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# Measuring Attention in Second Language Reading Using Eye-tracking: The Case of the Noticing Hypothesis

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Taking Schmidt's (1990) noticing hypothesis as point of departure this study aims to measure attention and learning gains during second language (L2) reading by making use of eye-tracking methodology. Relying on Robinson's hierarchical memory model (1995, 2003), it is hypothesized that vocabulary learning and attention are closely associated. After a vocabulary pre-test, seventy-five learners of English read a standard text individually while their eye movements were being recorded followed by an immediate post-test. The results revealed that learners spent more time on unknown words than they did on familiar ones. Attention and learning gains also positively correlated; fixation values on an unknown word increased its further recognition probability in post-test. Finally, the findings revealed a cut-off point of approximately 450ms as an activation threshold for noticing. Eye-tracking as a technique to measure attention in second language acquisition (SLA) was also discussed.

**Key words: Second language reading, eye-tracking, noticing hypothesis, attention**

## INTRODUCTION

Noticing, attention and consciousness in second language acquisition (SLA) have been controversial topics for more than 2 decades and still inspire many experimental studies in the field. While some researchers believe in the facilitative role of attention in second language learning by emphasizing its necessity and facilitative effect, others are more skeptical, approaching noticing and consciousness cautiously by advocating the unconscious aspects of SLA. As a form of weak interface hypothesis, the noticing hypothesis is grounded on the assumption that attention and learning are directly related: simply, people learn things they pay attention to and do not learn much about things they do not attend to (Schmidt, 2010). In his hypothesis, Schmidt (1990, 1992, 1993, 1994, 2001, Schmidt and Frota, 1986) claimed that consciousness at the level of noticing had a crucial role in second language acquisition and was necessary for learning. This claim was also supported by a number of researchers assuming that consciousness and focus on form have a critical role in SLA (Rutherford, 1987; Fotos, 1993, 1994; Fotos & Ellis, 1991; Long, 1991; Zalewski, 1993; Sharwood Smith, 1991, 1993; Robinson, 1995, 1996). However, objections emerged to this strong form of the hypothesis on the basis that the hypothesis was conceptually weak, vague and empirically untestable



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(Schmidt, 1990, 1993a, 1994, 1995; Tomlin & Villa, 1994; Truscott, 1998; Gass, 1997). Obviously this claim also countered Krashen's (1981, 1982, 1985) popular dual-system hypothesis which assumed that second language acquisition was a result of an unconscious system: conscious experiences in SLA were limited and peripheral, merely acting as a monitor and modifier of the unconsciously learned information which is also called as "input".

Using eye tracking methodology, the current research aims to elaborate the facilitative effect of noticing as a form of attention and its role in incidental vocabulary acquisition in second language (L2) reading. Rather than being too assertive and emphasizing the "vitality" of noticing in SLA, this research is grounded on the weak form of the hypothesis which treats attention as a facilitative quality. Relying on Robinson's (1995, 2003) hierarchical memory model which was founded on Cowan's (1988) model of memory, this research approaches attention (visual attention) as the medium through which input encoding occurs in working memory and is retrieved from long term storage. In terms of noticing, attentional mechanisms are responsible for allocating the cognitive resources that lead to noticing and encoding in memory (Robinson, 1995). In this way, visual attention on a linguistic stimuli during reading facilitates learning. In this respect, a vast amount of research proposed that vocabulary can be acquired incidentally while reading by attentional mechanisms (see Jenkins, Stein and Wysocki, 1984; Nagy, Anderson and Herman; 1987; Day, Omura and Hiramatsu, 1992; Laufer, 2003; Hulstijn, 2003; Laufer and Hulstijn, 2001). The core of this well-established assumption lies within learning psychology's proposal that repetition of new vocabulary items promotes their retention (Anderson, 2005; Baddeley, 1997). In other words, the frequency and amount of attention paid to encoding of input predicts its retrieval from long term storage. Noticing and incidental vocabulary acquisition are thus associated (see Laufer and Hulstjin, 2001), with the assumption that attention functions as a predictor and facilitator of vocabulary acquisition. In this respect, second language learners can learn new vocabulary through reading and the hypothesis is that attention and learning gains in SLA are positively associated.

