The Effect of Dots on Arabic Visual Word Recognition: A Psycholinguistic Perspective

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Abstract: ***The Arabic orthographic system is a rich system, owing to several properties of which is the use of dots to differentiate the various graphemes and thus recognize the different words. However, native speakers of Arabic cannot only read undotted words using context, but they can also read single undotted words. The current study examines the cognitive processes underlying the identification of single undotted words, that can be used to provide a cognitive basis for automatic identification of undotted words. Two experiments are designed, the first experiment is a masked priming lexical decision task. In which participants are presented with two words: a prime, an undotted word and a target, a dotted word. The relation between the prime and the target is manipulated. Participants are asked to respond whether the target is a word or not using two keyboard buttons, response time is recorded in milliseconds accuracy. The second experiment is a lexical decision task, in which two factors are conflicted, the number of dots and the word frequency. The results of experiment 1 showed that undotted primes can facilitate a dotted counterpart, only when the undotted primes are meaningless such as سرٮ. The results of experiment 2 showed a significant effect of word frequency and a facilitation for words with more dots that disagrees with the general principal that visual complexities induce a perceptual load. The several cognitive factors that contribute to single undotted words identification are discussed.***

Key words: ***Undotted Arabic words, Visual complexity, priming, word frequency, psychological models, Cognitive based computational approaches.***

1 INTRODUCTION

The study of graphemes properties and their identification is crucial for examining the cognitive system, the reading mechanism, and visual word recognition, especially in a language such as Arabic whereby the orthographic system is complex and unique. One distinctive property of the Arabic orthographic system is the use of dots to differentiate various graphemes, the former property is the focus of the current study, as will be specified in the following section.

Examining the properties of the graphemes and single words reading are important for various areas for instance educators, are concerned with the complexity of the written form of different graphemes and they can rule out the order of graphemes to which the learner can receive [1]. Investigating the graphemes properties is further important for computational linguistics, whereby it can aid the developing cognitive based models, thus boosting the computational language modeling on real cognitive basis, and lastly examining grapheme properties is crucial in probing the processes underlying visual word recognition. Such areas of interest are fundamental for semitic languages in general and Arabic in particular, as Arabic imposes a very complex orthographic system.

The Arabic orthographic system poses several challenges; the first is the use of a shallow orthography and a deep orthography via diacritization marks that represent short vowels. The second one is that each grapheme has several allographs depending on its position in the word. The third is that different graphemes are formed through varying the number of dots superimposed over the letter thus, the absence of dots raises graphemic ambiguity, making it more challenging to identify the grapheme. Surprisingly, native speakers cannot only read undotted text relying on the sentential context, but also undotted words. Early skilled readers of Arabic depended on undotted texts, and the interplay of dots was only recently developed. The cognitive mechanisms by which native speakers identify undotted words are the focus of the current study.

The role of the dot evolved from being a text separator marker to having a structural significance, such as in the case of Arabic. In Arabic different graphemes share a base form, and they are unique according to the number of dots as well as their position. Basically, the dot is the tiniest symbol used in writing. and it is considered as the oldest continuously used graph in history. It has been used in several notations such as numerical notations, currency notations, mathematical notations, musical notations, and URLs. In the ancient near east was the emergence of the dot. Around the mid-second millennium BCE, early semitic writing separated words by vertical stroke, around the same period, some transcripts used a three vertical dots. The vertical stroke was shortened until it became a single dot. By the end of the first millennium, the dot took on a structural function. In Semitic languages such as Arabic and Hebrew, some consonants started to resemble each other, since that the dot gained its structural function to differentiate two consonants. Arabic has 15 graphs to represent 28 consonants. For instance one graph is ٮ , a tiny stroke above the base line that represented five sounds /b t t̲ n y/, a combination of single and double, and triple dots are used supralinearly and sublinearly to account for the different phonemes [2-4].

2 THE CHARACTERISTICS OF ARABIC ORTHOGRAPHY

MSA is an inflected Semitic language that is written from right to left. MSA belongs to the Semitic family that also includes Hebrew, Amharic, and Maltese. MSA owes around 400 million speakers [5]. It is the language taught in schools and universities over the Arab world, it is used in media and formal settings as well. On contrary the colloquial variety is used for daily life conversation. The study of written Arabic in general and the visual features of letters in particular impose several challenges induced by the features of the Arabic writing system.

One important feature of the Arabic orthographic system is that it is a consonantal system all the letters are consonantal phonemes except for three, they function as the three long vowels of the language /aa, uu, ii/. The remaining three short vowels /a, u, i/ have no corresponding letters; instead, they are written as diacritical marks above or below the letter [6-8]. The written text can be shallow through superimposing diacritization markers over it. The orthography can also be deep through ignoring these diacritization marks thus raising several ambiguities in the text. The short vowels are written in instructional, religious texts, or children's books [9] but not in the texts used on daily basis. Readers at the age of 9 are usually given texts undiacritized and they rely on context to disambiguate and read skillfully [10]. The absence of short vowels leads to various heterophonic homographs [7], usually defined as words with one spelling, different pronunciations, and different meanings, such as كتب.

A second important feature of Arabic orthography is allography. The alphabet of MSA consists of 28 letters, 22 of which connect to the following letter and 6 letters connect to the previous letter. Arabic owes a unique writing system whereby graphemes have position dependent allographs, they vary based on their location in the word. 15 graphemes vary according to their position (isolated, initial, medial, and final). The voiceless pharyngeal (ح) is written initially, حي medially يحي andيح finally. The rest 13 graphemes maintain the same form regardless of their position in their sound sequence, but they can have ligature marks on their side. Graphemes connectivity affects visual word recognition [11-13] these indicated that Arabic readers show more errors in identifying words with semi connected letters than words with connected letters.

Allographs affect visual word recognition. [8] reported a series of priming experiments to investigate whether a target word is facilitated by a nonword transposed letter prime that doesn't cause an allographic change than a prime that does cause an allographic change. The results showed that the non-allographic transposed letter primes showed a significant facilitation than allographic transposed letter primes, indicating that Arabic readers rely on allographic variation during the early stages of orthographic processing.

The third feature of Arabic orthography is that it uses dots to mark different graphemes, such as,(ت ,ث ,ب A grapheme can have up to three dots superimposed over the grapheme thus creating a complex visual percept. Native speakers are capable of reading undotted text, with the aid of context. However, the same notion is even extended to single words reading. In such a case the undotted form has several possible words. For instance the form ٮٮٮ has several possible words such as بيت بنت نبت. Words are sometimes mistakenly written undotted in handwritten scripts or intentionally written undotted on social media to avoid content classification [5]. Readers cannot only read undiacritized words and sentences fluently, but they can also read undotted words and sentences.

