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Optimal Viewing Position for Fully Connected and Unconnected words in Arabic

Abstract: *In order to assess the unique reading processes in Arabic, given its unique orthographic nature of natural inherent variations of inter letter spacing, the current study examined the extent and influence of connectedness disparity during single word recognition using the optimal viewing position (OVP) paradigm (three-, four- and five-letter stimuli presented at a normal reading size, at all possible locations). The initial word viewing position was systematically manipulated by shifting words horizontally relative to an imposed initial viewing position. Variations in recognition and processing time were measured as a function of initial viewing position. Fully connected/unconnected Arabic words were used. It was found that OVP effects occurred during the processing of isolated Arabic words. In Arabic, the OVP may be in the center of the word. No OVP was found in three-letter words; for four- and five-letter words, the OVP effect appeared as a U-shaped curve with a minimum towards the second and third letters. Thus, the OVP effects generalize across structurally different alphabetic scripts.*

Key words: *OVP*

The Optimal Viewing Position (OVP) is a well-known phenomenon in visual word recognition (O'Regan & Jacobs, 1992; Stevens & Grainger, 2003). The OVP is assessed by shifting words horizontally at different offsets to the left and right of a central fixation position between two vertically aligned fixation lines, so that participants fixate at all possible letter fixation locations within each word (Brysbaert, 1994; Hunter, Brysbaert, & Knecht, 2007) (Figure 1). The OVP effect reflects how the initial horizontal placement of the fixation position in a word constrains its recognition (Brysbaert & Nazir, 2005; Rayner, 1998).

Studies on OVP have found that words are recognized fastest and with fewest errors when a reader's gaze is fixated in a region between the beginning of a word and its center (Van der Haegen, Drieghe, & Brysbaert, 2010). As the initial fixation position deviates from the OVP, recognition time increases at a rate of 20–30 ms per letter (O'Regan, Levy-Schoen, Pynte, & Brugaillere, 1984). This OVP has been observed in many tasks, including word naming, lexical decision-making, and perceptual identification; these results have been observed in different languages, including French, Dutch, Hebrew, Arabic, and Japanese (Brysbaert & Nazir, 2005).

Brysbaert and Nazir (2005) proposed that the OVP results from the interplay of numerous factors that play a role in visual word recognition. These factors including lexical constraints, letter visibility, perceptual learning and hemispheric lateralization may contribute jointly to word recognition performance (Yao-N'Dré Castet, & Vitu, 2013).

Lexical constraints and informativeness (information structure of the word stimuli) affect the OVP since the first letters contain most of the information about a word's identity because they are shared by a smaller number of words in the lexicon (known as orthographic neighbors) (Yao-N'Dré et al., 2013). About words that share all but one letter in the correct stimulus position, research has demonstrated that low-frequency words with at least one high-frequency orthographic neighbor are harder to recognize than those with no such high-frequency neighbors (Grainger, 1990; Grainger, O'Regan, Jacobs, & Segui, 1989; Grainger & Segui, 1990).

The visibility of letters to each side of the fixation position (perceptual span in reading) affect the OVP since the visual acuity of letters decreases with increased distance from the fixation position; there is also greater crowding when retinal eccentricity increases. Therefore, greater letter information is available when the eyes' initial fixation

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is near the center of a word. Even at an eccentricity of 1 degree, there is already 40% deterioration in visual acuity (Wertheim, 1894). Words presented a few letter positions to the left or to the right of the fixation position are, therefore, difficult to recognize. The center of vision is generally estimated to subtend 3 degrees of visual angle, with some three or four letters per degree of visual angle.

In line with these findings, the shape of the OVP curve varies with the visual characteristics of a particular stimulus. Nazir, Heller, and Sussmann (1992) varied inter-letter spacing and showed that the slopes of the curves became gradually greater as spacing increased, alongside increases in the eccentricity of each letter. Additionally, Nazir, Jacobs, and O'Regan (1998) scaled letters in words proportionally to their distance from the fixation location, and found flatter OVP curves.

Additionally, perceptual learning based on reading habits affect the OVP since fixating on a word's beginning makes word recognition easier, because eyes tend to land at a word's beginning and frequently fixated locations improve reading performance (Nazir, Ben-Boutayab, Decoppet, Deutsch, & Frost, 2004). Accordingly, variations in word identification performance with retinal location would result from the preferred viewing position effect, or the tendency, in languages read from left to right, for the eyes to land more near the center, or slightly to the left, of words (Rayner, 1979). Left-to-right-reading adults should be better at identifying words within the central or right-to-central part of their visual field because that is where they have adapted to visualize words while learning to read (Chung, Legge, & Cheung, 2004). Yet, there is no clear leftward asymmetry of the OVP effect in languages read from right to left, such as Arabic or Hebrew (Farid & Grainger, 1996; Nazir et al., 2004).

Hemispheric lateralization is another factor affecting the OVP since words presented in the left visual field (LVF) are projected to the right hemisphere (RH), and information from the right visual field (RVF) is sent to the left hemisphere (LH) (Stevens & Grainger, 2003), with the fovea of each eye divided precisely at its vertical meridian (Brysbaert, 2004; Jordan & Paterson, 2009; Lavidor & Walsh, 2004; Lindell & Nicholls, 2003; Shillcock, Ellison, & Monaghan, 2000). A word recognition advantage has been shown when letters in a word (or the entire word) are presented to the right of the fixation rather than the left. This reflects unilateral projection to LH and RH on either side of the fixation position (Paterson, Jordan, & Kurtev, 2009), because the left cerebral hemisphere plays a greater role in language processing (Brysbaert, 1994, 2004) and the split-fovea processing (Brysbaert, 1994; Brysbaert, Vitu, & Schroyens, 1996; Hunter et al., 2007; Lavidor, Ellis, Shillcock, & Bland, 2001; Martin, Thierry, Démonet, Roberts, & Nazir, 2007). Whitney's (2001) SERIOL model argues that foveal letters assemble in the dominant hemisphere before recognition starts. This would mean that letters from a word's beginning (in RVF) are directly sent to the LH, but have to be temporarily inhibited until letters from the word's end (in LVF) are transferred from the RH to LH (Van der Haegen & Brysbaert, 2011). Despite the converging evidence in support of a functional split in human foveal processing, it is still a controversial claim with respect to the precision of foveal splitting and how far the effects of foveal splitting extend from the retina into the higher processing associated with visual word recognition.

