# Effect of Two Trigram-Words Displayed at Different Visual Angles on Word Recognition Accuracy and Reaction Time

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## Abstract

The objectives of this study were to study visual recognition accuracy (correct rate – CR) of reading and reaction time (RT) responses when two trigram-words presented at different visual angles. Thirty graduate students were recruited. Each pair of trigram-words were shown at 1, 2, and 3 degrees of arc from the center of the fovea (horizontal visual angles of 2, 4, and 6 degrees), in three experimental blocks. Each block used a total 180 pairs of trigram-words comprising Type 1 (two identical trigram-words, e.g. "pan-pan"), Type 2 (two completely different trigram-words, e.g. "pan-box"), and Type 3 (different only the middle letter of trigram-words, e.g. "pan-pin") stimuli. The participants were instructed to press button "1" if the two-words shown were identical, and press button "2" if they were different, as quickly as possible. CRs and RTs were recorded. The results showed that CR of Type 1 stimuli was highest at 2 degree apart when compared with those at 4 and 6 degrees apart, indicating that two identical words could be identified best at the foveal edge (at the edge of 2 degrees in diameter). At 6 degree, CR of Type 2 stimuli was highest, followed by Type 3 and Type 1 stimuli, respectively, indicating that at peripheral vision, completely different words could be easiest identified. Moreover, RTs of Type 2 stimuli were shortest, and CRs of Type 2 stimuli were highest in every visual angle. These findings were the first to show that completely different words recognitions were not affected by wider visual angles, possibly caused by orthographic processing of different word shapes. These data can be used for further developing reading training software for improving visual span.


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## Introduction

Visual span is the visual area that a person can read or recognize a number of letters or words without moving eye fixation from the central point of the visual field.[1] The horizontal visual field of a human eye is about 120 degrees of arc of visual angle. There are three regions called foveal, parafoveal, and peripheral regions. According to a previous study on visual span, central foveal region is defined to a central circular area of 2 degrees in diameter with the highest visual acuity of 80-100 % correct rate of reading identified by using trigrams (strings of three letters) as stimuli.[2] Trigram recognitions are gradually reduced when the visual spans are wider in the parafoveal region (2 to 5 degrees in diameter), and lowest in the peripheral region (beyond the parafoveal region). The width of visual span affects visual word recognition.

Visual word recognition is the ability to match words with those kept in memory. Recognition includes four fundamental stages of processing. The first is the processing of basic object components, such as color, depth, and form. The second is grouping all basic components on the basis of similarity, providing information on distinct edges to the visual form. Subsequently, figure-ground segregation is able to take place. The third is matching visual representation with structural descriptions in memory. Lastly, the semantic attributes are applied to the visual representation, providing meaning, and thereby recognition.[3] This visual word recognition processes are necessary for reading comprehension.

Reading is composed of accurate eye movements and fixations, visual sensory input, and higher cognitive aspects of reading comprehension.[4] Typically, reading is one of the most important strength for people who have the motivation to learn new things and it is critical to fully participate in modern society.[5] Normally, people can read a sentence clearly with the combination of both foveal and parafoveal visions.[6,7] Previous studies revealed that people fix their eyes on a word about 50-250 ms before moving to another word,[8,9] and the estimated size of the visual span for high-contrast is 1 degree in radius and an average of 10.6 letters can be clearly read.[10,11] There are many previous behavioral studies on the effect of foveal and parafoveal visions on reading demonstrating many different results. According to the visual span profile analysis on reading, visual recognition accuracy or performance accuracy or percent correct rate (CR) at the central foveal region

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is highest (80-100%) when compared with further wider visual spans resulting in faster reading speed,[2,4,10] and indicating that visual span is one of the most important factors that affect the reading speed of a person.