Several questions are raised regarding how people determine to recognize undotted words such as, how does the reader recognize such a base form? Which word does the reader select? And what are the criteria for selecting one word over the rest? Is it ruled out by word frequency or the least complex orthographic visual form? How can readers retrieve a lexical entry when undotted? And What are the cognitive processes beyond reading undotted words? These questions are the main interest of the current study. Consequently, the aims of this study are to examine the capability of native speakers to recognize undotted Arabic words through presenting undotted words as masked primes (experiment one) and to investigate the cognitive and the processing strategies beyond that. To examine the effect of word frequency and the number of dots on visual word recognition (experiment two), the study aims to provide a cognitive framework for developing a cognitive AI model for automatic recognition of undotted words.

There are only few studies that tackles the effect of dots in Arabic. The only available studies on recognizing undotted Arabic words come from computational studies [5] striving to examine the effect of applying pre-trained Arabic language models on "undotted" Arabic texts. The increased interest in examining undotted Arabic comes from the increased rising behavior on social media whereby users intentionally remove consonantal dots so that they bypass content classification algorithms as having offensive content. Consequently, the current study can aid the recognition of undotted words whether they are mistakenly handwritten or electronically on purpose.

The current study achieves its significance since there is a gap in the available literature concerning undotted Arabic. It is considered as an early attempt to investigate the underlying processes beyond reading dotted words and trying to disclose if the dots affect the speed of recognition of Arabic words just as vowelization does. In addition, attempts to provide a framework for developing an AI model that is cognitively based aware of the word recognition process in general and undotted words in particular.

3 CHALLENGES IN ARABIC WORD RECOGNITION

In the sections that follow, we will review recent empirical findings that show how the properties of the Arabic language and the orthographic system that were just reviewed affect the identification of Arabic words. Consequently, we will conclude how the study of Arabic reading might guide future reading research and the development of more comprehensive models of reading.

The complexity of the Arabic orthographic system gave rise to various studies in different research areas. The available literature highlights the challenges imposed in the Arabic orthography in terms of three main aspects. The first aspect addresses how the Arabic orthography is more complex compared to other semitic languages such as Hebrew as well as Indo European languages such as English. [14] showed that unlike Indo European languages that rely heavily on grapheme phoneme conversion Arabic is more dependent on letter - based morpho - orthographic processing. On contrary [15] reported that Arabic and English readers follow the same strategies in learning to read, an initial "discrimination-net" phase, followed by a phonological-recoding phase, after which there is a gradual transition to an orthographic phase.

The second aspect addresses how the complexity of the Arabic orthography affects the mastering of the reading of Arabic in native speakers [10, 16]. Ibrahim [17] showed that Arab children showed low scores in reading achievements as compared to Hebrew speakers. The author claimed that the Arabic orthography is far more complex when compared to Hebrew or English. Each grapheme has several allographs depending on their placement in the word.

The third aspect addresses the effect of diacritization marks in lexical processing as well as its role in slowing the reading processes due to visual complexity [18]. The role of diacritics was examined in Arabic word identification using eye movements. [18] showed that skilled readers use diacritic marks if they are necessary to disambiguate a word; otherwise, the diacritic marks are regarded as redundant information. On contrary, [7] examined the effect of context and diacritization on the reading accuracy of poor and skilled Arabic readers, The results showed that both diacritization and contexts were important variables to facilitate word recognition in poor and skilled readers in Arabic. Moreover, Hermena, Liversedge [19] examined diacritization in parafoveal words, they showed that skilled readers generally rely on expectation and if a word is undiacritized readers map it to the most frequent printed form. To sum up, studies showed contradicting views regarding the role of diacritization, some view it as redundant information, that can only be used to disambiguate deep orthographic forms. However, this view seems an attractive one as native speakers of Arabic are used to read undiacritized texts as modern books, journals, social media do not involve diacritization marks. The other view emphasizes the role of diacritization, context, and expectancy in lexical recognition.

As previously mentioned, some studies showed that diacritization marks involve a more complex visual text hence slowing reading rate. The same notion might be extended to dots. Do dots provide a more complex visual text? or do they provide an integral part of the word identification process? Undisputable undotted words are more simple than dotted words, however they raise several lexical ambiguities, a similar notion can be found in deep orthographic words whereby undiacritized words raise several heterophonic homographs. Although undotted words raise several ambiguities, they might show speeded word recognition as ambiguity has a large facilitatory effect known over the literature as ambiguity advantage [20, 21]. Consequently, if undotted words are read faster this could be to their simpler form and ambiguity advantage effect.

4 THE DUAL ROUTE MODEL

The most influential model of reading is the dual route model [22], that speculates two routes to read by. A lexical route for reading familiar words which are processed as orthographic wholes and sent to the mental lexicon for meaning retrieval, consequently by passing most of the phonological analysis, and a sub lexical route that relies on phonological rules to establish grapheme phoneme conversion, the current route is predominant in reading new and unfamiliar words. Despite the importance of the former model in reading literature, the uniqueness of Arabic orthography must be put into considerations.

[15] examined the cognitive processes in learning to read Arabic, as it is unique for its orthographic structure, thus might involves a different cognitive process from those involved in English. However. They reported that learning to read Arabic is quite like reading English, and that three stages are involved. The first stage is discrimination net phase, in which children have a small sight vocabulary known as their reading words, children read through discriminating these words set based on partial orthographic cues, if for instance in this set only ballon contain ll then any word contains ll will be read as ballon, thus relying on the partial orthographic cue of ll. The second stage is phonological recoding phase, in which children have large auditory vocabulary and few sight vocabulary, children can make use of the auditory vocabulary to recognize a visual word. To apply the previous strategy, children make use of phonological recoding to apply grapheme–phoneme rules to convert print to speech, though these rules might be inaccurate with irregular words.

The third stage is the orthographic phase, it involves direct visual recognition as orthographic wholes. The current technique is fast as it recognizes words as orthographic wholes.

5 PROPOSING A TWO STAGE MODEL OF READING UNDOTTED BASE FORM

In the current study we propose a two-stage model for reading single Arabic words in general and reading undotted words in particular. The first stage relies on direct visual recognition as orthographic wholes depending on word frequency [15], whereby no effect is observed for visual complexities, if a word is mistakenly undotted, readers dot it based on the frequency of the nearest orthographic form.

Over the psycholinguistic literature, particularly in visual word recognition and single word reading word frequency is regarded as the most influential factor [23-26]. In reading single words we propose an initial effect for word frequency. When presenting undotted primes, the undotted base form might activate multiple lexical entries depending on the positioning and the number of dots, we suggest that readers initially rely on word frequency, thus reading the undotted form based on the most frequent dotted form. High frequency words are provided as a first response. At this point an important question is raised, what if the words have equivalent frequency or low frequencies, in such case readers rely on other cognitive and orthographic cues.