*Previous Methods of Measuring Attention in SLA*

The relationship between attention and SLA has been explored through a number of methodologies ranging from online to offline protocols including verbalizations, note taking, underlining, questionnaires and eye tracking. A detailed table is given below:

*Table 1*
*Previous related research and techniques*

| Technique | Related Research |
|---|---|
| Note taking | Hanaoka, 2007; Izumi, 2002. |
| Underlining | Izumi & Bigelow, 2000; Izumi, Bigelow, Fujiwara, & Fearnow, 1999; Uggen, 2012. |
| Stimulated recall (Retrospective verbalization) | Adams, 2003; Mackey, 2004; Mackey et al., 2000; Mackey et al., 2002; Morris & Tarone, 2003; Nabei & Swain, 2002; Egi, 2004, Philp, 2003. |
| Questionnaires | Alanen, 1995; Mackey et al., 2002; Robinson, 1995b. |



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| | |
|---|---|
| Concurrent think-aloud protocols | Alanen, 1995 ; Hama & Leow, 2010; Leow & Morgan-Short, 2004; Swain & Lapkin, 1995; Jourdenais, Ota, Stauffer, Boyson, & Doughty, 1995; Leow, 1997 , 2000, 2001; Rosa & Leow, 2004; Rosa & O'Neill, 1999; Sachs & Polio, 2007; Lai, Fei & Roots, 2008. |
| Eye tracking | Godfroid, 2010, 2013; Smith, 2012; Winke et al. 2013. |

In general, verbal reports are the most common technique used to measure noticing in SLA. It can be classified into two major groups: concurrent think-aloud protocols and retrospective think-aloud protocols. The first technique refers to online verbal measurement of noticing during the task, while retrospective think-aloud protocols are post-task procedures. Concurrent think-aloud procedures require participants to verbalize their attention during the task. As task requirements and verbalization take place simultaneously, the effectiveness of this technique is open to debate due to reactivity. Having a detrimental effect on learner performance during the task, reactivity refers to the cognitive overload caused by simultaneous cognitive demands. The study by Sachs and Polio (2007) used concurrent verbalization to examine the effectiveness of written error corrections versus reformulations of second language learners' writing. The results of the study revealed a considerable reactivity effect due to concurrent verbalization. In contrast, the study by Leow and Morgan-Short (2004) found no remarkable reactivity effect in concurrent verbalizations. However, when the limited capacity of attention and working memory is considered, concurrent think-aloud protocols should be handled with care.

Another verbalization technique is stimulated recall: this is a popular retrospective procedure used to obtain participants' comments in an interview setting with visual and auditory cues identical to those of the original task. As verbalization takes place after the task, it is assumed that stimulated recall suffers from memory limitations and a time decay effect which limit tasks to very short periods - about 10 seconds (Ericsson & Simon, 1993). Egi (2004) employed a pre-test–treatment–post-test design with two groups to compare the robustness of the immediate retrospective verbal report technique and the technique of stimulated recall with video clues. The study's qualitative results suggested that immediate reports are more effective than stimulated recall. In addition, stimulated recall is time consuming due to its interview format and use of audio-video editing (Gass & Mackey, 2000).

Questionnaires are self-reports with highly subjective data. Mackey et al. (2002) used a noticing questionnaire with 5 questions as the final phase of their study. In their research this exit questionnaire was only an auxiliary technique for listening span tests, non-word recall tests and communicative tasks. Due to their highly subjective nature, questionnaires and Likert-scales are not commonly employed in noticing research.