In a letter discrimination task, previous research has found (Bouma, 1973; Legein & Bouma, 1977; Legge, Mansfield, & Chung, 2001; Stevens & Grainger, 2003) that the likelihood of correctly identifying a letter embedded in a string of homogeneous letters decreases faster in the left, compared to the right visual field.

Although, several factors may be responsible for the shape of OVP curves, visual factors appear to have the greatest role (Yao-N'Dré, Castet, & Vitu, 2013). In a study by Nazir, Heller, & Sussmann (1992), the effect was found to become gradually stronger as inter-letter spacing and letter eccentricity increased. In another study by Nazir et al., (1998), the OVP effect was cancelled out when word letters were scaled as a function of their eccentricity and leading to letter visibility.

One of the most relevant reading models is the cascaded dual route model (Coltheart, 2005; Coltheart, Rastle, Perry, Langdon & Ziegler, 2001) that assumes the usage of two processing routes during reading which may operate simultaneously and in parallel (Stuart, Masterson, Dixon & Quinlan, 1999). The lexical route relies on activation of word form visual representation in the mental lexicon allowing the reading of familiar pre-stored words and raising the speed and accuracy of word recognition and spelling (Ehri, 2005; Frith, 1985; Vellutino, Fletcher, Snowling, & Scanlon, 2004). The non-lexical route relies on grapheme-phoneme conversion rules allowing the reading of unknown words (unfamiliar and novel words) and nonwords (or pseudowords) (Coltheart, 2005; Ehri & Snowling, 2005).

The Arabic language has unique orthographic features as its orthography consists of connecting and un-connecting un-connecting letters, which create different word forms. This Arabic unique orthographic nature allowed exploring the effect visual information of connected vs. unconnected word form in Arabic has on reading. Accordingly, the existence of connected vs. unconnected word form in Arabic enabled us to determine word legibility and the extent of both sequential-analytical (letter-based recognition) and parallel-holistic processing (global word shape based recognition)—all without creating an artificial reading task.

The OVP pattern found in isolated words could provide key insights into understanding visual word recognition processes (Brysbaert et al., 1996; Clark & O'Regan, 1999; O'Regan & Jacobs, 1992), especially when investigating Arabic, with its unique visual connectedness.

Arabic orthography

Arabic orthography is unique and complex: dots are part of the grapheme, and letters have a similar basic form differentiated by the number and location of the dots (ب – ت – ث). Dots appear in 15 letters: 10 letters with one dot, 3 letters with two dots, and 2 letters with three dots,

leading to great visual similarity between the letters. This letter similarity causes recognition errors (Blommaert, 1988; Bouma, 1971; Briggs & Hocevar, 1975; Cattell, 1896; Gervais, Harvey, & Roberts, 1984; Geyer, 1977; Gibson, Osser, Schiff, & Smith, 1963; Loomis, 1982; Townsend, 1971a, 1971b; Townsend & Ashby, 1982; Townsend, Hu, & Evans, 1984; Watson & Fitzhugh, 1989). Some letters have different forms that depend on their position in the word, while the letter's basic form is preserved within these different forms (Abd El-Minem, 1987). Twenty-two letters out of 28 letters have 4 different letterforms (Table 1): a separate or basic form (ه), an initial form connecting to the left (هـ), a medial form connecting to the right and left (ـهـ), and a final form connecting to the right (ـه). Since most of the Arabic letters are similar in their basic form, precise recognition of these Arabic letter-forms and their writing rules is essential for word recognition. This process consumes attentional resources (Abu Rabia, 2001), slowing the grapheme-phoneme conversion process (Taouk & Coltheart, 2004).

Most of the letters connect from both sides (referred to as connecting letters), while six un-connecting un-connecting letters (ا ذ د ر ز و) connect to the right only. Accordingly (and distinctly from other languages), Arabic words can consist of one unit where the words contain no un-connecting un-connecting letters (without inter-letter spaces: home بيت), or consist of several sub-units where the words contain several un-connecting un-connecting letters (with inter-letter spaces: home دار). Consequently, Arabic orthography consists of words with different forms which depend on the number and position of the un-connecting un-connecting letter strings in the word: connected words (without inter-letter spaces, where all the letters are connected), unconnected words (with inter-letter spaces, where most of the letters are unconnected), mixed words (with some inter-letter spaces, where some letters are connected and some are not) (Table 2). A previous study found that in a corpus of 262,647 words, the average number of letters was 4.3, with a sub-unit average of 2.2 per word (with one inter-letter space). Sub-units are an important point of focus, because computerized optical recognition studies of Arabic handwriting have suggested that the sub-unit, rather than the word, is the basic unit of recognition (Belaid & Choisy, 2008).

It is worth to mention that, Arabic indeed has a nonconcatenative morphology in which the root and some other letters of a word pattern intermingle to create the desired inflectional meaning. Thus, in contrast to alphabetical languages, it often happens that Arabic readers cannot rely on the beginning of the word to identify written words. Farid & Grainger (1996) found that the initial fixation curves in Arabic depended on the morphological structure of the stimuli. Prefixed words produced a leftward (word ending) advantage whereas suffixed words produced a rightward (word beginning) advantage. In the present study we used words with the first, second and third letters to be root letters. Indeed, root letters that are of special importance for word recognition are concentrated in our study towards the beginning (as in Latinate languages).

