The influence of perceptual load on the orthographic complexity of Arabic words processing: ERP Evidence

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DOI: http://dx.doi.org/10.7358/neur-2018-024-moha Tarik@kfupm.edu.sa

ABSTRACT

The current study manipulated according to perceptual load theory (PLT) by increasing the letters' numbers of Arabic words and pseudowords to examine the effect of selective attention on the orthographic complexity of Arabic words. The current study's objective is to investigate the effect of selective attention on Event-Related Potentials components associated with orthographic codes such as N170. Participants were requested to perform lexical decision task by identifying words vs. pseudowords. Results showed that there is a significant effect of selective attention on N170 component, which reflects orthographic coding of words with increase negatively for three-letters words compared to six-letters words or nine-letters words. Interestingly, Selective attention does not affect the pseudowords, in that there are no differences between different pseudowords according to length. These findings suggested that selective attention influenced both words and pseudo-words. These findings showed that orthographic coding stages strongly depend on selective attention.

Keywords: Load; words; event-related brain potentials; N170

1. Introduction

Arabic word recognition is unique because, all letters connected to each other mandatory, suggesting that Arabic words are processed differently compared to other visual stimuli. Forgoing studies on visual word recognition suggested that words involve many of complex cognitive processes such as encoding of visual letters, letter's shape translation into a sequence of graphemes and orthographic pattern (Bentin, Mouchetant-Rostaing, Giard, Echallier, & Pernier, 1999). However, (Coltheart, 2006) and (Ehri, 2005) showed that visual words lead to the development of the mental orthographic lexicon that allows for efficient recognition of words.

Neuroimaging studies showed that there are two separate regions in the fusiform gyrus responding to words. The first region represented in posterior fusiform gyrus that responds accurately to words and letters regardless of their semantic context. The second:- anterior fusiform gyrus, which is affected by the semantic context (Allison, McCarthy, Nobre, Puce, & Belger, 1994; Nobre, Allison, & McCarthy, 1994). Additionally, there is a specific region in the left hemi-retinal which is specialized for word recognition (Mishkin & Forgays, 1952), suggesting that left hemisphere is responsible for word processing. However, there are many cognitive models explained the cognitive processes underlying the visual word recognition. In Nelson, Reed, and McEvoy (1977) model showed five different cognitive stages which underlie visual words recognition represented in pictorial coding, orthographic coding, word recognition units (Logogens), semantic representation, and memory coding.

Event-Related Potentials (ERP) studies on word recognition connected between cognitive components and neuro-components. However, these components are responding selectively and actively to different stages in word recognition (Adamo & Ferber, 2009; Ashby, Sanders, & Kingston, 2009; Bechtereva, Abdullaev, & Medvedev, 1992; Nobre et al., 1994). For instance, pictorial coding is responsible for the main properties of words, such as length, contrast, and luminance which connected to the neuro-component that occurred in the occipital-temporal region in the time between 060 ms to 120 ms and peaks positively around 100. Accordingly, researchers in the field of cognitive neuroscience have termed this component P100.

Moreover, orthographic coding associated with another neuro component occurs in the time between 120 to 200 ms and peaks negatively around 170 ms. Thus it has been termed N170 (Taha, Ibrahim, & Khateb, 2013). However, this component is responsible for the Orthographic complexity of visual words. Additionally, the recognition unit "Logogens" is connected to neuro component occurs in the time range between 200 to 350 ms and peaks negatively around 250 ms "N250r" (Mohamed, 2018). While, semantic

representation associated with another neuro-component termed N400 (Van Den Brink, Brown, & Hagoort, 2001).

It has been controversial in the literature whether visual attention is capacity limited. When the task-relevant information was perceived, the attentional capacity will engage with the task-relevant process. Any spare capacity left was not required for the processing of task-relevant information "spills over," and the irrelevant information (Words Type) was processed (Lavie & Tsal, 1994; Lavie, 1995; Lavie, 2005; Lavie, Hirst, De Fockert, & Viding, 2004). This process occurs routinely in the sense that it cannot withdraw voluntarily. Therefore, for efficient filtering to occur it is necessary that an attended task consume all attentional capacity.