The reader must use not only visual, orthographic, or morphological information to identify individual words, but must also keep track of the currently fixated word and the preceding word, their meaning, syntactic properties, and resulting thematic roles. It is quite likely that, given all this necessary processing for a foveal word, readers will not have many resources left to identify a parafoveal word.[12] Visual acuity varies across the retina due to the heterogeneous concentration of visual receptors investigated by using rapid serial visual presentation (RSVP) procedure with flanker words. It was found that the visual acuities are maximal at the fovea with a diameter of about 2 degrees of the visual field around fixation, smaller parafoveally (between 2 and 5 degrees), and minimal in the periphery (beyond 5 degrees).[13] In reading, the eyes jump rapidly across the text (saccade) and fixate for about 200 to 250 ms at individual words. Within these fixation periods, almost all relevant information for word processing is extracted from the central 2 degrees of vision by using the flankers with probe paradigm.[8] It was also found that parafoveal single letters, letters within words, or even whole words can be identified when shown in isolation.[8,14] However, there were no previous studies about showing 3-letter (trigram) words simultaneously at both sides of the central fixation point at the edge of the foveal region (2 degrees), parafoveal region (4 degrees), and peripheral region (6 degrees), respectively. Therefore, it is questionable what the trigram-words recognition profile is when two trigram-words are displayed at 2, 4, and 6 degrees of visual angles. Apart from words recognition accuracy, reaction time used for processing of decision making should also be considered.[15]

Choice reaction time, a kind of behavioral study, is the time recorded from the stimulus onset to the motor response time by pressing a corresponding button, and the unit is in milliseconds (ms). In general, reaction time (RT) is longer, and performance accuracy is lower in response to more difficult stimuli.[15] Performance accuracy or correct rate (CR) is the test that indicates one's ability to produce predefined correct responses to simple visual or auditory stimuli. A previous study showed that a single non-word trigram shown at wider visual angles have less CR than those shown at closer visual spans.[2] In general, it could be assumed that two trigram-words shown simultaneously in wider visual angles should be more difficult to read than those shown in closer visual angles; however, this needs to be investigated in this study.

The first objective of this study was to identify the effect of trigram-words shown on both sides of the central fixation point (at the foveal edge, parafoveal region, and peripheral region) on performance accuracy (or correct rate) and RT. Moreover, there have not been any studies demonstrating the effect of different attributes of trigram-words (same two words, different two words) shown at different visual angles on performance accuracy and RT either. The second objective of this study was to investigate the effect of trigram-word types displayed at different visual angles on the CR of reading and RT.

## Materials and Methods

### Participants

This study recruited 30 graduate students (15 men and 15 women, age [mean ± SD] 27.9 ± 4.2 and 27.2 ± 3.7 years, respectively), from the Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand. All participants were needed to provide written informed consent to join the study approved by the Siriraj Institutional Review Board (SI-420/2017), Faculty of Medicine Siriraj Hospital, Mahidol University. The participants could withdraw or suspend participation at any time without losing any rights. All participants were right-handed according to the Edinburgh handedness inventory[16] with normal or corrected visual acuity (tested with Snellen chart) and could read English well (Mahidol University English Graduate Test 60 marks, IELTS score 5, TOFEL-IBT score 61, or TOFEL-ITP score 500). Subjects received minimal participating fees. All rights of the participants were protected.

### Stimuli preparation

Stimuli were selected from daily used meaningful 3-letter (trigram) words from Merriam-Webster dictionary (Google occurrence > 500 millions) and the words were evaluated whether they were easily

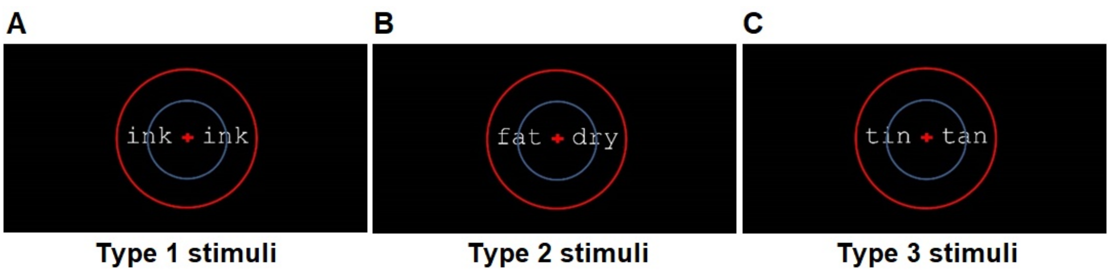
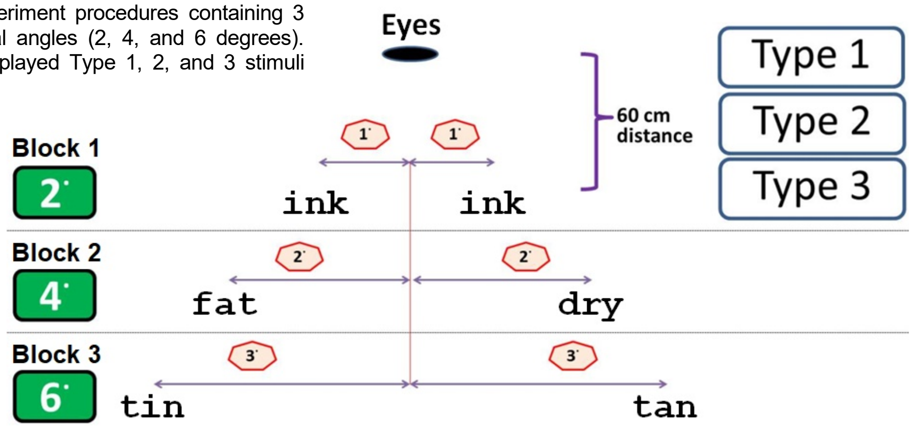