However, if the possible dotted words are low in frequency, instead, readers rely on several cognitive and orthographic cues. One of the possible cognitive cues is cognitive economy in which words with the minimal number of dots are retrieved first, for instance, both بلح ثلج are low frequency words, however participants read the undotted form as بلح, as it is more simple owing to the few imposed dots. In addition, readers rely on orthographic cues to provide appropriate dots, such as allograph frequency, in which dots are imposed based on the allograph with the higher frequency.

The former framework was triggered by the pilot study, in which 15 participants were presented with a set of undotted orthographic forms and they were instructed to write down the first word that come into their minds. The most highlighted observation is that participants wrote down the most frequent word more often. However, in most cases of equivalent frequency (two words with similar high or low frequency), participants were more prone to the simplest form with the minimal number of dots as well as the most common allograph.

6 THE CURRENT STUDY

The available literature on Arabic word identification indicates the complexity of the process of Arabic word recognition because of the visual complexity of the Arabic graphemes and allographs. Readers are required to count the number of dots imposed over and below the graphemes to discriminate the different letters, such as ب ت [1, 10, 27]. The capability of the native speakers to read undotted Arabic is incontrovertible. It represents challenges to reading models in general and reading Arabic in particular that relies on identifying the visual cues including dots and strokes. This study attempts to investigate the cognitive strategies and processes beyond reading undotted Arabic words. Several studies emphasize the role of context in reading [7, 28], however people are capable of reading single undotted words as well. Two strategies are proposed to read single undotted words, the first is the reliance on word frequency, whereby if the undotted orthographic form suggests several dotted words, readers select the most frequent dotted form. The second strategy is based on cognitive economy, whereby readers select the word with the minimal number of dots. Both approaches are tested in two lexical decision experiments. The first experiment uses the masked priming paradigm that takes part in subliminal perception and lexical decision task to engage lexical processing [8], whereas the second experiment uses merely a lexical decision task with two factors conflicted the frequency of the word and the number of dots imposed.

A. Data Collection

Words were collected from two main sources, the Hans Wehr dictionary of modern standard Arabic [29], and the International corpus of Arabic [30]. Words were conditioned to have an average length of 3 to 5 letters. Root repetition was avoided, owing to the significance of the Arabic triliteral root [31].

Two types of words were collected, words that are meaningless when undotted such as تربة and words that are meaningful when undotted such as سكر . 50 meaningful when undotted words were collected, for instance (سحر وشجر), and 140 pairs of words meaningless when undotted were collected. Words were excluded if they had more than two options, such as عطس has two options when dotted غطس عطش.

The orthographic frequency of each word was collected from Aralex [32]. Words were categorized as a low frequency word if its orthographic frequency is below 20, on the other hand words were categorized as high frequency word if its orthographic frequency is above 20. Words were controlled for their orthographic frequency, number of letters, and their root.

B. The Pilot Study

In order to select the final stimulus lists to meet the experimental criteria two pretests were designed. In the first pretest, 15 participants were asked to write down the first word that come into their mind when presented with an orthographic form. A total of 140 undotted words were presented in a list no time limit was required. The aim of the pretest was to proof the capabilities of the native speaker to read undotted words and to observe which word is first selected by the participants in case of an undotted form has several possible words when dotted.

The results of the pretests showed that participants relied on two factors when reading undotted orthographic forms. Word frequency and the number of dots imposed. Participants were more prone to graphemes such as (ح) than (خ), the word أحب was produced by all participants, but no one selected أخت as their first associate. One prominent difference is the orthographic frequency, in which the frequency of أحب is 15.87 whereas the frequency of أخت is 1.12. In another observation, most participants were prone to the word (محرج) than (مخرج), although (محرج) has significant lower frequency than (مخرج). Such bias by participants to select one form rather than the other might relates to the frequency of the grapheme itself as reported by [1] or the word frequency as suggested earlier.

In the second pretest, another 15 participants were guided to write down all the possible options of a given undotted form, no time limit was required. Participants took 25 minutes on average. The same 140 words previously used in the first pretest were also tested in the current pretest. This pretest aimed at recognizing the range of possible words a given undotted form can have. The current pretest was crucial to select forms with only two possible words for the main experiment.

C. Participants

A total of 70 participants, aged 20 to 24, were recruited to take part in the main experiment. All participants were literate MSA speakers who were undergraduate students in Alexandria university, faculty of Arts, phonetics and Linguistics department. All participants speak English as a second language, but Arabic is their first and dominant language. 35 participants took part in the first experiment, a masked lexical decision task, and 35 participants took part in the second lexical decision task.

7 EXPERIMENT 1: MASKED PRIMING LEXICAL DECISION

The first experiment examines the significance of dots in Arabic word recognition and investigates the capability of native speakers of Arabic to read words undotted. Both a lexical decision task and a masked priming paradigm were used. In a lexical decision task, participants are asked to respond whether the target is a word or not, (yes/no) response using two keyboard buttons. However, in masked priming paradigm participants are presented with a prime for a very brief duration (50 to 100ms) followed by a target stimulus on which a response is required. Masked priming affects subliminal perception also known as perception without awareness, even though primes are presented for very brief duration they are processed and affect target recognition [33]. In masked priming an undotted base form was used as a prime, presented for a very brief duration, 100ms and followed by a target word, upon which participants were instructed to respond with a word / nonword response. The undotted primes were created using undotted application available on: https://dotless.app/. A lexical decision task was used to collect responses. Stimuli were controlled for the number of letters and orthographic frequency. The average number of letters was from 3 to 5. The orthographic frequency was collected from ARALEX [32] as shown in table I.

TABLE I
THE ORTHOGRAPHIC FREQUENCY AND THE AVERAGE NUMBER OF LETTERS FOR EACH STIMULUS TYPE.

	Meaningless when undotted			**Meaningful when undotted**		**Baseline**		**Nonwords**	
	Prime	Target list1	Target list2	Prime	Target	Prime	Target	prime	Target
Word length	3.4	3.4	3.4	3.3	3.3	3.5	3.5	3.5	
Orthographic frequency		6.3	5.9	4.7	4.7	4.7			

Three types of trials were created; each trial consists of a prime followed by a target. Primes were undotted, followed by a dotted target word. The primes were of two types; unmeaningful when undotted such as; بربه and meaningful when undotted such as سحر . The first type of trial consists of a meaningless prime followed by a meaningful target that have the same orthographic structure. The second type of trial consists of a meaningful undotted word followed by a meaningful dotted counterpart, and the third type of trial consists of an undotted orthographic form followed by a target unrelated form that were used as baselines. Fifteen trials of each type were used in addition to forty-five nonwords to run a lexical decision task. The nonwords were created by changing one or two letters of a meaningful word. 45 undotted nonwords were used as primes and 45 dotted nonwords were used as targets, a sample of the trials is shown in table II. Two lists were constructed and were run between subjects. The only difference between the two lists lies in the set of meaningless primes when undotted as different targets were used for each list, for instance in list 1 the prime بربه was used as a prime followed by تربة in list1, and برية in list2, as shown in table III.

