced by other images and shown to the same individuals and 5 other individuals who named them correctly.

### 2.2.3 Semantic ratings

A semantic relation rating task was conducted to make sure that only the semantic competitors and root competitors were semantically related to the target. Fifteen participants were recruited from the Saudi Students Club (9 females, mean age = 28 years). They were asked to evaluate the semantic association between each target word and each word that appeared with that target in the same display. The rating scale was as follows: (1) no connection, (2) remote connection, (3) moderate connection, (4) strong connection, and (5) the first immediately brings the other to mind. Only words that had a mean score of 4 or above were included in the semantic word group. The semantic association between targets and their counterparts in the root group ranged from 1 to 5 with a mean of 2.86. Semantic associations between the target words and their counterparts in the phonological group, and unrelated groups were all rated 1 (no connection) indicating no semantic association.

## 2.3 Procedure

Participants were tested in one session, which lasted 30 to 40 minutes. The experiment was presented in a sound-attenuated booth. Eye movements were recorded using a chin rest with the Eyelink 1000 (SR Research Ltd., Canada). Monocular recording was performed using participants' dominant eye (determined by the Miles-Test). The eye-tracker was calibrated using a 9-point calibration grid, at a sampling rate of 500 Hz, and all participants had calibration validity measurements less than 1.00 degree visual angle. Drift correction was performed between every trial in the form of a central fixation dot to account for shifts in eye position.

For each trial, four images appeared on the screen (Figure 1). An auditory stimulus of the target word was played 500 ms into the trial. The auditory stimulus was an isolated word, i.e., not included in a carrier sentence. Participants were instructed to click on the target word using a mouse in their dominant hand. Participants received colour feedback upon clicking on an image (red for incorrect responses, green for correct responses). All trials consisted of a target word (e.g. 'mudarris', teacher), a competitor related to the target word (e.g. root competitor 'madrasah', school), and two unrelated distractors (e.g. 'ʃaʕar', [hair] and 'ṭamatim', [tomato]). The location of the 4 images was randomized across trials. Each target word was presented 3 times, in the presence of the 3 different types of competitors, but no target word appeared twice in a single block. That is, the 15 target words were presented visually and auditorily in each block, however, 5 of them appeared with phonological competitors, 5 with semantic competitors, and 5 with root competitors in Block 1. 10 filler trials were added to each block resulting in 25 trials per block. The same targets were presented in Blocks 2 and 3 but with different types of competitors. Repeating primes and targets have been found to cause block effects due to strategic processes used by participants such as guessing or picking the goals of tasks (Dufour 2008) Therefore, it was possible that a block effect might be found over the course of the study because of this organization. However, as this is a new paradigm for investigating root processing in Arabic, a block designed was used to collect as much data as possible for the initial study. Analyses were run to test for the possibility of block effects.

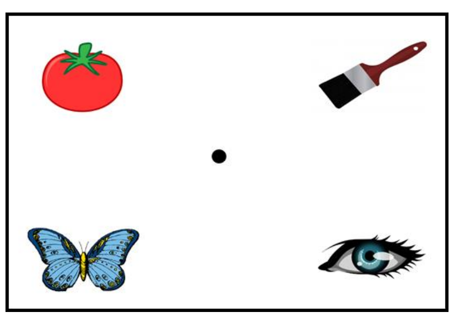

Figure 1: Example of a typical trial display. Target: furʃah 'brush' , root competitor: faraʃah 'butterfly' and unrelated: ṭamaṭim 'tomato' and ʕajn 'eye'.

Before beginning the experimental task, participants completed 5 practice trials to assure compliance with the task instructions. Proportional fixation times to the four areas of interest were automatically recorded and later analyzed with DataViewer software (SR Research, version 1.11.1).

## 3. Results

This section reports and discusses the results of the two types of data that were collected: proportional eye fixation data and RT data. The fixation data were analyzed by looking at the amount of fixation directed to different images in each display across the different test trials. The RT data were analyzed by measuring the time between the onset of the spoken target word and the time at which the participant clicked on the target image (one of four images). The results of these analyses are discussed below.

### 3.1 Fixation Results

A python script was used to extract the fixation data from word onset + 1000 ms, using 100 ms time bins. Consistent with how eyetracking data are analyzed in the field, individual participant data in a time bin was excluded if there was no fixation to any of the four interest areas. Practice trials and fillers were not included in the analyses.