In the study of (Yang et al., 2017), the authors examined the possibility whether the right hemisphere is responding selectivity for words during the N170 epoch. The authors used single-trial analysis. Results showed that words evoked greater single-trial N170 than control stimuli in the right hemisphere. The authors concluded that the N170 could be selective to words over the right hemisphere. Moreover, the study of (Chen & Allport, 1995) examined the effect of selective attention to different orthographic components within compound, single-character words, as a function of different reading tasks (Pronunciation vs. Meaning). The authors used same-different comparison paradigm, using both words and pseudowords. The results showed that the skilled readers showed a strongly selective attentional bias in both tasks (Pronunciation vs. Meaning). The authors concluded that selective spatial attention is playing a significant role in word processing.

In the study of (Lin et al., 2011), the authors examined the left lateralized word-related N170 for the orthographic encoding of Chinese characters and three types of structurally matched but unpronounceable stimuli: pseudo-characters, false-characters, and stroke combinations. The authors used a content-irrelevant color-matching task. Results showed that real and pseudo-characters evoked greater N170 in the left posterior brain region. In addition to, pseudo-characters produced the same amplitude and left-lateralized N170. However, these results showed that visual word evoked N170 strongly depends on orthographic encoding rather than phonological encoding. In the study of Taha, Ibrahim and Khateb (2013) the authors examined the effect of orthographic connectivity on the time course of early brain electrical response (N170) during visual word recognition. Findings showed that orthographic coding stage seems to influence the reading process during the early stages of word recognition.

Overall, there is a long-term argument about the influence of attentional load on the early processing stages of word processing. Therefore, the current study aimed to reassess the potential selectivity of orthographic codes

modulation of the words N170 with the attentional load using attentional load manipulation in the context of perceptual load theory by increasing the number of letters-words or pseudo-words (i.e., three letters word; 6 letters words; 9 letters words). Words and pseudo-words presented in two conditions of words and pseudo-words. Participants were instructed to detect the words vs. pseudo-words and ignore the length of these words. However, this study assumed that the word evoked N170 will be affected by the word length and reduction might have occurred when the letter- words decreased. The current study assumed that words with three-letters processed in letter based, while the words consist of six or nine letters processed holistically. The current study focuses on the early Orthographic effect when Arabic words and pseudowords presented in different length.

2. Method

2.1 Partecipants

24 students (12 female), aged between 19 and 24 years old (M = 21.78, SD = 1.67) contributed data to this study. All participants were right-handed, which specified by Edinburgh Handedness Inventory. Participants have normal or corrected-to-normal visual acuity. They all gave written informed consent. All participants are University students from Sohag University, Faculty of Education. The study followed the declaration of Helsinki.

2.2 Stimuli

The current study used a set of 90 Arabic words which consist of 30 three-letter words, 30 six-letter words, 30 nine-letter words. All words were rated for frequency effect by the participants (Nr.24), using Likert scale (from 1 for non-frequent to 5 highly frequent). However, the average frequency for each item in each category was then computed, and values were statistically compared using one-way ANOVA with the three categories. Results showed that the stimuli did not differ regarding word frequency $F(2, 87) = 1.03$, $p=0.10$.

In addition to 90 pseudo-Arabic words which consist of three groups (30 three letters pseudowords, 30 six-letter pseudowords, 30 nine-letter pseudowords). Pseudowords (which have corresponding phonological but not semantic representations) constructed by rearranging the letters of the words (e.g., for words "**انفعال**" for pseudowords "**اعفنال**"), thereby matching the letters in the word and pseudowords conditions.

All stimuli presented in a block design, which counterbalanced randomly. Participants instructed to detected words versus pseudowords.

2.3 Procedures

In the current experiment, participants seated in a light- and sound-attenuated room, with viewing distance 90 cm. During each experimental trials, an initial display for 500 ms of black fixation stimuli was presented and replaced by the blended display for 200 ms, and followed by a blank screen for 1800 ms. Participants were made a choice response to the blended display stimulus presentation by pressing right response button if stimuli were words or left response button if stimuli were Pseudowords. The experiment consists of 360 trial, which included three blocks. Each block includes 120 trial and the time duration is 5 minutes. The total time of the experiment was 15 minutes.