TABLE II
SAMPLE STIMULI USED IN EXPERIMENT 1

Prime		Word	Target
1.	Meaningless undotted	ٮرٮه	برية barii:h
2.	Meaningful undotted	حرس ħaras ‹guard’	جرس ʒaras ‹bell’
3.	Unrelated	حلٮ	نوم nau:m ‹sleep’
4.	Nonword	مسلل *musalal	مشلل *muʃalal

Note Examples are in Arabic script with a transliteration and English gloss where appropriate (the asterisk indicates a nonword).

TABLE III
STIMULI USED IN LIST1 AND LIST2

	List1	**List2**
Prime	**Target**	**Target**
ٮرٮه	برية	تربة
سرٮ	شرب	سرب
ٮاح	تاج	باح
حڡل	حفل	حقل
محرڡ	مجرف	محرف
ٮاڡه	ناقة	باقة
محٮوم	محتوم	مختوم
عرٮٯ	عريق	غريق
حرٯ	حرق	خرق
حطٮ	حطب	خطب
دره	درة	ذرة
ٮمل	ثمل	نمل
سكٮ	سكب	سكت
رحٮ	رحب	رجب
ٮال	نال	بال

The current experiment examines the effect of dots on visual word recognition. The study investigates the effect of using undotted primes on the speed of target recognition. The main assumption is that if participants are capable of reading undotted words, then undotted primes should facilitate the recognition of the targets. Consequently, we should observe facilitation for pairs such as ٮرٮه and برية. If words are primed by the orthographic forms, then we should observe facilitation for pairs such as حرس and جرس, whereby the only significant difference is the number of dots imposed as well as the meaning. However, if the priming effect (average response time) for the targets preceded by meaningless undotted prime is comparable to the targets preceded by meaningful dotted prime then readers can benefit even from the undotted forms to prime the dotted word. Readers can activate a dotted word from through the undotted prime. The facilitation from undotted primes, if found minimizes the role of dots in Arabic word reading.

Each trial contained a fixation point (+), that was presented for 500ms, followed by a prime that was presented for 200ms a target was then presented for 2000ms or until the participant responded. Participants were asked to respond quickly and accurately as they can. They were asked to respond with “l” for a word and “a” for a nonword.

Participants were tested in a quiet room; each participant was tested individually. The experimenter explained the instructions. They were then given 12 training trials: 6 words and 6 nonwords before starting the main experiment. The experiment lasted for 15 minutes on average.

A. Results Experiment1; List1

The analysis of data focused mainly on the effects of dots on word recognition, the effect of meaningful undotted primes and meaningless undotted primes were compared relative to unrelated undotted primes. The reaction time (RT) and error data were analyzed using the standard by subjects and by items approach. The analysis was run using SPSS and was based on RTs from correct trials. Mean response times were trimmed by removing trials smaller than two hundred milliseconds or greater than two thousand milliseconds were excluded from the analysis. Mean lexical decision latencies of target words and nonwords are presented in table IV. Targets preceded by meaningless primes showed faster RTs (740ms) than targets preceded by meaningful primes that had the longest RTs (783ms), targets preceded by unrelated primes serving as the baselines showed (742ms). Consequently, according to the mean response time of the three groups reported in list1, targets preceded by meaningless primes showed 2ms facilitation, however targets preceded by meaningful primes showed significant inhibition (-41ms) when compared to unrelated baselines.

TABLE IV
MEAN RESPONSE TIME AND ERROR RATE (STANDARD DEVIATION)

Word Type	**RT**	**ER**	**Facilitation effect**	
			RT	**ER**
Meaningful	783 (86.6)	0.105(0.124)	-41	0
Meaningless	740 (86.5)	0.667(0.673)	+2	-0.5
Unrelated	742 (73.5)	0.105 (0.021)		

A series of one-way ANOVA's by subjects (F1) and by Items (F2) was run on the RT data with Word Type (Meaningful, Meaningless, and Unrelated) as within subject variable as shown in tables V,VII. The results showed a reliable Word Type effect by subjects [F1 (1.7, 31.495) = 5, p<0.05] but not by items [F2 (2, 42) = 1.26, p>0.05], thus documenting an effect of the undotted primes on the recognition of the targets. Further planned pairwise comparisons showed a significant difference between meaningless primes and meaningful primes (p= 0.027), whereas no other difference is significant as shown in tables VI,VIII.

TABLE V
UNIVARIATE ANALYSIS, BY ITEMS, LIST1

Univariate Tests
Dependent Variable: RT

	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Contrast	17269.378	2	8634.689	1.269	.292
Error	285891.200	42	6806.933		

The F tests the effect of conditions. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

TABLE VI
MULTIPLE COMPARISONS BY ITEMS

Pairwise Comparisons
Dependent Variable: RT

(I) conditions	**(J) conditions**	**Mean Difference (I-J)**	**Std. Error**	**Sig.[a]**	**95% Confidence Interval for Difference[a] Lower Bound**	**Upper Bound**
meanful	**Meanless**	**42.333**	**30.126**	**.502**	**-32.792**	**117.458**
	Unrelate	**40.733**	**30.126**	**.551**	**-34.392**	**115.858**
meanless	**Meanful**	**-42.333**	**30.126**	**.502**	**-117.458**	**32.792**
	Unrelate	**-1.600**	**30.126**	**1.000**	**-76.725**	**73.525**
unrelate	**Meanful**	**-40.733**	**30.126**	**.551**	**-115.858**	**34.392**
	meanless	**1.600**	**30.126**	**1.000**	**-73.525**	**76.725**

Table VII
REPEATED MEASURES, BY SUBJECTS ANALYSIS, LIST1

Tests of Within-Subjects Effects
Measure: MEASURE_1

Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
conditions	Sphericity Assumed	22292.316	2	11146.158	5.017	.012
	Greenhouse-Geisser	22292.316	1.750	12740.390	5.017	.016
	Huynh-Feldt	22292.316	1.923	11594.056	5.017	.013
	Lower-bound	22292.316	1.000	22292.316	5.017	.038
Error(conditions)	Sphericity Assumed	79979.018	36	2221.639		

	Greenhouse-Geisser	79979.018	31.495	2539.400		
	Huynh-Feldt	79979.018	34.609	2310.914		
	Lower-bound	79979.018	18.000	4443.279		

TABLE VIII
MULTIPLE COMPARISONS BY SUBJECTS ANALYSIS

(I) conditions	(J) conditions	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	42.842*	14.642	.027	4.201	81.483
	3	41.000	17.841	.101	-6.086	88.086
2	1	-42.842*	14.642	.027	-81.483	-4.201
	3	-1.842	12.996	1.000	-36.139	32.455
3	1	-41.000	17.841	.101	-88.086	6.086
	2	1.842	12.996	1.000	-32.455	36.139

Parallel analyses of the error data revealed the Word Type to be significant by subjects and Items analysis as shown in tables IX,XI, [F1 (1.6, 30) = 8.1 $p<0.05$; F2 (2, 42) = 4.995 $p<0.05$]. Besides, pairwise comparisons among the 3 levels of Word Typed showed a significant difference between meaningful and unrelated (p= 0.000). No other comparisons were significant as shown in tables X, XII.