**Figure 1** Three types of trigram-words: (*A*) Type 1 stimuli, the same words; (*B*) Type 2 stimuli, completely different words; and (*C*) Type 3 stimuli, almost the same but different in the middle letter of trigram-words.

**Figure 2** Experiment procedures containing 3 blocks of visual angles (2, 4, and 6 degrees). Each block displayed Type 1, 2, and 3 stimuli (60 pairs each).




understandable or not by five English language experts with the score of 3 or above (0 : not recognizable, and 1 : recognizable). Six hundred trigram-words were evaluated by the experts and all of them were accepted. There were three types of word pairs used for this study: Type 1, two identical trigram-words (Figure 1A); Type 2, completely different trigram-words (Figure 1B); and Type 3, different only in the middle letter of two trigram-words (Figure 1C). There was a separate set of stimuli for each visual angle (2, 4, and 6 degrees). Each set contained 180 pairs of words (60 pairs for each type), and a total of 540 meaningful trigram-words were used.

The font type and size of each word was Courier New (monospace) 24 pt, and the font color was white on black background. The computer used was a Dell Computer with a monitor size of 15x12 inches, and a screen resolution of 1,280 × 1,204 pixels. The width of each letter was 0.4 degree visual angle (4 mm on the screen at a distance of 60 cm away), hence, one trigram (3-letter word) occupied 1.2 degree or 12 mm. The distance between the middle letters of 2 words stimuli at a visual span of 2 degrees was calculated by using the formula of tan θ = object width/object distance (tan 2 degree = 0.035). So, at 60 cm away, the object width was supposed to be 0.035 timed 60, resulting in 2.1 cm. Subsequently, 4.2 and 6.3 cm were used for 4 and 6 degrees visual angles, respectively. The set of 3 visual word files were pseudorandomly sequenced by Stim2 software (Compumedics Neuroscan, Charlotte, North Carolina, USA) using the Gentask to set the pseudorandomized inter-stimulus interval between 1,000-2,000 ms.

**Experimental procedure**

Participants were requested to take a good rest by sleeping 6-8 hours before the experiment day. Each participant sat in a comfortable position and tried not to move the head and eyes during the experiment. Each was instructed to fix the eyes on a red plus sign shown in the center of the computer screen located 60 cm in front. During the experiment, trigram-word pairs were shown on both sides of a central plus sign at the visual angles of 2, 4 and 6 degrees in diameter for 3 blocks of experiment, respectively.

For the first block (2 degrees), a pair of 3-letter words of either Type 1 (two identical trigram-words), or Type 2 (completely different trigram-words), or Type 3 (different only in the middle letter of two trigram-words) were shown simultaneously. The participant was instructed to press button “1” or “2” with their right index or middle finger as quickly as possible when they identified that the shown words were the same or different, respectively, resulting in an RT response recording and giving either a correct or incorrect response which could be used to calculate the CR. The above procedures were repeated in the second block (4 degrees) and third block (6 degrees) of the experiment (Figure 2).