#### 3.1.1 Growth Curve Analyses

A Growth Curve Analysis (GCA: Mirman 2014, Mirman, Dixon, and Magnuson 2008) was used to analyze differences in target fixations across conditions. Fixations to targets were predicted because the task required the participants to click on the image that matched the spoken word; however, a graded competition effect was predicted to result in difference in fixation proportions to targets across the three conditions. That is, fixation proportions to the target would be affected by the presence of phonological, semantic, and root related competitor. The plot in Figure 2 shows the participants' fixation proportions to targets across the three conditions based on the proportional data in the 0-1000 window. Fixations to the target in the root condition were the lowest, whereas fixations to the phonological were the highest. Fixations to the phonological competitor did not differ from fixation to the unrelated distractor (not shown). This entails that participants' fixation proportions were not much affected by the presence of the phonologically related competitors, however, they were affected by the presence of a root-related competitors and semantically related competitors.

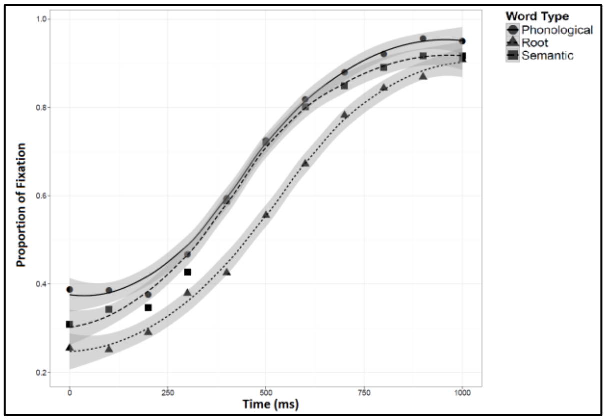


Figure 2: Proportion of fixation directed at targets in the phonological, semantic and root conditions.

In order to investigate the differences between the three conditions, a quasi-logistic GCA method (Mirman 2014) was used to analyze the time course of target fixation across conditions. As the data are categorical in the sense that the target is either fixated or not, the empirical logit transformation (Barr 2008) was used to accommodate the categorical nature of the data. The analyses show the intercept of fixation proportion as well as the linear, quadric and cubic orthogonal polynomials. The intercept term is sensitive to the average overall fixation proportion across the time course. The linear (first-order) term reflects monotonic changes in fixation proportion. The quadric (second-order) term is sensitive to the rise and fall of fixation curve (increase then decrease in fixation proportions). Finally, the cubic (third-order) term is sensitive to the minor changes in the 'asymptotic tails of the fixation proportion curves' (Mirman, et al. 2008, p. 1030). The following sections report the three quasi-logistic GCA used to compare target fixations between the phonological condition and semantic condition; between the phonological condition and root condition, and lastly between the semantic condition and root condition, respectively.

### 3.1.2 Target Fixation of phonological vs. semantic Conditions

Results showed that target fixations were more affected by the presence of semantic competitors that by the presence of phonological competitors. Thus, targets were recognized faster when in the presence of phonological competitors than when presented with semantic competitors. A significant difference was found between the target fixation proportions across the time course between the two conditions. The difference was captured with the intercept (Est = -0.34, SE = 0.13, p = 0.01) resulting in an asymmetric difference in the average height of curves. The type of trial also produced a significant interaction with the quadratic polynomial. There were no other significant effects reflecting faster recognition of targets in the phonological conditions than in the semantic condition.

Figure 3 below shows that the difference in target fixations was very small around the 400 - 600 ms window. This indicates that semantic activation in SWR can start before listeners hear the whole word. The results confirm previous findings suggesting parallel access of semantic information in SWR, that is, it occurs simultaneously with phonological access (not after phonological access is completed), however, can be delayed depending on the amount of phonological activation (Apfelbaum et al. 2011, Zwitserlood 1989).