Table 1. Arabic letters (connecting, non-connecting) in different shapes as a function of word-position

	Basic	Initial	Medial	Final
	Connected Letters			
1	ب	بـ	ـبـ	ـب
2	ت	تـ	ـتـ	ـت
3	ث	ثـ	ـثـ	ـث
4	ج	جـ	ـجـ	ـج
5	ح	حـ	ـحـ	ـح
6	خ	خـ	ـخـ	ـخ
7	س	سـ	ـسـ	ـس
8	ش	شـ	ـشـ	ـش
9	ص	صـ	ـصـ	ـص
10	ض	ضـ	ـضـ	ـض
11	ط	طـ	ـطـ	ـط
12	ظ	ظـ	ـظـ	ـظ
13	ع	عـ	ـعـ	ـع
14	غ	غـ	ـغـ	ـغ
15	ف	فـ	ـفـ	ـف
16	ق	قـ	ـقـ	ـق
17	ك	كـ	ـكـ	ـك
18	ل	لـ	ـلـ	ـل
19	م	مـ	ـمـ	ـم
20	ن	نـ	ـنـ	ـن
21	ه	هـ	ـهـ	ـه
22	ي	يـ	ـيـ	ـي
	Unconnected Letters			
1	ا	ا	ـا	ـا
2	د	د	ـد	ـد
3	ذ	ذ	ـذ	ـذ
4	ر	ر	ـر	ـر
5	ز	ز	ـز	ـز
6	و	و	ـو	ـو

Table 2. Arabic word forms of connected and unconnected 3-letters, 4-letters and 5-letters (Space -, Connecting letter □, Un-connecting letter -□)

	5-Letters word	4-Letters word	3-Letters word
Connected	□□□□□	□□□□	□□□
Un-connected	□-□-□-□-□	□-□-□-□	□-□-□

The present study

To date, previous research has only examined OVP in long Arabic words (Farid & Grainger, 1996), and occurrence and effect of fixation disparity in single word recognition tasks is yet to be assessed. Accordingly, the present study examined the extent and influence of connectedness disparity during single word recognition using the OVP paradigm (three-, four- and five-letter stimuli presented at a normal reading size, at all possible locations). In line with previous research, we used the initial fixation-letter paradigm in a naming or recognition task. Fully connected/unconnected Arabic words were used (Table 3).

Previous research that has investigated hemispheric influences on recognition of Arabic words (Ibrahim & Eviatar, 2009) and other languages that read from right to left (Adamson & Hellige, 2006) indicated a LH superiority for words. Additionally, several studies indicate that the RH is particularly poor at identifying Arabic letters (Eviatar, Ibrahim, & Ganayim, 2004), which may be exacerbated by the poor discriminability of individual letters and additional crowding (Pelli et al., 2007).

The study hypotheses address fully connected/unconnected Arabic word levels at all possible locations of letter fixation. For the fully connected/unconnected Arabic words level, we asked:

(1) Is word readability affected by the visual differentiations in Arabic connected\unconnected word forms? We expected that naming connected words to be faster than naming unconnected words because the former enable more differentiation in the word template and global shape as one unit (Abdelhadi, Ibrahim, & Eviatar, 2011; Kahteb, khateb-Abdelgani, Taha, & Ibrahim, 2014; Khateb, Taha, Elias, & Ibrahim, 2013; Taha, Ibrahim & Khateb, 2012). This pattern supports a holistic processing of word recognition and the lexical route in reading.

(2) Is the Arabic OVP affected by the visual differentiations in Arabic connected\unconnected word forms? We expect that the Arabic OVP would be in the central fixation position, in accordance with previous research. Nevertheless, this central OVP was expected to be more apparent for unconnected words than connected words.

(3) Does the word length effect exist in fully connected/unconnected Arabic words? We expected to find the word length effect reflected in a longer naming time for long words, supporting the sequential processing model of visual word recognition and the non-lexical route in reading.

Experiment 1

Experiment 1 addressed the influence of Arabic word form on visual word recognition, manipulating word connectedness. The goal of this experiment was to explore the OVP of three-letter word forms (connected and unconnected: without inter-letter spaces and with inter-letter spaces). An initial fixation paradigm was used to present words in all letter fixation positions. The participants were asked to read all the words in a naming task. We note that this is the first study to examine whether the OVP is modulated by visual features of connected and unconnected three-letter Arabic words and their resultant effects on reading.

Table 3. Outline of the study experiments

Experiments	Word Length	Words Type
Experiment 1	3-Letter	Connected Vs. Unconnected
Experiment 2	4-Letter	Connected Vs. Unconnected
Experiment 3	5-Letter	Connected Vs. Unconnected

Method

Variables

The independent variables were the word form (connected, unconnected) and the initial fixation letter (first, second, third). The dependent variables were the accuracy rate and the response time. The experiment matrix is a within-subjects 2×3 bi-factorial design.

Participants

A total of 41 university students participated in the study (average age: 22.7, *SD* = 2; 20 males and 21 females). All were right-handed native Arabic speakers of middle socio-economic status who displayed normal or corrected-to-normal vision in both eyes. No participants had a history of neurological or emotional disorders. Participants, being university students, were assumed to read at a satisfactory level, and none was formally diagnosed as having reading impairments.

Stimuli

The stimuli were 2 lists of 10 three-letter words, each varying according to word type (connected, unconnected) and presented in all positions of the initial fixation letter (first, second, third letter). The words were nouns selected from primary and secondary school textbooks, as well as those occurring in the dictionary with medium frequency (2.5–3.5) in accordance with previous studies (Abdelhadi et al., 2011; Kahteb et al., 2014), as judged by 52 university on a 1–5 frequency scale (1 = very rare, 2 = rare, 3 = average, 4 = frequent, 5 = very frequent). The words were displayed in white 24-point Simplified Arabic Fix font on black background of a PC screen (Table 4). The words were introduced randomly.