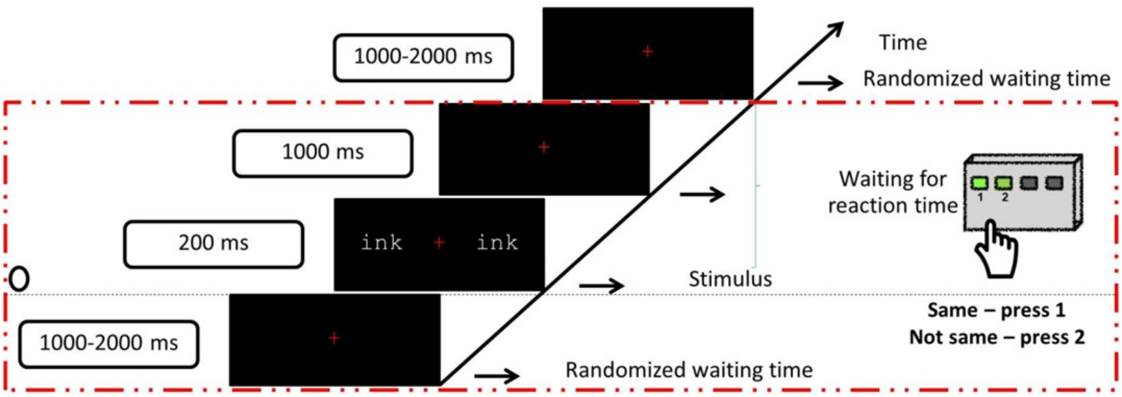



**Figure 3** Experiment timeline of one trial containing 1,000-2,000 ms randomized waiting time, 200 ms of stimulus presentation, and 1,000 ms waiting time for reaction time recording.

**Table 1** Correct rate (CR) in response to to Type 1, 2, and 3 stimuli at visual angles of 2, 4, and 6 degrees.

| Visual angles | CR (%) | | | |
|---|---|---|---|---|
| | Type 1 | Type 2 | Type 3 | *P* value |
| 2 degree | 63.9 ±15.3 | 85.6 ± 10.3 | 67.0 ± 15.9 | < 0.05 [a,c] |
| 4 degree | 55.1 ± 16.2 | 82.6 ± 18.5 | 61.5 ± 18.8 | < 0.05 [a,c] |
| 6 degree | 45.4 ± 17.9 | 82.0 ± 13.5 | 66.7 ± 19.5 | < 0.05 [a,b,c] |
| *P* value | < 0.05 [d,e] | NS | NS | |

Data are mean ± SD. Statistical comparisons were performed with repeated measures ANOVA followed by Bonferroni *post hoc* test. Within block comparisons: significant difference was found between [a], Type 1 *vs* Type 2; [b], Type 1 *vs* Type 3; and [c], Type 2 *vs* Type 3. Between block comparisons: significant difference was found between visual angles [d], 2 *vs* 4 degrees; and [e], 2 *vs* 6 degrees. NS, not significant.

Figure 3 shows the timeline for each block of the experiment. First, when experimental the setup was ready, there was a pseudorandomized 1,000-2,000 ms waiting time (1,500 ms on average) and only red plus sign was shown in the middle of the computer screen before showing the stimuli. Then, one pair of stimuli were shown simultaneously on the left and right sides of the red plus sign for 200 ms. After that, the participants needed to press a corresponding button on the response pad within 1,000 ms to record the RT. This completed 1 trial of experiment and the next pairs of word were repeated as mentioned above until 180 pairs of words were shown. After the block finished, a rest of 5-10 minutes was allowed for the participant to blink, drink water, or move the head and neck to relax. Each block took about 7-10 minutes and lasted about 45 minutes total.

**Behavioral response measurement and analysis**

The behavioral response was recorded by using the Stim2 software. The performance accuracy was calculated by dividing the number of correct responses by the total number of stimuli, and multiplied by 100 (reported in percentage). Only the RTs of correct responses were used for statistical analyses.

For behavioral data analyses, RT was presented as mean ± SD (RTs of above 1,000 ms were excluded). For CR and RT analyses, repeated measures analysis of variance was applied followed by Bonferroni *post-hoc* test for multiple comparison to identify whether there was any difference between factors, for both within block comparison (types of stimuli: 1, 2, and 3), and between blocks comparison (visual angles: 2, 4, and 6 degrees). Statistical significance was set at $P < 0.05$. The normality of CR and RT data were tested with Kolmogorov-Smirnov test and found that the data were normally distributed.