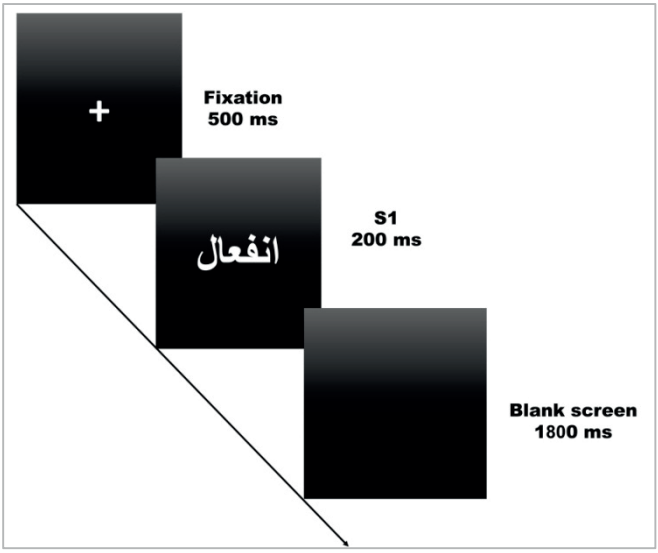

Figure 1. Examples of the stimuli. Participants had to perform Lexical choice responses ("Words" vs. "Pseudo words")

2.4 Apparatus

30 electrodes (10-20 standard set-up) mounted in an elastic cap. EEG was recorded at:- Fz, FCz, Cz, CPz, Pz, POz, F3, F4, FC3, FC4, C3, C4, CP3, CP4, P3, P4,

PO3, PO4, F7, F8, FT7, FT8, T7, T8, TP7, TP8, P7, P8, PO7 and PO8. All of the data were sampled at 524 Hz. The current study used two mastoid references. Cz was used as the ground electrode. Data were re-referenced offline to a standard average reference. ERP epochs quantified for 800 ms (-200 ms pre-stimulus baseline). Eye movement artifacts were excluded by an algorithm of independent component analysis as implemented in Brain Vision Analyzer 2.0. Data were filtered with a bandpass at of 0.5-35 Hz. Trials with eye movements or EEG artifacts exceeding 50 µV were omitted from further analyses.

2.5 Data Analysis

Repeated measure analysis of variance (MANOVA) was calculated for analyzing effects of Word length "Load" (3 categories"3 letters words; 6 letters words & 9 letters words"), and Type (Words vs. Pesudowords). P1 was quantified in the time segment 80-120 ms at occipital-temporal electrodes (PO7, PO8), with the additional factor of Hemisphere (right vs. left). N170 was quantified at the time segment 120 to 200 ms at occipital-temporal electrodes (P7, PO7, P8, PO8) with additional factors Electrode Position (P7/PO7 vs. P8/PO8) and Hemisphere (right vs. left). The current study assessed N300 (200-400ms) in the frontal-central electrodes position (FC3, FCZ, FC4), with load and type factors. Epsilon corrections for heterogeneity of covariance were always performed using the Huynh–Feldt method, where appropriate.

3. Results

3.1 Behavioral Results

Repeated measure ANOVAs were conducted on factors, Load and Type on both Accuracy (ACC) and Reaction Times (RTs). ACC analyses showed main effect of Type $F(1, 23) = 7.05$, $p < .01$, with increasing error rates when pseudowords were presented compared to words (Mdiff= 3%). Moreover, there is an interaction between perceptual load and Type $F(2, 46) = 10.98$, $p < .01$. Further analyses were conducted using One-way ANOVA for three different categories of words and pseudowords, which showed no main effects or interactions all Ps> 0.10.

RTs analyses revealed no main effects or interactions were reported all Ps > 0.30.

These findings showed that there is no effect of Perceptual load occurred for the processing of Arabic words. Results showed that there is no effect of perceptual load on the RTs.

3.2 Event-Related Potentials Results

P1 (080-120 ms)

An initial analysis of mean amplitude on the region of interest (ROI), with the factors of Hemisphere, Load, and Type. Results showed main effects of Hemisphere $F(1, 23) = 36.95$, $p < .001$, with larger activity in the right than the left hemisphere (Mdiff= 1.83 μv), Load $F(2, 46) = 4.95$, $p < .05$, with lager positivity for words and pseudowords consists of 9 letters compared to other groups (M =4.28 μv; 3.71 μv; 3.31 μv). No other effects or interactions all ps> 0.10 had reported. P1 Latency analysis showed that there is no central effects or interaction all ps> 0.20.