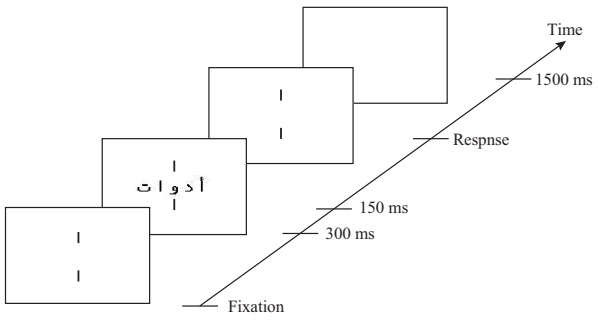
Procedure

A CRT display (19 inch) was placed at a viewing distance of 60 cm from the participant. There were 60 trials. Each trial contained the following steps using super lab software:

1) Two vertical fixation lines were presented in the middle of the screen for 300 ms.
2) The word stimulus was presented for 150 ms between the lines with the letter that was to be fixated on placed between the lines. Fixating on the first letter meant that the word was shifted to the left
3) The fixation lines remained on the screen until the voice key registered a response, or until a time-out of 1500 ms was reached (Figure 1). A break was provided after 30 (three-letter words) trials, or whenever the participant indicated that (s)he needed a break.

Participants received notice that there would be an Arabic word between two vertical lines in the middle of the screen. It was stressed, explicitly and repeatedly, that it was important to fixate between the two lines, when these lines were presented. Participants were asked to name the words as quickly and as accurately as possible. They were informed that they could ask for a break whenever they wanted.

Figure 1. Time course of one trial in the optimal viewing position task

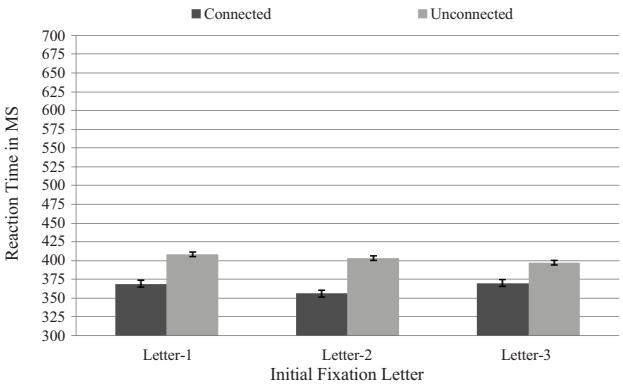


Each participant was tested individually in a random presentation sequence of the words. The response time was a measurement of the time between the presentation of a word and the onset of a spoken response, at which *onset* is defined acoustically. The word noted by the participant was written by the experimenter.

Results

Because the accuracy percentage exceeded 99% in all conditions, an analysis of accuracy was not conducted. The differences in reading time according to the two types of words (connected, unconnected) and their initial fixation letters (first, second, third letter) were tested with a repeated-measures analysis of variance (RM-ANOVA). There was a significant effect of word type ($F(1,40) = 25.88$, $p < 0.00001$) (Figure 2), with reaction time for connected words being significantly shorter than for unconnected words. The effect of the initial fixation letter, however, was not significant ($F(2,39) = 0.458$, $p = 0.636$) (Figure 2). The interaction between the factors was non-significant ($F(2,39) = 0.427$, $p = 0.656$) (Figure 2).

Figure 2. Reaction time as a function of three-letter word type (connected, unconnected) and initial fixation letter (first, second, third)



Note. Error bars represent standard error

Table 4. Word Stimuli and frequency (frequency scale: 1 = very rare, 2 = rare, 3 = average, 4 = frequent, 5 = very frequent) used in the different experiments

Experiments	Word Length	Connected words		Unconnected words	
		Word	Frequency	Word	Frequency
Experiment 1	3-Letter	عضة	3.5	أرز	3.5
		فضل	3.5	أزر	2.5
		غيب	3.5	درر	2.3
		هضم	3.5	وأد	3
		خفة	2.3	زرد	3.1
		لحد	2.7	زور	3.1
		محل	3.5	أرز	3.5
		نجم	3.5	أزر	2.5
		قضم	2.1	درر	2.3
		شحم	3.5	زرد	3.1
Experiment 2	4-Letter	Connected words		Unconnected words	
		Word	Frequency	Word	Frequency
		عضلة	3.5	أرزه	3.5
		عظمة	3.5	أزره	2.5
		طبقة	3.5	درره	2.3
		بعثة	3.5	وأده	3
		فتنة	2.6	زرده	3.1
		جلبة	3.2	زوره	3.1
		ختمة	3.5	أرزه	3.5
		صفقة	3.5	أزره	2.5
		شحنة	3.5	درره	2.3
		تحفة	3.5	زرده	3.1
Experiment 3	5-Letter	Connected words		Unconnected words	
		Word	Frequency	Word	Frequency
		عطفهم	3.5	أدوات	3.5
		بحثهم	3.5	أرزات	3.5
		فعلهم	3.5	دورات	3.5
		غصبهم	3.4	زردات	3.1
		همسهم	3.5	ازرات	2.5
		كنفهم	2	ذروات	2.3
		لطفهم	3.3	وردات	3
		مضغهم	2.5	زورات	3.1
		نفيهم	2.5	أدوات	3.5
		قصفهم	3.5	دورات	3.5

Discussion

The present study explored how initial viewing position affected the processing of fully connected/unconnected three letter Arabic words. No OVP effect was observed and all reaction times were similar for fully connected/unconnected three letter Arabic words. These words fell within the fovea in the visual span; since visual acuity drops off rapidly with retinal eccentricity, most letters of a short word can be seen in a single glance when fixating on the word center. However, with longer words (e.g., four or five letters words), it becomes more difficult to recognize all letters with a single fixation position, which increases the likelihood of an OVP effect (Hyönä & Bertram, 2011). Recently, White, Hirotani, and Liversedge (2012) found that there was no

OVP for two-character kanji words. It seems that the OVP effect is more evident in extrafoveal locations, with no OVP effects observed for foveal locations (Almabruk, Paterson, McGowan, & Jordan, 2011; Liu & Li, 2013).

The effect of word type on visual word recognition was reflected in shorter reaction time for connected words than for unconnected words. This supports the hypothesis of a word recognition spectrum in Arabic visual word recognition, with sequential-analytical processing at one end (lexical route) and parallel-holistic (non-lexical route) at the other. Thus, the connectivity of words in the Arabic script makes it easier for adults to read connected words than unconnected words, where the global word shape is less differentiated. This finding is consistent with recent finding of facilitating role for word connectiveity in Arabic (Abdelhadi et al., 2011; Kahteb et al., 2014; Khateb et al., 2013; Taha et al., 2012).