TABLE IX
ERROR ANALYSIS, LIST1, ITEMS ANALYSIS

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.068[a]	2	.034	4.995	.011
Intercept	.166	1	.166	24.423	.000
Conditions	.068	2	.034	4.995	.011
Error	.286	42	.007		
Total	.521	45			
Corrected Total	.354	44			

a. R Squared = .192 (Adjusted R Squared = .154)

TABLE X
ERROR ANALYSIS, LIST 1, PAIRWISE COMPARISON

(I) conditions	(J) conditions	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
meanful	Meanless	.039	.030	.622	-.037	.114
	Unrelate	.095*	.030	.009	.020	.170
meanless	Meanful	-.039	.030	.622	-.114	.037
	Unrelate	.056	.030	.209	-.019	.131
Unrelate	Meanful	-.095*	.030	.009	-.170	-.020
	Meanless	-.056	.030	.209	-.131	.019

Table XI
ERROR ANALYSIS, LIST1, BY SUBJECTS

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
meaningfulness	Sphericity Assumed	.086	2	.043	8.199	.001
	Greenhouse-Geisser	.086	1.673	.052	8.199	.002
	Huynh-Feldt	.086	1.824	.047	8.199	.002
	Lower-bound	.086	1.000	.086	8.199	.010
Error(meaningfulness)	Sphericity Assumed	.189	36	.005		
	Greenhouse-Geisser	.189	30.112	.006		
	Huynh-Feldt	.189	32.836	.006		
	Lower-bound	.189	18.000	.011		

TABLE XII
ERROR ANALYSIS, LIST1, PAIRWISE COMPARISON

Pairwise Comparisons
Measure: MEASURE_1

(I) meaningfulness	(J) meaningfulness	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	.039	.022	.306	-.021	.098
	3	.095*	.019	.000	.044	.146
2	1	-.039	.022	.306	-.098	.021
	3	.056	.028	.182	-.018	.130
3	1	-.095*	.019	.000	-.146	-.044
	2	-.056	.028	.182	-.130	.018

B. Results: Experiment1; List2

The analysis of data focused mainly on the effects of dots on word recognition, the effect of meaningful undotted primes and meaningless undotted primes were compared relative to unrelated undotted primes. The reaction time (RT) and error data were analyzed using the standard by subjects and by items approach. The analysis was run using SPSS and was based on RTs from correct trials. Mean response times were trimmed by removing trials smaller than two hundred milliseconds or greater than two thousand milliseconds were excluded from the analysis.

Mean lexical decision latencies of target words and nonwords are presented in table XIII. Targets preceded by unrelated primes showed faster RTs (778ms) than targets preceded by meaningful primes that had the longest RTs (853ms), targets preceded by meaningless primes serving as the baselines showed (834ms). Consequently, according to the mean response time of the three groups reported in list1, targets preceded by meaningless primes showed -56ms inhibition, and targets preceded by meaningful primes showed significant inhibition (-75ms) when compared to unrelated baselines. Generally, List 2 showed longer response time when compared to list1, besides, both targets preceded by meaningful primes and meaningless primes are slower than targets preceded by unrelated primes.

TABLE XIII
AVERAGE RESPONSE TIME (STANDARD DEVIATION) FOR DIFFERENT WORD TYPE

Word Type	RT	ER	Facilitation effect RT	Facilitation effect ER
Meaningful	853 (95)	0.578(0.055)	-75	-0.489
Meaningless	834 (98)	0.089(0.234)	-56	0
Unrelated	778 (82)	0.089 (0.023)		

A series of one-way ANOVA’s by subjects (F1) and by Items (F2) was run on the RT data with Word Type (Meaningful, Meaningless, and Unrelated) as within subject variable as shown in tables XIV, XVI. The results showed a reliable Word Type effect by subjects [F1 (1.85, 25.9) = 10.7, p<0.05] but not by items [F2 (2, 42) = 2.641, p>0.05], thus documenting an effect of the undotted primes on the recognition of the targets. Further planned pairwise comparisons showed a significant difference between meaningless primes and unrelated (p=0.023), and between meaningful primes and unrelated (p= 0.002) whereas no other difference is significant as shown in tables XV,XVII.

TABLE XIV
UNIVARIATE ANALYSIS, LIST2, BY ITEMS

Univariate Tests

Dependent Variable: RT

	Sum of Squares	Df	Mean Square	F	Sig.
Contrast	45174.444	2	22587.222	2.641	.083
Error	359269.333	42	8554.032		

TABLE XV
PAIRWISE COMPARISONS, LIST2, BY ITEMS

Pairwise Comparisons

Dependent Variable: RT

(I) Conditions	(J) Conditions	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
meanful	meanless	19.000	33.772	1.000	-65.216	103.216
	unrelate	74.667	33.772	.098	-9.549	158.882
meanless	meanful	-19.000	33.772	1.000	-103.216	65.216
	unrelate	55.667	33.772	.320	-28.549	139.882
unrelate	meanful	-74.667	33.772	.098	-158.882	9.549
	meanless	-55.667	33.772	.320	-139.882	28.549

TABLE XVI
REPEATED MEASURES, LIST2, BY SUBJECTS ANALYSIS

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
conditions	Sphericity Assumed	46008.933	2	23004.467	10.751	.000
	Greenhouse-Geisser	46008.933	1.851	24853.313	10.751	.001
	Huynh-Feldt	46008.933	2.000	23004.467	10.751	.000
	Lower-bound	46008.933	1.000	46008.933	10.751	.005
Error(conditions)	Sphericity Assumed	59913.067	28	2139.752		
	Greenhouse-Geisser	59913.067	25.917	2311.722		
	Huynh-Feldt	59913.067	28.000	2139.752		
	Lower-bound	59913.067	14.000	4279.505		

TABLE XVII
PAIRWISE COMPARISONS, LIST2, BY SUBJECTS ANALYSIS

(I) factor1	(J) factor1	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	17.067	14.388	.766	-22.035	56.169
	3	74.733*	17.518	.002	27.124	122.343
2	1	-17.067	14.388	.766	-56.169	22.035
	3	57.667*	18.494	.023	7.405	107.928
3	1	-74.733*	17.518	.002	-122.343	-27.124
	2	-57.667*	18.494	.023	-107.928	-7.405

Parallel analyses of the error data revealed the Word Type to be significant by items but not by subjects analysis, [F1 (1.076, 15.06) = 4.04 p >0.05; F2 (2, 42) = 8.556 p<0.05] as shown in tables XVIII,XX. Besides, pairwise comparisons among the 3 levels of Word Typed showed a significant difference between meaningful and unrelated (p= 0.003) and meaningful and meaningless (p=0.003). No other comparisons were significant as shown in tables XIX,XXI.