## Results

### Correct rate (CR)

**Within block: Comparisons among Type 1, 2, and 3 stimuli**

At 2 degrees, a significant main effect of stimulus type on CR was demonstrated (F (2, 58) = 33.98, $P <$ 0.001, ηp² = 0.54). *Post hoc* comparisons showed that the CR response was significantly higher for Type 2 stimuli (Mean ± SD, 85.6 ± 10.3%) than for Type 1 and Type 3 stimuli (63.9 ±15.3% and 67.0 ± 15.9%, respectively) in 2 degrees representing the edge of foveal and parafoveal regions ($P < 0.001$) (Table 1, Figure 4). There was no significant difference between Type 1 and Type 3 stimuli.

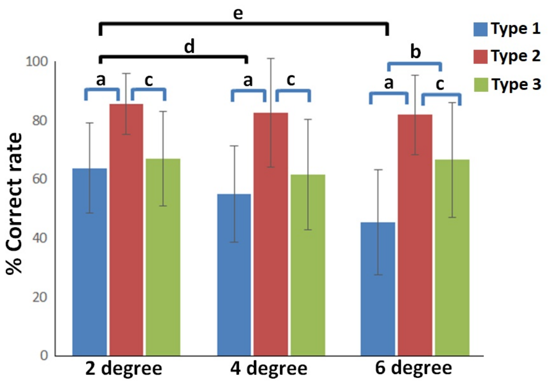



**Figure 4** Comparison of percent CRs within block (among stimulus types) and between blocks (among visual angles). Data are mean ± SD. Statistical comparisons were performed with repeated measures ANOVA followed by Bonferroni *post hoc* test. For abbreviations, see Table 1 legend.

At 4 degrees, a significant main effect of stimulus type on CR was demonstrated (F (2, 58) = 33.35, $P <$ 0.001, ηp² = 0.54). *Post hoc* comparisons showed that the CR response was significantly higher for Type 2 stimuli (82.6 ± 18.5%) than for Type 1 and Type 3 stimuli (55.1 ± 16.2% and 61.5 ± 18.8%) in 4 degrees representing the parafoveal region ($P < 0.001$) (Table 1, Figure 4). There was no significant difference between CRs of Type 1 and Type 3 stimuli.

At 6 degrees, a significant main effect of stimulus type on CR was demonstrated (F (2, 58) = 61.8, $P <$ 0.001, ηp² = 0.68). *Post hoc* comparisons showed that the CR response was significantly higher for Type 2 stimuli (82.0 ± 13.5%) than for Type 1 and Type 3 stimuli (45.4 ± 17.9% and 66.7 ± 19.5%) in 6 degrees representing peripheral visual region ($P < 0.001$). However, CR responded to Type 3 stimuli was significantly higher than Type 1 stimuli ($P = 0.01$) (Table 1, Figure 4).

**Between block: Comparisons among 2, 4, and 6 degrees visual angles**

In response to Type 1 stimuli, a significant main effect of degrees of visual angles on CR was demonstrated (F (2, 58) = 28.56, $P < 0.001$, ηp² = 0.50). *Post hoc* comparisons showed that the CR response was significantly higher for 2 degrees (63.9 ± 15.3%) than for 4 degrees (55.1 ± 16.2%; $P =$ 0.002) and 6 degrees (45.4 ± 17.9%; $P < 0.001$). Besides, the CR of 4 degrees was also significantly higher than that of 6 degrees ($P = 0.002$) (Table 1, Figure 4).

In response to Type 2 stimuli, a non-significant main effect of degrees of visual angles on CR was demonstrated (F (2, 58) = 1.14, $P =$ 0.326, ηp² =

**Table 2** Reaction time (RT) in response to to Type 1, 2, and 3 stimuli at visual angles of 2, 4, and 6 degrees.

| Visual angles | RT (ms) Type 1 | Type 2 | Type 3 | *P* value |
|---|---|---|---|---|
| 2 degree | 605.7±57.6 | 538.0±61.9 | 579.5±68.2 | < 0.05 [a,b,c] |
| 4 degree | 607.6±77.6 | 528.7±74.7 | 570.3±83.7 | < 0.05 [a,b,c] |
| 6 degree | 614.7±59.9 | 536.2±66.0 | 558.5±74.8 | < 0.05 [a,b,c] |
| *P* value | NS | NS | NS | |

Data are mean ± SD. Statistical comparisons were performed with repeated measures ANOVA followed by Bonferroni *post hoc* test. Within block comparisons: significant difference was found between [a], Type 1 *vs* Type 2; [b], Type 1 *vs* Type 3; and [c], Type 2 *vs* Type 3. Between block comparisons: no significant difference was found among visual angles 2, 4, and 6 degrees. NS, not significant.