Another technique used to measure noticing in SLA is underlining and note taking. Being a spatial technique, underlining requires learners to underline the words or linguistic items which



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attracted their attention. Izumi et al (1999) and Izumi & Bigelow (2000) tested participants' noticing function of output by asking them to underline parts of sentences they thought were "particularly necessary" for subsequent (re)production. Their research findings emphasized the subjective nature of underlining and argued that the ease and speed of underlining may distort the precision of the acquired data. Uggen (2012) took this technique further by blending underlining and stimulated recall in order to investigate second language (L2) learners' processes in output-input-output sequences. In this study, this triangulation revealed that stimulated recall is a more robust technique than underlining. In their studies, Hanaoka (2007) and Izumi (2002) employed a note-taking technique by asking participants to take notes about difficulties they face and the words they think important.  Like underlining, note taking is online but still too subjective: what to note down varies from learner to learner. In addition, all these techniques can only provide spatial data by pointing out the place of a reader's attention. The temporal aspects cannot be obtained; the amount of attention to the place of attention cannot be measured.

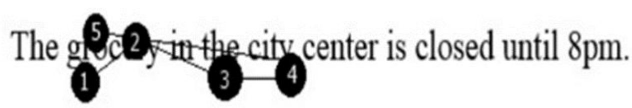
Eye tracking differs from the aforementioned conventional methodologies measuring attention in second language. It is quite a recently developed technique for measuring attention in SLA, and can provide highly robust, objective data. As the temporal and spatial data acquired are relatively objective, this technique is promising in exploring attention and consciousness issues in SLA.

*Eye Tracking in Second Language Research*

Eye tracking refers to the online measurement of eye movements via infrared illumination. Simply put, infrared reflected onto the cornea pursues eye movements on a screen or in natural environments with the help of a micro camera. The movements are recorded with the aid of dedicated software including an eye tracking algorithm. Within visual information processing including reading, two basic movements are registered: fixations (the place and duration of the eye fixation) and saccades (ballistic and rapid movements of the eye from one point to another). Eye tracking research in psychology is based on the "Eye-Mind Hypothesis" (Just & Carpenter, 1980) which assumes that eye movements and cognitive processes are closely linked.

Eye movement research in the context of reading, mean fixation duration in silent reading is about 225ms and mean saccade length is about 8 letters (Rayner, 1998). The most common measures of eye movements are first fixation duration, gaze duration, second pass time and total fixation duration. A scanpath example is given below:

*Figure 1. A scanpath example*



Gaze duration (fixation#1+2) refers to the sum of all successive fixations in the AOI until a following saccade regresses or exits out of the region. Second pass time (fixation#5) is calculated when a participant exits the AOI by making a forward saccade or a regressive saccade out of the region but then returns to the same AOI and rereads it. As the most common eye



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movement index, total fixation duration (fixation#1+2+5) refers to the sum of all fixation durations on the related AOI regardless of the type of fixation. Total fixation duration is therefore calculated by summing any fixation duration on the related AOI by dismissing its characteristic features such as whether or not it follows a regression or a second pass. First fixation duration and gaze duration indicate processes associated with early word recognition skills such as recognition of orthography, phonology and morphology. Inflated values for either of these indicate problems with initial word recognition processes. Second pass time is more syntactic and discursive; inflated values in this indicate an inability to recognize the word in a sentential construct. Total fixation duration is a general panorama giving clues about the overall cognitive load and word familiarity.