Experiment 2

Experiment 3 examined the influence of Arabic word form on visual word recognition, manipulating word connectedness. This experiment aimed to explore the OVP of four-letter word forms (connected, unconnected: without inter-letter spaces, with inter-letter spaces). An initial fixation paradigm was used to present words in all letter fixation positions. We note that this is the first study to examine whether the OVP is modulated by visual features of connected and unconnected four-letter Arabic words, and their resultant effects on reading.

Method

Variables

The independent variables were the word form (connected, unconnected) and the initial fixation letter (first, second, third, fourth). The dependent variables were the accuracy rate and the response times. The experiment matrix assumed a within-subjects bi-factorial 2×4 formation.

Participants

A total of 25 university students participated in this experiment (average age: 28.9, *SD* = 6; 10 males and 15 females). All were right-handed native Arabic speakers of middle socio-economic status who displayed normal or corrected-to-normal vision in both eyes. No participants had a history of neurological or emotional disorders. Participants, being university students, were assumed to read at a satisfactory level, and none was formally diagnosed as having reading impairments.

Stimuli

The stimuli were 2 lists of 10 four-letter words, each varying according to word type (connected, unconnected) and presented in all positions of the initial fixation letter (first, second, third, and fourth letter). The words were nouns selected from primary and secondary school textbooks, as well as those occurring in the dictionary with medium frequency (2.5–3.5) in accordance with previous studies (Abdelhadi et al., 2011; Kahteb et al., 2014), as judged by 52 university on a 1–5 frequency scale (1 = very rare, 2 = rare, 3 = average, 4 = frequent, 5 = very frequent). The words were displayed in white 24-point Simplified Arabic Fix font on black background of a PC screen (Table 4). The words were introduced randomly.

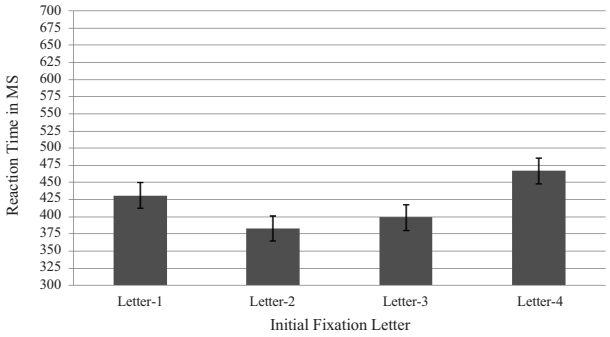
Procedure

The procedure was largely same as that of Experiment 1, but included a total numbers of 80 trials.

Results

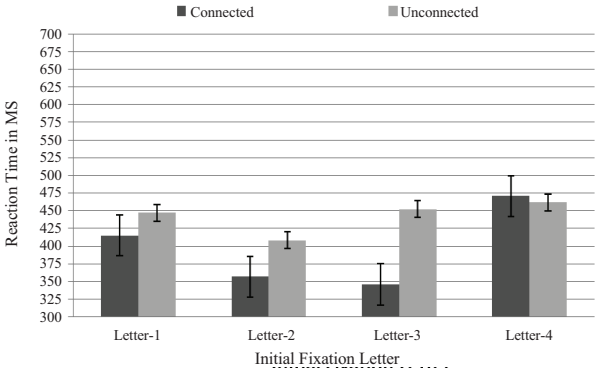
Because the accuracy percentage exceeded 99% in all conditions, an analysis of accuracy was not conducted The differences in reading time according to the two types of words (connected, unconnected) and their initial fixation letter (first, second, third, fourth) were tested using a RM-ANOVA. We found a significant effect of word type ($F(1,24) = 5.61$, $p < 0.03$), with reaction time for the connected words (Mean = 397, SD = 107) being significantly shorter than for unconnected words (Mean = 442, SD = 110). In addition, the initial fixation letter effect was significant ($F(3,22) = 4.47$, $p < 0.015$), with *Post- hoc* paired sample *t*-tests showing that the reaction time for the second and third fixation letters is similar but shorter than for the first and fourth fixation letters (Figure 3). The interaction between the factors, however, was non-significant ($F(3,22) = 2.05$, $p = 0.135$) (Figure 4).

Figure 3. Reaction time as a function of four-letter-word initial fixation letter (first, second, third, and fourth)



Note. Error bars represent standard error

Figure 4. Reaction time as a function of four-letter word type (connected, unconnected) according to their initial fixation letter (first, second, third, and fourth letter)



Note. Error bars represent standard error

Discussion

The present study explored how initial viewing position affected the processing of fully connected/unconnected four letter Arabic words. For four letter words, we observed a U-shaped curve of reaction time, as a function of initial viewing position with a minimum towards the second and third letter. As the fixation position deviated from the OVP, time cost increased (O'Regan et al., 1984). Since there is a drop in visual acuity with retinal eccentricity, it becomes more difficult to recognize all letters of four letter word with a single fixation position, which increases the likelihood of an OVP effect (Hyönä & Bertram, 2011). In addition, because most information used for word recognition can be extracted between the word's beginning and its center (Broerse & Zwaan, 1966; Brysbaert & Nazir, 2005; Eriksen & Eriksen, 1974; Li & Pollatsek, 2011; White et al., 2008; Yan, Tian, Bai, & Rayner, 2006), the initial fixation position occurred between the word beginning and center (i.e., at the second and third letters of 4-letter words).

In line with Experiment 1, shorter reaction time for connected words reflected sequential-analytical processing (non-lexical route) while longer reaction time for unconnected words reflected parallel-holistic processing (lexical route) in Arabic visual word recognition. This supports the special contribution of the connectivity as a unique visual feature of the Arabic orthography to visual word recognition (Abdelhadi et al., 2011; Kahteb et al., 2014; Khateb et al., 2013; Taha et al., 2012).