0.04). There were no significant differences among CRs of 2, 4, and 6 degrees (Table 1, Figure 4).

In response to Type 3 stimuli, a non-significant main effect of degrees of visual angles on CR was demonstrated (F (2, 58) = 3.18, $P = 0.06$, $\eta p^2 = 0.10$). There were no significant differences among CRs of 2, 4, and 6 degrees (Table 1, Figure 4).

**Reaction time (RT)**

**Within block: Comparisons among Type 1, 2, and 3 stimuli**

At 2 degrees, a significant main effect of stimulus type on RT was demonstrated (F (2, 58) = 34.69, $P < 0.001$, $\eta p^2 = 0.55$). *Post hoc* comparisons showed that the RT response was significantly shorter for Type 2 stimuli (538.0 ± 61.9 ms) than Type 1 and Type 3 stimuli (605.7 ± 57.6 and 579.5 ± 68.2 ms; $P < 0.001$). Moreover, the RT of Type 3 stimuli was significantly shorter than RT of Type 1 stimuli ($P = 0.009$) (Table 2, Figure 5).

At 4 degrees, a significant main effect of types of stimulus on RT was demonstrated (F (2, 58) = 51.26, $P < 0.001$, $\eta p^2 = 0.64$). *Post hoc* comparisons showed that the RT response was significantly shorter for Type 2 stimuli (528.7 ± 74.7 ms) than Type 1 and Type 3 stimuli (607.6 ± 77.6 and 570.3 ± 83.7 ms; $P < 0.001$) (Table 2, Figure 5). Furthermore, the RT of Type 3 stimuli was significantly shorter than RT of Type 1 stimuli ($P < 0.001$).

At 6 degrees, a significant main effect of types of stimulus on RT was demonstrated (F (2, 58) = 52.98, $P < .001$, $\eta p^2 = 0.65$). *Post hoc* comparisons showed that the RT response was significantly shorter for Type 2 stimuli (536.2 ± 66.0 ms) than Type 1 and Type 3 stimuli (614.7 ± 59.9 and 558.5 ± 74.8 ms; $P < 0.001$) (Table 2, Figure 5). Moreover, RT of Type 3 stimuli was significantly shorter when compared with RT of Type 1 stimuli ($P < 0.001$).

**Between block: Comparisons among 2, 4, and 6 degrees visual angles**

In response to Type 1 stimuli, a non-significant main effect of degrees of visual angles on RT was demonstrated (F (2, 58) = 0.43, $P = 0.66$, $\eta p^2 = 0.01$). There were no significant differences in RTs among

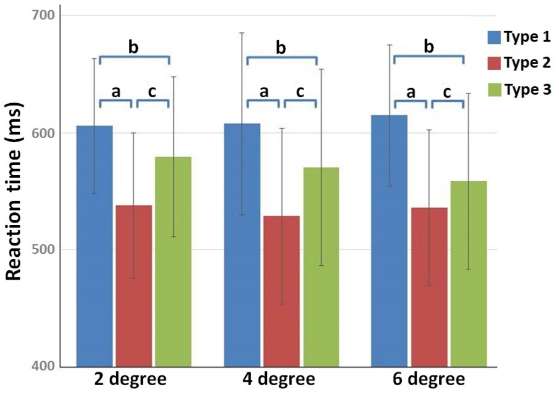



**Figure 5** Comparison of reaction time (RT) within block (among stimulus types) and between blocks (among visual angles). Data are mean ± SD. Statistical comparisons were performed with repeated measures ANOVA followed by Bonferroni *post hoc* test. For abbreviations, see Table 2 legend.

Type 1 stimuli in 2, 4, and 6 degrees (Table 2, Figure 5).

In Type 2 stimuli, a non-significant main effect of degrees of visual angles on RT was demonstrated (F (2, 58) = 0.51, $P = 0.61$, $\eta p^2 = 0.02$). There were no significant differences in RTs among Type 2 stimuli in 2, 4, and 6 degrees (Table 2, Figure 5).