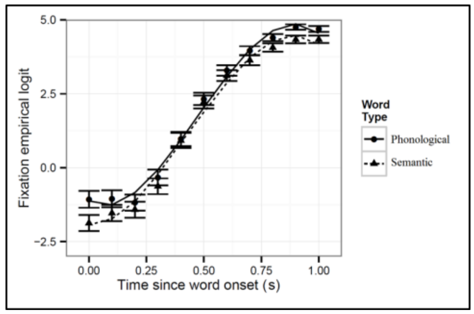


Figure 3: Target fixation in phonological condition vs. semantic condition

### 3.1.3 Fixation of phonological vs. root targets

Figure 4 shows target fixation proportions in the phonological and root conditions. We can observe that target fixations were more affected by the presence of root competitors than by the presence of phonological cohort competitors. There was a significant effect of condition (fixation of phonological vs. root targets) overall (Est = -1.17, SE = 0.12, $p < 0.001$). In addition, target fixation was captured with a first order (linear) term (Est = 0.87, SE = 0.30, $p < 0.01$) reflecting an overall increase in target fixation proportion in the phonological condition relative to target fixation proportion in the root condition, as well as a steeper linear relationship for target fixation in the phonological condition compared to the root condition.

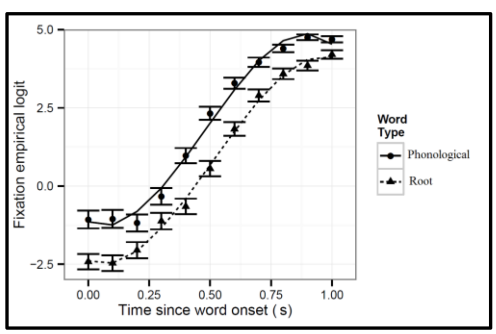


Figure 4: Target fixation in phonological condition vs. root condition

### 3.1.4 Fixation of semantic vs. root targets

Comparison of target fixations in semantic and root conditions using the same GCA methods showed that target fixations were affected by the presence of root competitors more than by the presence of semantic competitors. Therefore, targets were recognized faster when there were semantic competitors present than where there were root competitors present. The difference was captured by the intercept (Est = -1.67, SE = 0.22, $p < 0.001$) and the quadratic terms (Est = 2.28, SE = 0.58, $p < 0.001$) (Figure 5). These results provide support for previous findings (Boudelaa and Marslen-Wilson 2000, 2001, 2005, 2011; Deutsch et al. 1998; Frost et al. 1997, 2000). They also confirm the results obtained above from the comparing target fixations in phonological vs. root conditions which revealed more fixation proportion to root targets.

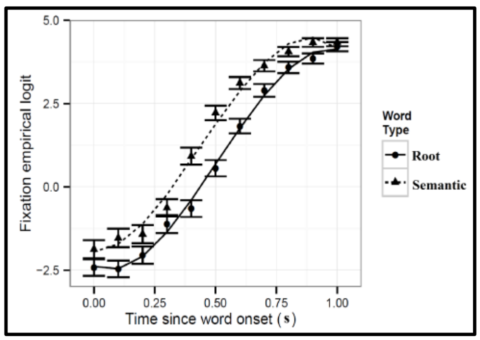


Figure 5: Target fixation in semantic condition vs. root condition

## 3.2 RT Results

Data from the test trials of all the 31 participants were included, however, trials were excluded on which a software error occurred as the system failed to record the timing of the onset of the spoken word, when participants gave incorrect responses, and RTs that were ± 2 SD from the condition mean. The total percentage of the trials trimmed was 4.3% (by condition: 1.37% phonological; 1.23% semantic, 1.71% root).

Figure 7 below which presents the data broken down by block (recall that there were 3 blocks), it can be observed that the mean RTs changed across blocks (3 blocks) for the three different conditions (phonological, semantic, and root). A block x trial type repeated-measures analysis of variance was performed on RTs, with three levels in each factor (3 blocks x 3 conditions). The results confirmed our observation (see Table 1) as they show that there was a significant effect of block, no significant effect of trial type, and a significant block x type interaction

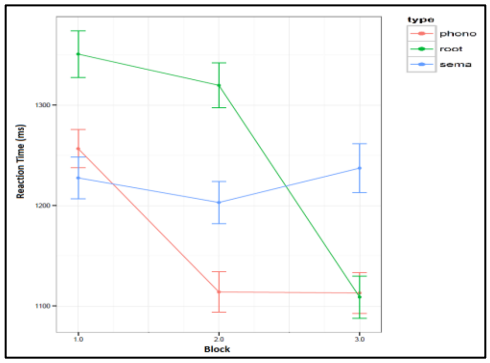


Figure 7: Plot of interaction of block and condition for all data.