Experiment 3

Experiment 5 addressed the influence of Arabic word form on visual word recognition by manipulating word connectedness. The experiment's aim was to explore the OVP of five-letter word forms (connected, unconnected: without inter-letter spaces, with inter-letter spaces). An initial fixation paradigm was used to present words in all letter fixation positions. The participants were asked to read all the words in a naming task. We note that this is the first study to examine whether the OVP is modulated by visual features of connected and unconnected five-letter Arabic words, and its resultant effects on reading.

Method

Variables

The independent variables were the word form (connected, unconnected) and the initial fixation letter (first, second, third, fourth, fifth). The dependent variables were the accuracy rate and the response time. The experiment had a within-subjects 2×5 bi-factorial design.

Participants

A total of 32 university students participated in the study (average age: 27.2, *SD* = 8; 15 males and 17 females). All were right-handed native Arabic speakers of a middle socio-economic status who displayed normal or corrected-to-normal vision in both eyes. No participants had a history of neurological or emotional disorders. Participants, being university students, were assumed to read at a satisfactory level, and none was formally diagnosed as having reading impairments.

Stimuli

The stimuli were two lists of 10 five-letter words, each varying according to the word type (connected, unconnected) and presented in all positions of the initial fixation letter (first, second, third, fourth, fifth). The words were nouns selected from primary and secondary school textbooks, as well as those occurring in the dictionary with medium frequency (2.5–3.5) in accordance with previous studies (Abdelhadi et al., 2011; Kahteb et al., 2014), as judged by 52 university on a 1–5 frequency scale (1 = very rare, 2 = rare, 3 = average, 4 = frequent, 5 = very frequent). The words were displayed in white 24-point Simplified Arabic Fix font on black background of a PC screen (Table 4). The words were introduced randomly.

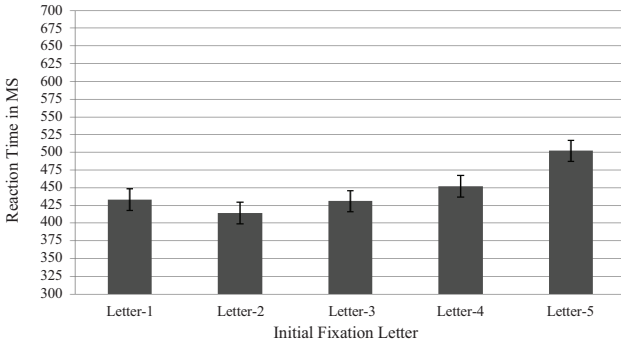
Procedure

The procedure was largely same as that of Experiment 1, but included a total numbers of 100 trials.

Results

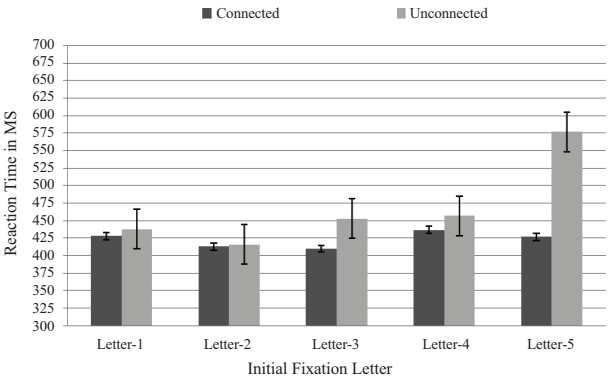
Because accuracy percentage exceeded 99% in all conditions, an analysis of accuracy was not conducted. The differences in reading time according to word type (connected, unconnected) and initial fixation letter (first, second, third, fourth, fifth letter) were tested using RM-ANOVA. There was a significant word type effect ($F(1,31) = 4.76$, $p < 0.05$), with reaction time for connected words (Mean = 423, *SD* = 109) significantly shorter than for unconnected words (Mean = 468, *SD* = 108). We also found a significant effect of the initial fixation letter ($F(4,28) = 4.07$, $p < 0.015$), with *Post- hoc* paired sample *t*-tests showing that the reaction time for the second and third fixation letters is similar but shorter than that for the first, fourth, and fifth fixation letters (Figure 5). The interaction between the factors was non-significant ($F(4,28) = 2.11$, $p = 0.106$) (Figure 6).

Figure 5. Reaction time for five-letter words as a function of initial fixation letter (first, second, third, fourth, fifth)



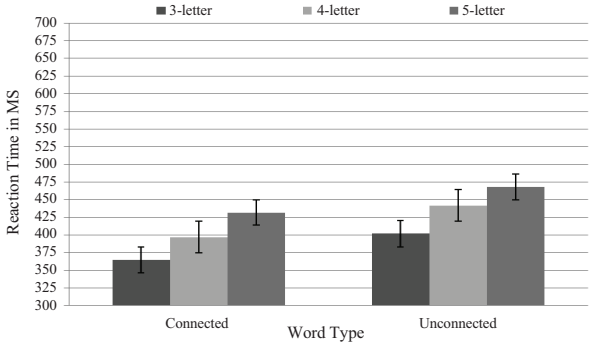
Note. Error bars represent standard error

Figure 6. Reaction time of five-letter words as a function of word type (connected, unconnected) and initial fixation letter (first, second, third, fourth, and fifth letter)



Note. Error bars represent standard error

Figure 7. Reaction times as a function of word type (connected, unconnected) and word length (3, 4, 5 letters)



Note. Error bars represent standard error

Discussion

As in previous experiments of long words (Experiment 1 and 2), for five letter words, we observed a U-shaped curve of reaction time, as a function of initial viewing position with a minimum towards the second and third letter. This could be explained by the retinal drop in visual acuity and the word information distribution.

In line with Experiment 1 and 2, shorter reaction time for connected words reflected sequential-analytical processing (non-lexical route) while longer reaction time for unconnected words reflected parallel-holistic processing (lexical route) in Arabic visual word recognition. This supports the special contribution of the connectivity as a unique visual feature of the Arabic orthography to visual word recognition (Abdelhadi et al., 2011; Kahteb et al., 2014; Khateb et al., 2013; Taha et al., 2012).