In the Type 3 stimuli analysis, a non-significant main effect of degrees of visual angles on RT was demonstrated (F (2, 58) = 1.96, $P = 0.15$, $\eta p^2 = 0.06$). There were no significant differences in RTs among 2, 4, and 6 degrees (Table 2, Figure 5).

## Discussion

CRs were calculated to show the percent correctly answered by the participants among all of the responses to the visual stimuli. Attention was the major factor to get a higher CR and it was a basic but complex cognitive process containing multiple sub-processes which were specialized for many aspects of attentional processing.[17,18] Visual attention is paid by focusing on a limited region of the visual field and modulation of visual attention in foveal region is more precise than parafoveal region.[8] Besides, previous studies about the accuracy results show that at least some word identifications are possible based on parafoveal information alone, and the presence of more than one task-relevant word causes interference due to some processing capacity taken up by suppressing saccades toward the parafoveal words.[19,20]

In this study, within group comparisons of CR were highest in Type 2 stimuli when compared with Type 1 and 3 stimuli at 2 (around 87%), 4 (around 83%), and 6 (around 82%) degrees, respectively. These results indicated that Type 2 stimuli resulted in higher CR and could be rapidly identified than Type 1 and Type 3 stimuli. This was due to the fact that Type 2 stimuli (Figure 6B) were completely different in each letter position, whereas Type 1 stimuli (Figure 6A) had no different letters at all and Type 3 stimuli (Figure 6C) had only middle letter difference.


**Figure 6** Demonstration of outlines or orthography of (*A*) Type 1, (*B*) Type 2, and (*C*) Type 3 stimuli.

Moreover, all CR of Type 2 stimuli were higher than 80% indicating that the participants could recognize or identify the paired words accurately. However, the CR of Type 1 and Type 3 stimuli ranged from 45% to 64% and 62% to 67%, respectively, indicating that the paired words of Type 1 (completely the same) and Type 3 (almost the same but different in the middle letter of a trigram) were difficult to recognize or identify even at 2 degrees apart.

Besides, CRs were progressively decreased (63.9%, 55.1%, and 45.4%) when the visual angle was wider in Type 1 stimuli at 2, 4, and 6 degrees, respectively. According to the visual span profile analysis on reading, central fovea region yields highest accuracy (80-100%) when compared with wider areas in the visual spans.[2] However, this was not found in Type 2 and Type 3 stimuli, indicating that it was contrary to previous study about visual attention which is paid by focusing on a limited region of the visual field and modulation of visual attention in foveal region is more precise than parafoveal region.[8]

At 6 degree, CR of Type 2 stimuli was highest, followed by that of Type 3 and Type 1 stimuli (Figure 4), respectively. This indicated that, at peripheral vision, completely different words could be easiest identified, whereas two identical words and two nearly identical words were more difficult to discern, possibly caused by orthographic processing. Orthographic processing depends on the contour of the stimuli (Figure 6) which could help participants guess when the stimuli could not be clearly identified at wider visual angles.[21] Apart from 6 degree, Type 1 and Type 3 stimuli were not different at 2 degrees and 4 degrees. This suggested that Type 1 and Type 3 stimuli were hard to identify because Type 3 was only different in the middle letter. According to this data, it can be due to the working memory performance of the participants because working memory is important to make prediction of complex cognitive abilities.[22] Semantic memory processing, on the other hand, is responsible for interpretation of how meaning-related information was stored in the brain including the correctness of word type differences.[23] It could be concluded that orthographic processing is sensitive when the visual span is wider and the readers will guess when they cannot see the stimuli clearly by using the shape and size of the stimuli.[21]

Therefore, it was proposed that Type 2 stimuli could be easily identified, and Type 1, and 3 stimuli could be more difficult to identify because of orthographic processing of the brain rather than lexicosemantic processing.