TABLE XVIII
ERROR ANALYSIS, LIST2 BY ITEMS

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.024[a]	2	.012	8.556	.001
Intercept	.029	1	.029	20.434	.000
Conditions	.024	2	.012	8.556	.001
Error	.059	42	.001		
Total	.111	45			
Corrected Total	.083	44			

TABLE XIX
ERROR ANALYSIS, LIST2, PAIRWISE COMPARISONS, BY ITEMS

(I) conditions	(J) conditions	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
meanful	Meanless	.049*	.014	.003	.015	.083
	Unrelate	.049*	.014	.003	.015	.083
meanless	Meanful	-.049*	.014	.003	-.083	-.015
	Unrelate	-7.401E-18	.014	1.000	-.034	.034
Unrelate	Meanful	-.049*	.014	.003	-.083	-.015
	Meanless	7.401E-18	.014	1.000	-.034	.034

TABLE XX
ERROR ANALYSIS, LIST2 BY SUBJECTS ANALYSIS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
meaningfulness	Sphericity Assumed	.024	2	.012	4.043	.029
	Greenhouse-Geisser	.024	1.076	.022	4.043	.060
	Huynh-Feldt	.024	1.094	.022	4.043	.059
	Lower-bound	.024	1.000	.024	4.043	.064
Error(meaningfulness)	Sphericity Assumed	.083	28	.003		
	Greenhouse-Geisser	.083	15.068	.005		
	Huynh-Feldt	.083	15.322	.005		
	Lower-bound	.083	14.000	.006		

TABLE XXI
ERROR ANALYSIS, LIST2 BY SUBJECTS PAIRWISE COMPARISONS

(I) meaningfulness	(J) meaningfulness	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	.049*	.022	.044	.002	.096
	3	.049	.026	.077	-.006	.104
2	1	-.049*	.022	.044	-.096	-.002
	3	.000	.007	1.000	-.014	.014
3	1	-.049	.026	.077	-.104	.006
	2	.000	.007	1.000	-.014	.014

C. *Discussion: Experiment 1*

The results of experiment one examine the effect of using undotted orthographic primes on the facilitation of a dotted counterpart, whereby the prime is either meaningful when undotted such as حرس or meaningless such as سرب . the study suggests that the orthographic similarity could facilitate the recognition of the targets. The results of the experiment showed a significant difference between the various conditions by subjects in both list1 and list2. However, the meaningless undotted primes list1 showed (+2) facilitation effect, however, all the other effects were inhibitory; meaningful primes list1 (-41), meaningful primes list2 (-75), and meaningless primes list2 (-56). The results generally show that the undotted primes interfered with the recognition of the targets thus raising a significant inhibition. The literature of orthographic priming disagrees on the impact of similar orthographic forms on facilitating orthographically related targets [25, 33]. Although, the effects reported in the current experiment are generally inhibitory, the results of meaningless primes are quite different from meaningful primes. In list 1 meaningless primes showed a small facilitation effect and in list 2 the inhibitory effect of meaningless primes is smaller than meaningful primes. The current results have a logical explanation, in meaningless primes participants took advantage of the orthographic similarity of the undotted allographs in activating the target words, as in list1, however, list 2 generally showed a slowed response time by subjects even in the three conditions when compared to list1, thus the small facilitation effect reported in list1 turned into inhibition in list2. On the other hand, the meaningful primes, although undotted are real words that showed spread of activation to their semantically related words [34], since that the target words aren't semantically related to the primes they showed a significant inhibition.

8 EXPERIMENT 2: LEXICAL DECISION TASK

The second experiment examines the effect of increasing the number of dots on visual word recognition using a lexical decision task, in which a stimulus is presented on the screen and a response is required with a yes/ no decision whether it is a word or not and the time taken to respond is recorded in milliseconds accuracy. Increasing the dots in a word presents a more complex visual orthographic form, that might slow the process of visual word recognition. A similar notion is reported for words with diacritic marks are assumed to be visually more complex and thus slow word recognition process [18].

Consequently, the experiment manipulates two independent factors; the number of dots imposed on a word, few dots and more dots and the frequency of the word, high frequency and low frequency. The two factors were conflicted forming four levels; high frequency few dots, high frequency more dots, low frequency few dots, and low frequency more dots. Each level had 10 words as shown in table XXII, consequently the total number of words was 40 as well as 40 nonwords, as the experiment is based on a lexical decision task. The dependent factor is the average response time (RT) collected by psychopy software package available at: https://www.psychopy.org.

TABLE XXII
STIMULI USED IN EXPERIMENT 2

Few dots_LF	More dots_LF	Few dots_HF	More dots_HF
سرب	تاج	حسن	قلق
بلح	نبش	عبر	قال
باح	شرخ	حجر	جديد
فناء	عشب	نهر	نشر
محرف	ثرى	حلف	خليل
محرج	ثقل	عبد	قرن
فطر	شوق	منع	حين
نطح	مبعث	فصل	خلق
حطب	غريق	فرد	تحديد
حبط	نشيط	فرع	مجلة

If words with fewer dots are easier to recognize then we should expect the shortest response time for words with few dots and high frequency words, followed by words with few dots and low frequency words, as word frequency has a robust effect that has long been reported over the literature. However, if the number of dots is an irrelevant factor in word recognition, then we should expect short response time for high frequency words regardless of the number of dots imposed. Table XXIII shows the average orthographic frequency for each level, collected from ARALEX, the average number of letters, and the average number of dots.

TABLE XXIII
EXPERIMENT 2 STIMULI DESCRIPTION

	Few dots High frequency	**Few dots low frequency**	**More dots High frequency**	**More dots Low frequency**	**Nonwords**
Orthographic frequency	114	1	177	1.8	-
Number of letters	3	3.4	3.5	3.3	3.4
Average number of dots	1	1	3.2	4.5	-

Design: Each trial contained a fixation point (+), that was presented for 500ms, followed by the target that was presented for 2000ms or until the participant responded. Participants were asked to respond with “l” for a word and “a” for a nonword. Participants were asked to respond as quickly and accurately as possible.

Procedures: participants were tested in a quiet room; each participant was tested individually. The experimenter explained the instructions. They were then given 8 training trials; 4 words and 4 nonwords before starting the main experiment. The experiment lasted for 15 minutes on average.