Having a long history in psychology research, eye tracking has revealed many issues in the psychology of first language reading behavior since the 1980s. Related native language (L1) research showed that when reading English, readers' eye fixations last about 200-250ms, the mean saccade length is 7-9 letter spaces and that 10-15% of the saccades are regressions (Rayner, 1998). Carpenter and Just (1983) point out that content words are fixated about 85% of the time, whereas function words are fixated about 35% of the time. There is a clear relationship with fixation duration and word length; as the length of a word increases, fixation duration on that word tends to be higher (Rayner & McConkie, 1976). Function words are shorter and easier to deduce from the context when compared to longer content words which also bear more complicated semantic nature. As a result, content words are fixated more and skipped less by the reader. 2-3 letter words are only fixated around 25% of the time, whereas words of 8 letters and longer are almost always fixated, and are often fixated more than once. Moreover, readers tend not to fixate in the blank spaces between words (Abrams & Zubel, 1972). In addition to length effect, frequency, familiarity, number of meanings, morphology and even age of acquisition are predictors of eye movements in reading (Rayner, Raney and Pollatsek, 1995; Williams and Morris, 2004; Juhasz and Rayner, 2006; Pollatsek, Hyönä, and Bertram, 2000). Regarding eye tracking, there is a marked scarcity of eye tracking research in L2 reading. Recently, using eye tracking as a technique to explore L2 topics such as noticing, learner consciousness and awareness has started to become popular. Research by Godfroid et al. (2010, 2013) focused on the role of attention and noticing in SLA, using eye tracking to measure noticing. With 28 participants, they analyzed the fixational values of pseudo-words and known words. In their within-subject design they estimated the facilitative role of noticing in the development of word recognition skills. Their results indicated that one second more attention on a pseudo-word increased its recognition probability in post-test by 8%. Similarly, Smith (2012) investigated the role of eye tracking technology in measuring noticing during SCMC with 18 participants. In his research, participants engaged in an online short chat interaction task with a native speaker. This research cross-validated eye tracking and stimulated recall, and concluded that eye tracking was a promising technique to investigate attention and noticing in SLA. In other research, Winke et al. (2013) scrutinized the caption-reading behavior of foreign language learners through eye tracking methodology to investigate cross-linguistics effects. The main aim of



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this research was to define the effect of native language on foreign language behavior. The findings showed that native language significantly affected the reading times in foreign language. Arabic learners are found to spend more time on captions than other learners from different languages. Chinese learners are observed to have spent comparatively less time on captions in the unfamiliar content video. Siyanova et al. (2011) used eye tracking to scrutinize the idiom processing of L2 learners. They used metaphoric expressions as stimulus, with 36 learners participating in their research. According to their results native speakers were better at idiom processing when compared with non-natives. In addition, non-natives were observed to have processed idioms and novel words at identical speed. Research by Liu (2014) using eye tracking examined the effect of morphological instruction in a second language. In this between-subjects research, 68 learners received traditional and morphological instruction on vocabulary learning for 7 weeks. This instruction aimed to increase learners' morphological awareness and competence to make them develop better word recognition strategies. According to the results, learners who received morphological instruction showed higher fixation-duration on morpheme areas, while other learners did not show the same sort of behavior. In addition, learners who received morphological instruction showed better success in post-test.

## CURRENT RESEARCH

This current research paper aims primarily to validate the use of eye tracking to measure attention in second language reading. In contrast to previous research, the present research aims to examine attentional differences between known and unknown words in detail, to elaborate on the facilitative role of noticing as a form of attention and to discuss any potential threshold of noticing in second language reading by using eye tracking. To reveal the link between linguistic stimuli and eye movements during reading is significant as attention is still a controversial topic in the field of SLA. Eye-tracking technique enables robust and online registration of the time (msec) spent on linguistic items regarding word familiarity and learning through language exposure. Three main research questions were addressed:

1. Is there a significant linear relationship between learners' fixation values and word familiarity? If so what is the effect of word familiarity on total fixation duration during L2 reading?

2. Does the fixation duration on an unknown word affect its further recognition?

3. What is the amount of attention required to trigger learning a new word?

## METHODS

### *Participants*

82 participants took part in all procedures of the experiment and received course credit for their participation. 7 participants were excluded due to the following reasons: the eye movement data of 4 participants was below %90 valid sample rate; 2 participants had a different L1 background; and 1 participant failed a comprehension check test. All participants were university students in an ELT department, possessing at least B1 level (B1= 27, B2=38, C1=10), within the age range 19 to 22. All of the participants started to learn English after a



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certain age in Turkey with the same L1 background. In total, 75 participants (12 males and 63 females) were included in the data analysis. All participants had normal or corrected to normal eyesight.