N170 (120-200ms)

An initial analysis of the region of interest (ROI), with the factors of Hemisphere, Sites, Load, and Type. Results revealed main effect of Load $F(2, 46) = 21.79$, $p < .001$, with larger negativity for 3 letters words or pseudowords compared to other groups (M =-8.20 μv; -7.29 μv; -6.29 μv). Additionally, results showed three-way interactions of Hemisphere by Load by Site $F(2, 46) = 6.21$, $p < .01$. To solve-up this three-way interactions further analysis conducted in the right and left hemispheres. The analysis of left hemisphere showed the main effect of load $F(2, 46) = 21.49$, $p < .001$, with increase negativity for three letters words and pseudowords compared to other groups (M = -8.34 μv; -7.19 μv; -6.31 μv). No other main effects or interactions were reported.

While the analysis of the right hemisphere showed the significant effect of Load $F(2, 46) = 12.39$, $p < .001$, with increase negativity for three letters words and pseudowords compared to other groups (M =-8.07 μv; -7.38 μv; -6.29 μv). Moreover, results showed that there are two-way interactions between Type and Load $F(2, 46) = 3.39$, $p < .05$.

To solve-up this two- way interactions, additional analysis were conducted for each Type. For Words there is main effect of Load $F(2, 46) = 10.30$, $p < .01$, with increase negativity for 3 letters words compared to other groups (M = -8.04 μv; -7.36 μv; -6.46 μv). For pseudowords there is main effect of load $F(2, 46) = 24.74$, $p < .001$, with increase negativity for 3 letters pseudowords compared to other groups (M = -8.36 μv; -7.20 μv; -6.11 μv). No other main effects or interactions all ps> 0.20. *For N170 Latency, the analysis revealed no main effects or interactions all ps> 0.25.*

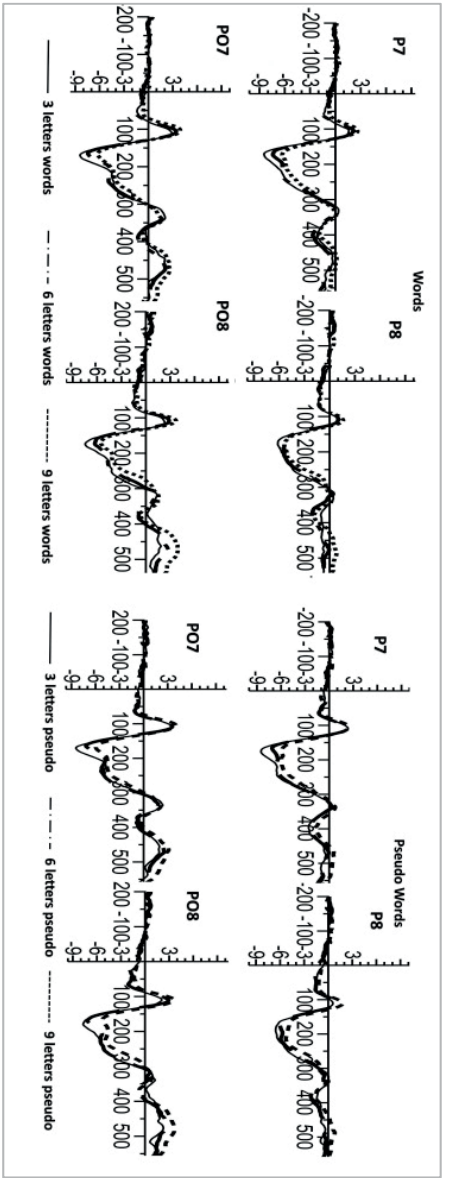

Figure 2. Grand average event-related potentials (ERPs) for occipital-temporal sites of interest, across 24 observers. Upper part Results of three-letter words. Middle part results of 6 letters words. The bottom part of nine letters words