A. Results

The analysis of data focused mainly on the effects of increasing the number of dots and word frequency on word recognition. Both factors were conflicted. The effect of increasing the number of dots and increasing the frequency of the word are examined. The reaction time (RT) and error data were analyzed using the standard by subjects and by items approach. The analysis was run using SPSS and was based on RTs from correct trials. Mean response times were trimmed by removing trials smaller than two hundred milliseconds or greater than two thousand milliseconds were excluded from the analysis.

Mean lexical decision latencies of target words and nonwords are presented in table XXIV. Targets with more dots and high frequency show the fastest RTs (684ms) followed by targets with few dots and high frequency (706ms), targets with more dots and low frequency have an average (766ms), and finally targets with few dots and low frequency have the slowest response time (780ms).

TABLE XXIV
AVERAGE RESPONSE TIME (STANDARD DEVIATION) FOR STIMULI

Word Type	RT	ER
Few dots_HF	706 (23)	0 (0)
Few dots_LF	780 (27)	0 (0)
More dots_HF	684 (20)	0 (0)
More dots_LF	766 (22)	

A series of one-way ANOVA's by subjects (F1) and by Items (F2) was run on the RT data with Word Type (few dots high frequency, few dots low frequency, more dots high frequency, and few dots low frequency) as within subject variable as shown in tables XXV, XXVII.
The results showed a reliable Word Type effect by subjects [F1 (2.53, 86) = 20.757, $p<0.05$] and by items [F2 (3, 36) = 4.132, $p>0.05$], thus documenting an effect of dots and word frequency on the recognition of the targets. Further planned pairwise comparisons showed a significant difference between few dots, high frequency and few dots low frequency (p=0.001), thus proving a significant effect of word frequency, a significant difference between few dots high frequency and more dots low frequency (p=0.003), and finally a significant difference between few dots low frequency and more dots high frequency (p=0.000) whereas no other difference is significant as shown in tables XXVI, XXVII.

TABLE XXV
EXPERIMENT 2, ITEMS ANALYSIS

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	116005.000[a]	3	38668.333	4.132	.013
Intercept	22512001.600	1	22512001.600	2405.632	.000
conditions	116005.000	3	38668.333	4.132	.013
Error	336889.400	36	9358.039		
Total	22964896.000	40			
Corrected Total	452894.400	39			

TABLE XXVI
EXPERIMENT 2, ITEM ANALYSIS, PAIRWISE COMPARISONS

(I) conditions	(J) conditions	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Few dots_HF	Few dots_LF	-98.100	43.262	.177	-218.887	22.687
	More dots_H	22.100	43.262	1.000	-98.687	142.887
	More dots_L	-92.800	43.262	.233	-213.587	27.987
Few dots_LF	Few dots_HF	98.100	43.262	.177	-22.687	218.887
	More dots_H	120.200	43.262	.052	-.587	240.987
	More dots_L	5.300	43.262	1.000	-115.487	126.087
More dots_H	Few dots_HF	-22.100	43.262	1.000	-142.887	98.687
	Few dots_LF	-120.200	43.262	.052	-240.987	.587
	More dots_L	-114.900	43.262	.070	-235.687	5.887
More dots_L	Few dots_HF	92.800	43.262	.233	-27.987	213.587
	Few dots_LF	-5.300	43.262	1.000	-126.087	115.487
	More dots_H	114.900	43.262	.070	-5.887	235.687

TABLE XXVII
EXPERIMENT 2, SUBJECT ANALYSIS

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
number_dots	Sphericity Assumed	224256.600	3	74752.200	20.757	.000
	Greenhouse-Geisser	224256.600	2.532	88558.873	20.757	.000
	Huynh-Feldt	224256.600	2.753	81459.478	20.757	.000
	Lower-bound	224256.600	1.000	224256.600	20.757	.000
Error(number_dots)	Sphericity Assumed	367326.900	102	3601.244		
	Greenhouse-Geisser	367326.900	86.098	4266.391		
	Huynh-Feldt	367326.900	93.601	3924.372		
	Lower-bound	367326.900	34.000	10803.732		

TABLE XXVIII
EXPERIMENT 2, SUBJECT ANALYSIS, PAIRWISE COMPARISONS

Pairwise Comparisons
Measure: MEASURE_1

(I) number_dots	(J) number_dots	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	-74.143*	17.144	.001	-122.171	-26.115
	3	22.029	10.826	.298	-8.301	52.358
	4	-59.486*	15.262	.003	-102.244	-16.728
2	1	74.143*	17.144	.001	26.115	122.171
	3	96.171*	13.357	.000	58.751	133.592
	4	14.657	15.977	1.000	-30.103	59.417
3	1	-22.029	10.826	.298	-52.358	8.301
	2	-96.171*	13.357	.000	-133.592	-58.751
	4	-81.514*	12.529	.000	-116.615	-46.413
4	1	59.486*	15.262	.003	16.728	102.244
	2	-14.657	15.977	1.000	-59.417	30.103
	3	81.514*	12.529	.000	46.413	116.615

Parallel analyses of the error data revealed the Word Type to be significant by subjects' analysis, [F1 (2.54, 86.3) = 28 p< 0.05], in table XXIX. Besides, pairwise comparisons among the 4 levels of Word Typed showed a significant difference between few dots, high frequency and few dots low frequency (p= 0.001) and few dots high frequency and more dots low frequency (p=0.003) and between few dots low frequency and more dots high frequency (p=0.000) and between more dots high frequency and more dots low frequency (p= 0.000). No other comparisons were significant.

TABLE XXIX
ERROR ANALYSIS, SUBJECT ANALYSIS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
number_dots	Sphericity Assumed	.850	3	.283	28.041	.000
	Greenhouse-Geisser	.850	2.541	.334	28.041	.000
	Huynh-Feldt	.850	2.763	.307	28.041	.000
	Lower-bound	.850	1.000	.850	28.041	.000
Error(number_dots)	Sphericity Assumed	1.030	102	.010		
	Greenhouse-Geisser	1.030	86.393	.012		
	Huynh-Feldt	1.030	93.956	.011		
	Lower-bound	1.030	34.000	.030		

B. *Discussion: Experiment2*

The results of experiment two examine the effect of increasing the number of dots and the word frequency on the speed of visual word recognition in Arabic using a lexical decision task. The results showed a significant difference between the various word types by items and by subjects, however the fastest response is for words with more dots and high frequency, few dots and high frequency, more dots and low frequency and finally few dots and low frequency. Consequently, the dominant factor in inducing fast responses is word frequency followed by words with more dots.