*Designing and Defining AOIs*

This research is a within-subject design with a pre-test and post-test. All participants were exposed to the same group of 15 vocabulary items. The areas of interest (AOIs) were 15 words given in the table below chosen depending on a number of criteria:

*Table 2. Words as AOIs*

| AOI | LENGTH (characters) | FREQUENCY |
|---|---|---|
| To travel | 6 | 36197 |
| Survey | 6 | 32827 |
| Traveler | 8 | 2907 |
| Billion | 7 | 66979 |
| Mainstay | 8 | 772 |
| Domestic | 8 | 27446 |
| Combined | 8 | 19895 |
| Agriculture | 11 | 11750 |
| Souvenirs | 9 | 1033 |
| Accommodation | 13 | 2133 |
| To spring up | 9 | 328 |
| Catering | 8 | 1670 |
| To pour into | 9 | 874 |
| Retail | 6 | 10624 |
| Manufacturing | 13 | 12034 |
| MEAN | 8,60 | 15164 |

To keep homogeneity and minimize any control effect of length and frequency on fixation duration, both long and short words with higher and lower frequencies were used. To keep a balance regarding word familiarity, both high and low frequency words were included depending in COCA (Corpus of Contemporary American English). The mean length for words was 8,60; the mean frequency was 15,164; and the average word recognition success was 56%.

*Text Stimulus*

This study aims to measure attention in natural L2 reading without manipulating linguistic features. To promote validity and reliability a standard IELTS (International English Language Testing System) General Reading passage was retrieved from the internet (www.ielts-exam.net/docs/reading/IELTS_Reading_General_13_Passage_1.htm.). The reading passage comprised 203 words, 1297 characters and 11 sentences. The extracted passage was divided into 2 homogenous parts ready to be visualized on a 23’’ TFT monitor. To promote natural reading, the passage was presented as a whole rather than in sentence by sentence fashion. To avoid any bias and to check whether participants really read for comprehension purposes in parallel with the purpose of the experiment, a multiple choice comprehension test with 3 items was prepared by the researcher. The comprehension check test aimed to assess if learners really read for comprehension purposes. First question assessed the main topic of the paragraph and last 2 questions tested some details such as numbers and places mentioned in the text. This test was given to the participants right after the eye tracking session. Most participants were observed to have responded correctly for all 3 questions.

*Pre-test and Post-test*

To assess participant word familiarity on 15 AOIs, a vocabulary knowledge scale as both unannounced pre-test and immediate post-test was designed (see Joe, 1995; McNeill, 1996;



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Scarcella and Zimmerman, 1998; Wesche and Paribakht, 1996). In this scale learners were required to choose the best of 3 options: “I know the word”; “I am familiar but not sure”; and “I have no idea”. If one of the first 2 options were chosen, participants should write the Turkish meaning(s) or their predictions about the word. This scale is used in unannounced pre-test and post-test procedures. The familiarity option was used to ensure that learners had minimal word recognition on a certain word.

### *Apparatus*

Eye movements were recorded with the Tobii TX300 with a sampling rate of 300Hz, equivalent to a temporal resolution of 3.3ms. The Tobii TX300 allows large head movements and provides a natural experimental setting without chinrest. For eye movement data acquisition, visualization and analysis, Tobii Studio Enterprise Software 3.2.3 was used.

### *Procedure*

All participants were volunteers, naïve to the research questions and tested individually. To ensure that all learners were at least B1 level, a sample IELTS General Reading test was conducted. Before starting the eye tracking session, the participants individually took the vocabulary knowledge scale as the pre-test at least 1 hour before eye tracking experiment to minimize any priming effect. Then each participant sat for the eye tracking session one by one within the control of the researcher. They were instructed to read the passage silently for comprehension purposes. To avoid anxiety and emotional arousal which might cause reactivity, no time limit was given; participants were asked to read freely and naturally to understand the text. Calibration was done with a 9 point grid calibration setting. The texts were presented in Times New Roman, 18-pt font, on a 23’’ monitor with 1920x1080 screen resolution set up at 67 cm from the participants’ eyes. Right after the experiment, each participant took the unannounced immediate post-test individually. At this step, they also took the brief comprehension check test.