The result of this study is contrary to a previous study, showing that RT was faster in the foveal region when compared with the parafoveal region.[13] Our data revealed that Type 2 stimuli (completely different words) had shortest RT in every visual angle (2, 4, and 6 degrees). In this study, RT of Type 2 stimuli (about 530 ms) was fastest when compared with Type 1 (605 ms) and Type 3 (580 ms) at 2 degree (foveal region). It implied that participants could not completely recognize or understand both words displayed within 2 degrees (at the foveal edge). Type 1 and Type 3 stimuli had lower CR than Type 2 stimuli because Type 2 stimuli can be easily identified with orthographic processing, and hence, Type 2 stimuli resulted in a faster response. It was also found that RT of Type 2 stimuli was fastest in 4 degrees (parafoveal) and 6 degrees (peripheral region), respectively. Type 1 and Type 3 stimuli were difficult to identify when visual angles were wider. These data were almost similar to a previous result, describing faster response time for easily identifiable stimuli when preceded by a briefly presented matched-case identity prime than when preceded by a mismatched-case identity prime.[24]

These results showed that RT of Type 2 stimuli was shortest because they were completely different words, while Type 3 stimuli were almost the same but different in the middle letter of the word which was more difficult to identify with orthographic processing. Besides, RT of Type 3 stimuli was shorter than that of Type 1 stimuli at 2, 4 and 6 degrees, possibly caused by easier orthographic processing of Type 3 stimuli than Type 1 stimuli (Figure 6).

These data indicated that the type of the stimuli and the stimulus conditions were affected by the structural description in memory during visual recognition processing.[25] According to the visual recognition processing of the stimuli, when a participant sees stimuli (words), the brain processes the color, depth, and form of the stimuli first. Second, the information of similarity or distinct edge of the visual form is processed. Subsequently, structural description in memory is processed to see whether they understand or know the stimuli. Finally, the participants understand the representation of the meanings of the stimuli (lexicosemantically applied to the visual stimuli).[3,25] These sensory sets of information were transmitted and processed into memory, thought, etc,, and command motor neurons to elicit muscle contractions in response.[26] Therefore, when a participant saw Type 2 stimuli, (completely different words), decision of which response pad to press could easily be made.

CR and RT were commonly used in the fields of cognitive neuroscience and psychology. CR can be used for evaluating or detecting the performance accuracy and RT is used to detect how fast the participant's response is when stimuli come in. In this study CR was highest in Type 2 stimuli when compared with Type 1 and Type 3 stimuli in all visual angles. CR was decreased when visual angles were wider in Type 1 stimuli. In 6 degree, CR of Type 3 stimuli was higher than that of Type 1. Besides, CR of Type 1 stimuli at 2 degree was higher than those at 4 degree and 6 degree. RT of Type 2 stimuli was shortest when compared with Type 1 and Type 3 stimuli at 2, 4, and 6 degrees. RT of Type 3 was shorter than that of Type 1 stimuli at 2, 4, and 6 degrees.

These data indicated that the brain can clearly identify the words shown at the edge of foveal region rather than parafoveal and peripheral regions because the visual acuity is highest and the participants can easily read with semantic processing in the central foveal region. Moreover, the participants can identify some of the stimuli that were shown in parafoveal and peripheral regions. Even though, the stimuli shown in these two regions are not clearly identified, the participants seem to use orthographic processing of the brain by recognizing the shape and size of the stimuli. According to these findings, if the participants can identify the words by using the parafoveal and peripheral regions clearly, these people could be a faster reader. These results can be used to invent speed reading tools for slow readers to become faster readers.

## Conclusion

CR of Type 2 stimuli was highest in all visual angles (2, 4, and 6 degrees) and RT of Type 2 stimuli was shortest in all visual angles. This indicated that the CR and RT of Type 2 stimuli (completely different words) could be equally recognized at 2-6 degrees of visual angles. This is the first study to show that completely different words recognition was not affected by the wider visual angles which have less visual acuity, suggesting that orthographic processing in the brain may play a dominant role. More importantly, this implies that completely different words could be identified easily at the edge of fovea, parafoveal, and peripheral visual regions, possibly by orthographic processing. In everyday life reading, people almost always read two different adjacent words, thus there is a good chance to read quickly with wider visual angles.

According to the present study, if the CR and RT were processed by orthographic processing, then using trigrams of non-words in three different types (Type 1 – same two trigrams, Type 2 – completely different trigrams, and Type 3 – different only the middle letter of trigrams) should produce similar results as the present study. For further study, first, it is suggested that there should be an investigation on effects of two trigrams of non-word recognition evaluated by CR and RT in order to better understand visual non-word recognition. Moreover, electro-physiological studies should be explored in order to investigate whether the lexicosemantic processing plays parts in visual word recognition processing of the brain.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## Conflict of Interest

None.

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