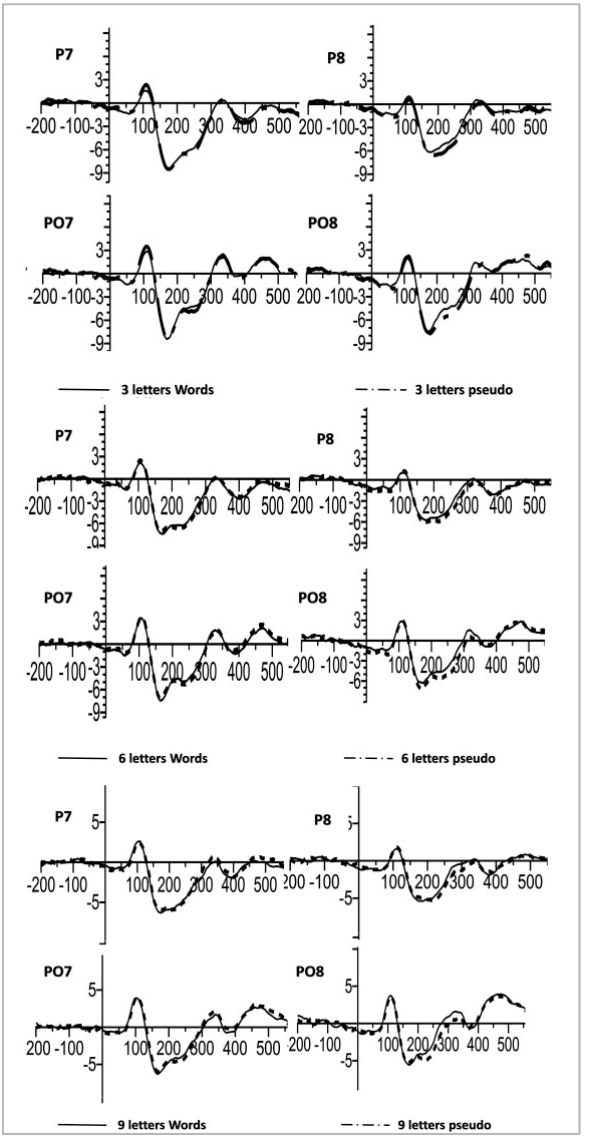

Figure 3. Grand average event-related potentials (ERPs) for occipital-temporal sites of interest, across 24 observers

N300 (200-400 ms)

The visual inspection showed that there is negative component was reported in the frontal-central region (FC3, FCZ, FC4) in the time between 200 ms and 400 ms and peaks negatively around 300 ms. Many of researchers have termed this component N300.

An initial analysis of the Region of interest (ROI), with the factors Sites, Load, and Type. Results revealed a significant effect of Load $F(2, 46) = 4.45$, $p < .05$, with increase negatively of 3 letters words and pseudowords (M = -3.04 µv; -2.59 µv; -2.46 µv). However, this effect was quantified by two-way interactions of Site by Load $F(4, 92) = 9.02$, $p < .01$. No other main effects or interactions have reported all ps> 0.35.

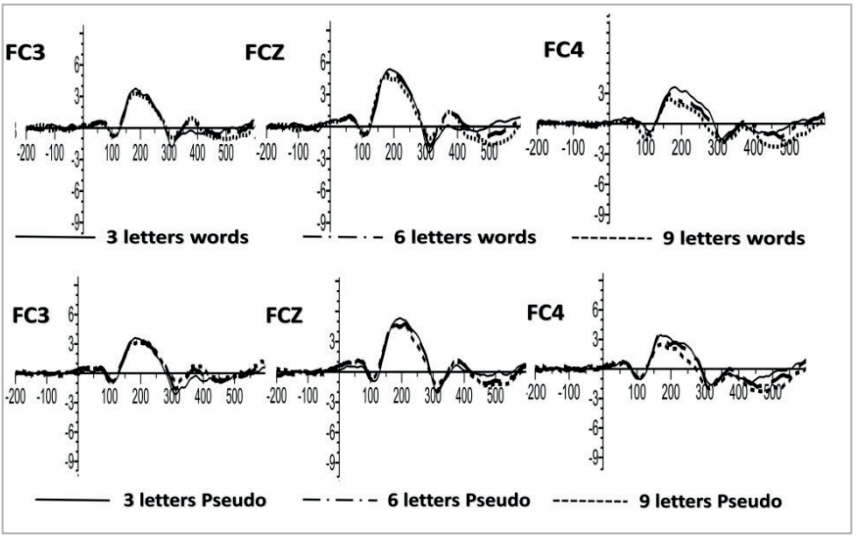

Figure 4. Grand average event-related potentials (ERPs) for occipital-frontal sites of interest, across 24 observers

4. General discussion

The Present study investigated the influence of the combined effect of perceptual load and words type on the Orthographic codes of Arabic words processing. Attention was manipulated by increasing the number of word/ pseudo words letters sequentially (i.e., 3-letters, 6-letters, 9-letters words), according to Lavie's

perceptual load theory. Hence, The study measured the brain activity of the P1, N170 & N300.