To sum up, the different conditions are in fact ordered in terms of word frequency and more dots. Although some of these results are predictable as high frequency is known for its robust effect on visual word recognition [35-37], the fast response time for words with more dots is controversial, as visual complexity provides slower recognition as shown in diacritized words [18]. The effect reported for words with more dots might be attributed to the frequency of the different allographs [1]. For instance, a word such as تاج shows fast response time comparable to باح, whereas the allograph ت is high frequency (6.87) compared to the ب (4.17) [8]. Despite the orthographic complexities enrolled in words with more dots, their fast recognition time is explicated via the allographic frequencies.

9 LANGUAGE ENGINEERING IMPLICATIONS

The ability of the native speakers to read undotted words is a well-established phenomenon in psycholinguistics. However, the major role of psycholinguistics is to uncover the cognitive processes underlying this ability. Language engineering utilize these cognitive findings to develop a cognitively plausible language model. The current study provides a step forward towards the cognitive modeling of reading undotted words. Based on the results of the former two experiments, we can assert that there are several significant factors, such as the frequency of the possible dotted words, the frequency of the allographs, the number of dots imposed, and the position of the allograph within a word. Generally, participants rely on the frequency of the words to impose the dots; for instance, if the undotted form has two dotted versions, people select the high-frequency version of those dotted words. However, if the words have equivalent frequency, several other factors come into play, such as using the word with more dots (as shown in experiment 2), the frequency of the allograph, is also important as revealed by the pilot study. Whereas the position of the allograph within a word is recommended for future work.

10 CONCLUSION AND FUTURE WORK

The orthographic system of Arabic is a very rich and unique system. It captures its strength from the diacritization marks and the structured writing of the different allographs, that vary as a function of the number of dots imposed and the position of the allograph in the word. Despite the strength of the cohort model in capturing the reading process in general, MSA requires an extended model that includes both the orthographic and the morphological aspects to capture the complexities of reading in Arabic.

The two experiments reported here provide new evidence that addresses important aspects in Arabic visual word recognition; in particular, whether undotted primes can facilitate a dotted counterpart and whether the word frequency and the number of dots imposed affect the speed of word recognition. The results of experiment 1 showed that undotted primes can facilitate a dotted counterpart, only when the undotted primes are meaningless such as سرٮ on contrary meaningful primes such as حرس induces a significant inhibition. Moreover, the results of experiment 2 showed a significant effect of word frequency and a facilitation for words with more dots that disagrees with the general principal that visual complexities induce a perceptual load.

Word frequency is a well-established effect, as emphasized by the pilot study, and the results of the second experiment. Where participants were given the undotted form such as ٮسٮط, most participants read it as بسيط rather than نشيط, as previously observed from the frequency data بسيط is higher in frequency than نشيط, (16.85, 2) respectively.

To sum up, there are several other factors that correlate to Arabic visual word recognition and might be unique to the Arabic orthography, especially when the words are mistakenly undotted in handwritten scripts or when intentionally undotted in social media. Two of the most influential factors are the frequency of the different allographs and the position of the undotted allograph within a word. With regards the frequency of the different allographs, undotted words require an orthographic decision to provide the appropriate dots. Initially readers rely on word frequency to provide an exact match. In addition, readers rely on the frequency of the different allographs to dot the undotted orthographic forms, for instance the words (باح ،تاج) that have similar orthographic frequency as reported from Aralex (0.23, 0.13) respectively, both are low frequency words, however, most participants reported تاج as their first option rather than باح, which might be attributed to the frequency of the grapheme themselves, as ت is more frequent (6.87) than ب (4.17) [1]. As for the position of the undotted allograph, in word initial position, participants don't impose dots in word initial position unless they are faced with difficulty in mapping the word meaning, such as ححر, participants will tend to dot the second allograph rather than the first as they are challenged by retrieving the meaning of the word at that point. On the other hand, participants might tend to dot the first allograph if it corresponds to a meaningless form such ٮ that must have a dotted equivalent. Both factors are quite important and require further research and experimentation. Apparently, there are many cognitive factors at work during word reading, but their interaction varies depending on the stage of reading, the frequency of the word and the individual allographs, and the nature of the orthography. Several manipulations and experiments are required to unveil and outreach the secrets of the Arabic orthography.

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BIOGRAPHY

I am Noha Fathy, a lecturer at the faculty of Arts, Alexandria, University. I am interested in psycholinguistics, the functioning of the language in the human mind how it relates different disciplines such as language engineering, and the entangled nature of psycholinguistics and computational linguistics, another interest is the developing of psycholinguistic resources for Arabic languages that can provide insights on the intuition of the native speaker.

تأثير النقاط على إدراك الكلمات المرئية في اللغة العربية: دراسة لغوية نفسية

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ملخص

النظام الكتابي العربي هو نظام غني، ويرجع ذلك إلى العديد من الخصائص التي تتمثل في استخدام النقاط للتمييز بين الحروف المختلفة وبالتالي التعرف على الكلمات المختلفة. يستطيع المتحدثين الأصليين للغة العربية قراءة الكلمات غير المنقطة باستخدام السياق، وكذلك يمكنهم أيضا قراءة كلمات واحدة غير منقطة. تبحث الدراسة الحالية في العمليات المعرفية الكامنة وراء تحديد الكلمات منفردة بدون نقط. تتناول الدراسة الحالية العمليات المعرفية الكامنة وراء تحديد الكلمات المفردة غير المنقطة، والتي يمكن استخدامها لتوفير أساس معرفي للتحديد التلقائي للكلمات غير المنقطة. تم تصميم تجربتين، التجربة الأولى هي مهمة قرار معجمي. حيث يتم تقديم المشاركين بكلمتين: الأولي، كلمة غير منقطة والثانية، كلمة منقطة. يتم التلاعب بالعلاقة بين الكلمة الأولي والثانية.

يطلب من المشاركين الرد سواء كانت الكلمة الثانية كلمة أم لا باستخدام زرين بلوحة المفاتيح، ويتم تسجيل وقت الاستجابة بدقة الميلي ثانية. التجربة الثانية هي مهمة قرار معجمي، حيث يتم دمج عاملين، عدد النقاط وتردد الكلمة. أظهرت نتائج التجربة الأولي أن الأعداد الأولية غير المنقطة يمكن أن تسهل نظيرا منقط، فقط عندما تكون الأعداد الأولية غير المنقطة بلا معنى مثل سرب. أظهرت نتائج التجربة الثانية تأثيرا معنويا لتكرار الكلمات وتيسيرا للكلمات ذات النقاط الأكثر التي لا تتفق مع المبدأ العام القائل بأن التعقيدات البصرية تحفز الحمل الإدراكي. تتم مناقشة العوامل المعرفية العديدة التي تساهم في تحديد الكلمات المفردة غير المنقطة.

الكلمات المفتاحية:

الكلمات العربية غير المنقطة، التعقيد البصري، التمهيد، تردد الكلمات، النماذج النفسية، النماذج الحاسوبية القائمة على علم اللغة المعرفي.