Joint analysis

A joint analysis using connected and unconnected word reaction times yielded by Experiments 1, 2, and 3 was conducted. The within-subjects factor was word type (connected, unconnected), and the between subjects factor was word length (3, 4, 5 letters). The mixed-design RM-ANOVA revealed a significant effect of word type ($F(1,95) = 4.4$, $p < 0.05$), with reaction time for connected words being shorter than for unconnected words. In addition, a word length effect was found ($F(2,95) = 6.4$, $p < 0.05$), with reaction time increasing with increases in word length. The interaction between the factors was not significant ($F(2,95) = 0.78$, $p = 0.46$) (Figure 7).

General Discussion

The present study explores how initial viewing position affects the processing of isolated Arabic word. In the present series of experiments, we systematically manipulated the initial word viewing position by shifting words horizontally relative to an imposed initial viewing position. Variations in recognition and processing time were measured as a function of initial viewing position. In a series of three experiments, stimuli were fully connected/unconnected words words of varying lengths (3, 4, 5 letters) with participants being asked to perform a recognition task. We explored how initial viewing position affected word processing efficiency. Overall, the results were consistent with previous findings on central OVP (Brysbaert & Nazir, 2005; Deutsch & Rayner, 1999; Farid & Grainger, 1996; Hyönä & Bertram, 2011; O'Regan & Jacobs, 1992; O'Regan et al., 1984; Van der Haegen et al., 2010; Vitu, O'Regan, & Mittau, 1990). The OVP for processing isolated Arabic words tends to be in the center of the word (second or third letter), where naming time is minimal. For four- and five-letter words, we observed a U-shaped curve of reaction time, as a function of initial viewing position with a minimum towards the second and third letter. As the fixation position deviated from the OVP, time cost increased (O'Regan et al., 1984). For three-letter words, no OVP effect was observed and all reaction times were similar.

Many factors may contribute to the OVP effect, and we will discuss their potential influence on Arabic OVP effects below.

Visual acuity limitations may explain the OVP effect. Previous research has argued that the decrease in visual acuity with retinal eccentricity contributes to the OVP effects of word recognition; this occurs because visual acuity decreases with greater letter distance from the fixation position, resulting in a loss of visual information (Brysbaert & Nazir, 2005; Nazir, 1991; Rayner, 2009; Vitu, Lancelin, & d'Unienville, 2007). When participants were required to fixate on the first or last letters of words, visual acuity limitations reduced their ability to recognize them. Thus, in the present study, response times were longer for four- and five-letter words when the initial fixation fell on the first and last letters than when it fell on other letters.

However, no OVP effect was found for three letters. These words fell within the fovea in the visual span; since visual acuity drops off rapidly with retinal eccentricity, most letters of a short word can be seen in a single glance

when fixating on the word center. With longer words (e.g., four or five letters words), it becomes more difficult to recognize all letters with a single fixation position, which increases the likelihood of an OVP effect (Hyönä & Bertram, 2011). Recently, White et al. (2012) found that there was no OVP for two-character kanji words. It seems that the OVP effect is more evident in extrafoveal locations, with no OVP effects observed for foveal locations (Almabruk et al., 2011; Liu & Li, 2013).

Arabic readers found it easier to recognize a word when the fixation position was located at the second or third letters. These results suggest that word beginning may play an important role in recognition OVP effect. Prior studies have demonstrated that the word beginning is more informative than the word ending for word recognition (Broerse & Zwaan, 1966; Brysbaert & Nazir, 2005; Eriksen & Eriksen, 1974; Li & Pollatsek, 2011; White et al., 2008; Yan et al., 2006). Fixating at the word beginning makes recognition easier because eyes tend to land at word beginnings and frequently fixated locations improve reading performance (Brysbaert & Nazir, 2005; Nazir et al., 2004). Thus, because most information used for word recognition can be extracted between the word's beginning and its center, the initial fixation position occurred between the word beginning and center (i.e., at the second and third letters of 4-letter and 5-letter words).

Perceptual learning based on reading habits (Brysbaert & Nazir, 2005; Deutsch & Rayner, 1999; Farid & Grainger, 1996; Nazir et al., 2004; Wong & Hsiao, 2012) does not account for the word recognition OVP effect observed in this study. Because Arabic is read from right to left, words are repeatedly recognized in the same location in the visual field. As a result, word recognition is more effective when the initial fixation occurs at the position that readers most often fixate on while reading (Brysbaert & Nazir, 2005; Ducrot & Pynte, 2002). According to the reading habit hypothesis, the leftward asymmetry of the initial fixation curve is due to the increased average visibility of letters to the right of the fixation position (compared to letters to the left of the fixation position). This asymmetry in letter visibility is typically attributed to the influence of reading habits on the deployment of attention, with a rightward bias induced in languages that are read from left to right. Therefore, this hypothesis incorrectly predicted that the Arabic initial fixation curve would be asymmetric to the right. This hypothesis was based on the assumption that because of a leftward bias in the deployment of attention (in a language that is read from right to left), letters would be more visible to the left of the fixation position, giving an advantage to fixations that are to the right of the word's center.

Prior research on left-to-right languages such as English, French, and German has shown a systematic leftward asymmetry in OVP. According to the hemispheric specialization hypothesis, the leftward asymmetry is because leftward fixations leave more of the word in the right visual field. This leads information extracted from a greater proportion of the word to be directly transmitted to the left hemisphere, where the principal neural structures subtending visual word recognition are located. This hypothesis incorrectly predicted that a leftward asymmetry should also be observed in Arabic, since speakers of Arabic presumably also have language structures lateralized in the left hemisphere. The results of our experiments showed, however, that the average initial fixation curve is central for Arabic words.

According to this view, all information to the left of the fixation position will project unilaterally to the right hemisphere (RH), at least during initial processing, and all information to the right of the fixation will project unilaterally to the left hemisphere (LH). Since it has been established that the LH generally has superior word-perception capabilities to the RH (Almabruk et al., 2011), this putative division in hemispheric processing at the point of fixation has been claimed to have important effects on word recognition (Ellis & Brysbaert, 2010). In particular, information projected separately to each hemisphere from each side of the fixation position is integrated in the language-dominant LH (for the majority of individuals) via interhemispheric transfer prior to lexical processing (e.g., Brysbaert, 1994, 2004; Brysbaert & Nazir, 2005; Hunter et al., 2007; van der Haegen et al., 2010). Thus, when the majority of letters in a fixated word falls to the right of the fixation position, it creates a perceptual advantage, because these letters project directly to the LH, with less information having to undergo disruptive interhemispheric transfer prior to recognition.