Consistent with previous studies (Adamo & Ferber, 2009; Bentin, Mouchetant-Rostaing, Giard, Echallier, & Pernier, 1999; Nelson, Reed, & McEvoy, 1977), a positive P100 followed by a negative N170 was evoked around the occipital-temporal area by stimuli used in the present study. Regarding P1, the study found a more significant amplitude elicited by nine letters words than other categories of stimuli. Many previous studies that focused on P1 component also showed a smaller amplitude for three-letter words than other words categories (Mohamed, 2018). Interestingly, the pseudo-words showed the same pattern. There are no differences has been reported between words and pseudowords. P1 component is correlated with physical information (Bentin et al., 1999; Nobre, Allison, & McCarthy, 1998; Weber-Fox & Neville, 2001). These findings are suggesting that both words and pseudowords not differ according to physical information because all of the stimuli consist of the same letters (Ashby, Sanders, & Kingston, 2009). Moreover, all stimuli have the same local feature analysis (Ashby et al., 2009). Interestingly, the P1 latency does not affect selective attention or word type. These findings suggested that selective attention is playing an essential role in the physical properties of words processing.

Regarding N170, results showed that there is a primary effect of selective attention has reported for both words and pseudowords. Results showed more massive negativity for three letters words or pseudo-words than other categories stimuli. These findings suggested that Arabic words lost superiority under perceptual load. When the word-letters increased, it is difficult for the human brain to recognize and classified these words as words in this short time interval (200 ms). Accordingly, word recognition is affected by attentional load, in that the ability to identify words will be decreased when the word-letters increased. Consequently, the perceptual load will lead to decrease the neural activity of the N170 when words letters were increased. Evidence for this interpretation has come from the study of (McClelland, 1976) which showed that word superiority effect is compatible with a parallel letter identification process. Moreover, N170 latency does not affect by attentional load or words type.

Interestingly, the N170 findings of pseudowords showed the same effect of selective attention, with reducing N170 for 3-letters pseudowords compared to other Stimuli Categories. These findings in variation with the findings of (Xu et al., 2001) which showed a difference in neural activity between words and pseudowords. However, these findings showed the same pattern of the influence of the selective attention on words and pseudowords.The study assumes that both words and pseudowords in this short time intervals (200 ms), depending on word recognition more than letter identification. Consequently, leads to decrease the neural activity when these letters of words or pseudowords increased.

Moreover, the N170 latency of pseudo-words showed that there is no difference under different conditions of perceptual load.

Another exciting and counterintuitive findings represented in N300 component which evoked in the frontal-central region, which showed the primary effect of the attentional load with increase negatively of 3 letters words and pseudowords compared to other groups. However, these findings suggested that N300 related to word categorization effect (see, Hamm, Johnson& Kirk, 2002). These findings suggested that word superiority effect is not only related to the identification stage of word recognition but could be extended to be related to many of reflected component which can occur in different areas in the human brain. Interestingly, no one knows how the effect of word categorizations of words and pseudowords showed the same effect.

4. Conclusion

The current study examined the combined effects of selective attention and words type on the N170 ERP component of Arabic word Processing. Nelson, Reed and McEvoy (1977) model showed that this component "N170" related to word identification units (Orthographic coding). The current study found that N170 is strongly depended on Selective attention. The findings showed this effect of selective attention occurred massively in both hemispheres for 3- letters words, while this effect is diminished for the other categories. These findings suggested that the word superiority effect is completely lost under the different conditions of selective attention. These findings concluded that the early stages of word recognition depend on selective attention.

Acknowledgment

This work supported by Start-Up research grant SR151013 provided by Deanship of Academic Research "DSR" at *King Fahd University of Petroleum and Minerals* "KFUPM."

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