## RESULTS

All variables in the data set were observed to have been distributed normally. Regarding vocabulary scores, knowing the word by writing its meaning equaled to 2 points, familiarity and reasonable prediction equaled to 1 point and not knowing the word came up with no points. Word familiarity was coded dichotomously for GEE logistic regression procedure. The familiarity option as the control effect was not included. To reveal statistical differences for word familiarity and fixational values, each word was computed one by one with “if cases” for each participant. It refers to the statistical process to distinguish fixation values on known and unknown words. For a single participant, the related fixation value was calculated if the word is known or unknown. For instance, total fixation value on known words can be calculated accurately in this way. Long form data was used for GEE procedures and wide form was employed for “t” tests, Pearson correlation and linear regression. All statistical assumptions were tested and met, including normal distribution, linearity, sample size and outliers.

### *Analysis of Pre-test Data: Word Familiarity and Fixation Values*

For the first research question, it was hypothesized that word familiarity is a predictor of



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the attention paid to a word; unknown words were expected to have higher fixation values than known words. The findings indicated a negative relationship between vocabulary knowledge and total fixation duration at p <, 001 level; r (75) = -.618, p = .000. Specifically, linear regression with vocabulary scores as the predictor and total fixation duration as the dependent variable revealed a significant effect of vocabulary knowledge on total fixation duration; $\beta_1$= -14.321, t(74) = 6.721, p = .000. Vocabulary knowledge also explained a significant proportion of variance in total fixation duration: R2= .38, F (1, 73) = 45.173, p = .000. These results marked an influence by familiarity on attentional values: higher vocabulary knowledge brought about less total fixation values while lower scores caused inflated values. In other words, word familiarity has a crucial effect on total fixation duration; knowing the meaning of a word means less time spent on that word while more attention is paid to unknown words.

Technically, total fixation duration consists of first fixation duration, gaze duration and second pass time. For in-depth analysis, the mean values for each eye movement index are as follows:

*Table 3. Mean fixation values for known and unknown words*

| | *First Fixation (ms/SD)* | *Gaze Duration (ms/SD)* | *Second Pass (ms/SD)* | *Total Fix. (ms/SD)* |
|---|---|---|---|---|
| Known | 258 (47.8) | 364 (73.5) | 297 (143.8) | 379 (92.9) |
| Unknown | 276 (71.7) | 479 (143.7) | 405 (142.3) | 569 (164.6) |

The findings revealed a significant difference between total fixation duration regarding word familiarity: t(71) = -9.122, p = ,000. An identical effect was also observed for gaze duration: t(71) = -6,099, p = ,000, and second pass time: t(19) = -2.265, p = .035. Unlike these 3 metrics, first fixation duration was not found to be significant: t(65) =-1.642, p = .105. According to these findings, learner total fixation duration, gaze duration and second pass time were affected significantly by learners' familiarity with the words. Learners spent less time on the words they already knew and unknown words were attended to more. In detail, however, the same effect was not observed for the first fixation duration.