Moreover, like Latinate languages, Arabic produces perceptual superiority for words displayed to the right of the fixation position, indicating classic LH dominance for processing words (Ibrahim & Eviatar, 2009). Arabic is written using a cursive script that decreases the distinctiveness of individual letters within words. This introduces additional crowding (Jordan, Paterson, & Almabruk, 2010; Pelli et al., 2007), which may further decrease letter resolution (Eviatar et al., 2004; Ibrahim, Eviatar, & Aharon-Peretz, 2002).

Furthermore, we also observed a word length effect consistent with results of previous English studies (Joseph, Liversedge, Blythe, White, & Rayner, 2009; Plummer & Rayner, 2012; Rayner et al., 2011). The word length effect has been considered as an evidence for sequential process (Eviatar & Zaidel, 1991; Iacaboni, & Zaidel, 1996; Reichle, Rayner, & Pollatsek, 2006), while its absence in skilled readers indicates parallel letter processing in word recognition (Aghababian & Nazir, 2000; LaBerge & Samuels, 1974). Its presence in recognition of fully connected/unconnected Arabic words supports the analytic-sequential processing and the non-lexical route in reading. Our findings provide original evidence suggesting inhibitory effects of word length (longer words are harder) in Arabic.

The findings of the present experiments introduce evidence to support the hypothesis of a word recognition spectrum in Arabic visual word recognition, with sequential-analytical processing at one end (lexical route) and parallel-holistic (non-lexical route) at the other. Holistic processing (recognition based on global

word shape) was reflected in the difficulty participants experienced processing unconnected Arabic words, where the integration of the word sub-units and the assembly of the word letters were less evident. Because connected Arabic words lead to strong perceptual unity between its letters, representing the whole word form as a global hierarchical entity facilitates the recognition of connected words. Thus, the connectivity of words in the Arabic script makes it easier for adults to read connected words than unconnected words, where the global word shape is less differentiated. These finding are consistent with recent finding of facilitating role for word connectiveity in Arabic (Abdelhadi et al., 2011; Kahteb et al., 2014; Khateb et al., 2013; Taha et al., 2012). The inhibitory word length effect found in fully and partially connected/unconnected Arabic words, however, must be taken into account because longer words are harder to recognize supporting non-lexical processing. A regression analysis revealed that Arabic word connectivity and word length predicted visual word recognition reaction time. The positive linear relationship ($b = 0.346$, $p < 0.05$) indicated that the higher reaction time was associated with unconnected words ($r = 0.481$). However, data on word length showed a negative linear relationship ($b = -0.278$, $p < 0.05$), and indicated that the longer reaction time was associated with longer words ($r = -0.394$). Thus, 23% of the variance in the reaction time was shared with word connectivity ($R^2 = 0.23$), while 15% of the variance was shared with word length ($R^2 = 0.15$).

The present study found that OVP effects occurred during the processing of isolated Arabic words. In Arabic, the OVP may be in the center of the word. No OVP was found in three-letter words; for four- and five-letter words, the OVP effect appeared as a U-shaped curve with a minimum towards the second and third letters. The present research may be the first systematic study to explore OVP effects in the processing of isolated fully and partially connected/unconnected Arabic words, and may help elucidate Arabic visual word recognition. We also note that letter visibility and/or lexical constraints might play critical roles in word recognition OVP effects during the processing of isolated fully connected/unconnected Arabic words and letters.

Additionally, the present experiments suggest that a systematic study of visual features, OVP, and word length in Arabic—read from right to left—provides appropriate means of testing our hypotheses. The results from the present experiments indicate that the reading habit hypothesis is lacking, while the hemispheric specialization, lexical constraint and letter visibility hypothesis merit further elaboration and testing.

It is worth to note that, although word stimuli were presented repeatedly in different fixation positions, possible repetition effects can be discarded since all word stimuli were repeated the same number of trials in each experiment, and especially since a word length effect was found. Eventhough long words were repeated more often than short words since they include more letter positions (3-letter words were presented in 3 fixation positions, 4-letter words were presented in 4 fixation positions, 5-letter words were presented in 5 fixation positions) it took longer time to recognize them.

Several limitations must be considered when interpreting the results. Prior studies have explored the effect of reading direction and morphological structure on OVP effects (Deutsch & Rayner, 1999; Farid & Grainger, 1996; Nazir et al., 2004). Farid & Grainger (1996) found that the initial fixation curves in Arabic depended on the morphological structure of the stimuli. Prefixed words produced a leftward (word ending) advantage whereas suffixed words produced a rightward (word beginning) advantage. In the present study we used words with the first, second and third letters to be root letters. Indeed, root letters that are of special importance for word recognition are concentrated in our study towards the beginning (as in Latinate languages). Previous studies raised the question of how the distribution of critical information across a word (as manipulated with morphological structure) does play a role in shaping the initial fixation curve and may influence the OVP effects in Arabic; this will need further investigation. Additionally, in the present study we used only three, four, five letter words. Despite the fact that most Arabic words are of the above word lengths (Belaid & Choisy, 2008), this may not allow the generalizebility of our findings to other word lengths (such as two, six, seven, etc.). Furthermore, to our knowledge, no systematic data exist on word form frequency in Arabic, so we cannot address any possible effects of word form frequency with our findings.

It is worth to note that, although word stimuli were presented repeatedly in different fixation positions, possible repetition effects can be discarded since all word stimuli were repeated the same number of trials in each experiment, and especially since a word length effect was found. Eventhough long words were repeated more often than short words since they include more letter positions (3-letter words were presented in 3 fixation positions, 4-letter words were presented in 4 fixation positions, 5-letter words were presented in 5 fixation positions) it took longer time to recognize them.

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