The significant interaction prompted an examination of simple main effects. Thus, the effect of block on each trial type was separately analyzed for the phonological, semantic, and root conditions. These analyses show significant main effects of block on both phonological and root trials, but not on semantic trials. Recall that each target was presented 3 times across the course of the experiment.

Table 1: Summary of ANOVA for block by trial-type interaction

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| block | 1.00 | 1643867.83 | 1643867.83 | 26.40 | 0.00 |
| type | 2.00 | 224821.65 | 112410.82 | 1.81 | 0.16 |
| block:type | 2.00 | 515044.53 | 257522.27 | 4.14 | 0.02 |
| Residuals | 1246.00 | 77579930.06 | 62263.19 | | |

The main effect of block could be a reflection of strategic processes used by the participants. It is possible that the organization of trials encouraged participants to generate response strategies based on repeated phonological, semantic, and root overlap between targets and competitor. That is, the repetition of the same target in every block might have caused some participant to notice the relationship between the target and its related competitor over repeated representations.

### 3.2.1 Block 1 data analysis

Due to the aforementioned changes in RT data across blocks, the remaining analyses focused only the data from Block 1 only. Moreover, to be consistent, fixation analyses were repeated using only the data from Block 1. The fixation results of Block 1 data were similar to the results obtained from data collapsed across all three blocks and hence, these results are not explained further.

RT analyses based only on the data from Block 1, however, show different results than when using all 3 blocks. Participants took longer to respond to root targets than to phonological or semantic targets (see Table 2). In addition, participants took longer respond to phonological targets in this analysis compared the previous analysis of the three blocks. It seems that the results were affected by the fact that the same target was repeated three times across the study and that participants developed some strategic plans that resulted in the drop of RTs for the phonological condition.

Table 2: Summary of RT means and standard deviations across trial types (Block 1).

| | Type | Mean | St. D. |
|---|---|---|---|
| 1 | Phonological | 1256.84 | 229.55 |
| 2 | Root | 1350.97 | 258.26 |
| 3 | Semantic | 1227.67 | 249.48 |

Pair-wise comparisons of levels of trial types were used because in the Block analysis presented in 3.2, there was a statistical significant block x type interaction. Below is a summary table showing the results of the pair-wise comparisons. The Dunnett-Tukey-Kramer test used to compare the means between the different levels of trial types. This test was appropriate because there were unequal numbers of trials in each block and trial type (see Table 3 and Figure 9).

Table 3: Dunnett-Tukey-Kramer test.

| | Diff | Lower CI | Upper CI |
|---|---|---|---|
| root-phono | 94.14 | 22.76 | 165.52 |
| sema-phono | -29.17 | -96.38 | 38.05 |
| sema-root | -123.31 | -197.19 | -49.42 |

In the Dunnett-Tukey-Kramer test, the pair-wise test is significant if zero is not in the range of confidence intervals (CI) values. The results of this test, then, show that there is significant difference between RT to targets in the phonological and root conditions. There is also significant difference in RT between the semantic and the root conditions. Finally, there is no significant difference between RT to targets in the phonological and semantic condition. Figure 12 below illustrates these results.

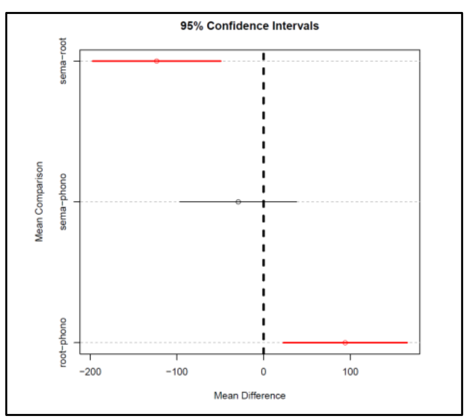


Figure 9: Pair-wise comparisons of RT data across test conditions

The RT results of Block 1 showed that participants took longer time to click target images when presented with root competitors than when presented with phonological or sematic competitors. They took the shortest time to click on target images when presented with phonological competitors. In terms of average RTs, these results were similar to the results obtained from the three blocks.

## 4. Discussion

This study was conducted to investigate phonological, semantic, and root activation in Arabic SWR. Adult participants were tested on the recognition of 15 Arabic words that were presented with three types of related competitors, namely, phonological, semantic, and root competitors. The first goal of this study was to explore whether the presence of related competitors (phonological, semantic, and root) would affect the proportion of fixation to targets. Participants' fixation results showed graded competition effects of the related competitor across the three conditions. This confirms previous findings that have found similar graded competition for related competitors based on the amount of linguistic overlap (Huettig and Altman 2005, Huettig et al. 2006, Mirman et al. 2008, Yee and Sedivy 2005). The second goal of the current study was to explore if there were significant differences in the proportions of fixations to targets among the three conditions. The fixation results from data collapsed across all three blocks and from just Block 1 showed that there were significant differences between the proportions of fixation to the target among the three conditions. The comparison between target fixations in the phonological and semantic conditions revealed that targets in the phonological conditions were recognized faster than in the semantic condition. The comparison between target fixations in the root and semantic conditions and in the root and phonological conditions revealed that targets in the semantic and phonological condition were recognized faster than in the root condition. This suggests that root-related competitor caused the largest effect on the recognition of targets. Targets in the root condition received the lowest fixation which may reflect higher the degree of competition in the root condition than in the other conditions. This was expected as root competitors shared both phonological and semantic properties with targets.

The last goal was to explore whether there were significant differences in RTs to targets among the three conditions. There was a significant block by condition effect. Therefore, the RTs were analyzed again based on data from Block 1 alone. Results showed that there were significant differences in RTs to the target between the root condition and the phonological condition, and between the root condition and the semantic condition. Participants took longer time to click target images when presented with root competitor than when presented with phonological or sematic competitors. Unlike with the eyetracking data, there was no significant difference in the RT data between the phonological and semantic conditions.

The RT data raises issues that can be interpreted in different ways. The main effect of block can be attributed to the organization of trial presentation in this research and to the fact that only one experimental list was used in this study. The repeated presentation of the same targets (three times each) might have encouraged participants to use a strategic process as they became more familiar with the target images across the study. In addition, the stronger effect of root competitors can be attributed to a stronger competition in the root condition, due the fact that root competitors shared both phonological and semantic properties with targets. As a result, participants took longer to respond to targets in the root condition. The competitors in the other two conditions, on the other hand, had either pure phonological overlap or pure semantic overlap and hence the competition was smaller than in the root condition.

The significant difference between the phonological and semantic condition in the fixation data vs. the non-significant difference in the RT data can be attributed to the fact that eyetracking data may be more sensitive and fine-grained than RT data. However, it may also be a result of having more trimmed RT trials in the phonological and semantic condition compared to the root condition (3% phonological, 3.08% semantic, 2.67 root).

Over all, the phonological competitors had the least effect on both target fixations and RTs. This can be attributed to the weaker phonological overlap in the phonological condition (2-3 initial segments) and the stronger semantic overlap in the semantic condition and root condition. Although the amount of phonological overlap between the targets and the phonological competitor at the initial position was greater than that of the root competitors, the root competitors had larger phonological overlap overall. In addition, the root competitors had semantic relationship with the targets.

## 5. Conclusion

The results of this study show that the presence of root competitors caused the largest effect on both target fixation proportions and RTs. This is in line with previous findings that have found priming effect of root-related primes on target recognition in both spoken and visual word recognition in Arabic (Boudelaa and Marslen-Wilson 2005, 2000, 2001, 2011) and in Hebrew (Deutsch et al. 1998, Frost et al. 1997, Frost et al., 2000). They also provide support for models of morphological processing that allow morphological decomposition (Marslen-Wilson et al. 1994, Taft 1981, Taft and Forster 1975, Wurm 1997).

Being the first eyetracking study to investigate the effect of phonological, semantic and root activation in spoken word recognition, this research opens avenues for future eyetracking research. One avenue would be to explore the difference between transparent and opaque semantic relations of root related words. Boudelaa and Marslen-Wilson (2005) found that there is a priming effect for the Arabic consonantal root, even when the semantic relation between the target and the root-related prime is opaque. Although this finding was obtained from a different modality (visual word recognition) and using different methodology (priming), it is also expected that this issue can be tested using the visual world paradigm with eyetracking. These types of studies can also be extended to other Semitic languages such as Hebrew, Maltese, and Amharic as they could provide insights on the effect of the consonantal root in languages with rich and complex morphological systems. The same line of research could also be extended to the effect of word pattern in SWR by comparing same pattern competitors with different pattern competitors. Across these future avenues of eyetracking research, one may find more fine-grained results concerning the effect of the Semitic consonantal root and word pattern that cannot be obtained from other behavioral methodologies.

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