*Analysis of Post-test Data: Attention as a Facilitative Quality in L2 Reading*

Attentional mechanisms are responsible for allocating the cognitive resources that lead to noticing and encoding in memory (Robinson, 1995). Regarding learning gains, although the difference was not high, learners did significantly better in post-test, (M = 21, 77, SD = 4. 34) than they did in pre-test (M = 19, 21, SD = 4.44); t(74) = -6.524, p = .000. Based on the weak form of the noticing hypothesis and given that noticing as a form of attention can facilitate retention and incidental vocabulary acquisition in SLA, it is hypothesized that fixation values on an unknown word predict its further recognition and retrieval from long term memory. To estimate the further recognition rate, GEE Logistic regression was conducted. Generalized estimating equations (GEE) enable accurate data analysis for within-subject designs in which each participant is tested under the same several conditions with a dichotomous or binary outcome (Diggle, 2002; Ziegler, 2011). For GEE



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procedure, post-test results are nested within participants as the dichotomous outcome, and each fixation index (first fixation duration, gaze duration, second pass time and total fixation duration) was taken individually as the predictor covariate. To obtain a more meaningful $\beta_1$coefficient, the test was run with the covariate/100. The results of the odds calculation was multiplied by 1000 to obtain results for 1 second.

The results indicated that total fixation duration significantly predicted the post-test recognition: Wald $\chi 2$ (1) = 30.601, p = .000, $\beta_1$ = 0.222. To estimate the predictive power of total fixation duration on post-test recognition, related regression coefficients[1] were used. The calculation results revealed that 1 second longer total fixation by a reader on an unknown word increased its recognition in post-test by 11%. First fixation duration was also found to have a significant effect: Wald $\chi 2$ (1) = 11.544, p = .001, $\beta_1$= 0.187. The odds calculation depending on the regression coefficients[2] indicated that a 1 second longer first fixation duration on an unknown word increased its further recognition by 9%. Regarding gaze duration, a stronger significance was observed: Wald $\chi 2$ (1) = 21.485, p = .000, $\beta_1$ = .228. The estimation calculations[3] showed that 1 second longer gaze duration by a reader on an unknown word increased further recognition by 13%. Re-reading times were found to be relatively less significant; Wald $\chi 2$ (1) = 4.346, p = .037, $\beta_1$= .131. Thus, the odds calculation depending on regression coefficients[4] revealed only a 5% increase in post-test recognition with 1 second longer re-reading time. In general, learning gains and fixation values were found to be closely associated.

*Threshold for Noticing*

The findings in current research indicated a remarkable effect of fixation values on readers' further recognition of an unknown word. In this respect, however, the amount of attention required for this activation has not yet been clear. In Robinson et al (2012), Robinson mentioned a threshold for noticing across individuals; this is a potential amount of attention required to activate noticing. Smith (2012) claimed the threshold was about 500ms but this assertion remained untested. In this research, it is hypothesized that noticing is facilitative after an optimal level of attention. To test if a threshold for noticing exists, pre-test and post-test differences predicted by total fixation duration were plotted.

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1 Related regression coefficients for total fixation duration as the covariate are as follows: ($\beta_1$= 0.222, $\beta_0$ = -2.343 and Exp(β) = 1.248).

2 Related regression coefficients for first fixation duration as the covariate are as follows: ($\beta_1$ = 0.187, $\beta_0$ = -1.550 and Exp(β) = 1.206).

3 Regression coefficients for gaze duration as the covariate used in calculation are as follows: ($\beta_1$= 0.228, $\beta_0$ = -2.232 and Exp(β) = 1.256).

4 Related regression coefficients for rereading time as the covariate are as follows: ($\beta_1$= 0.187, $\beta_0$ = -1.550 and Exp(β) = 1.206).



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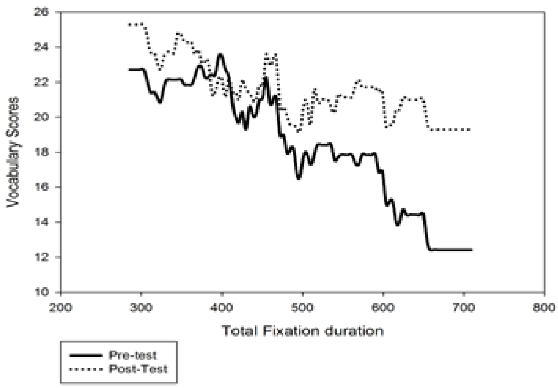
*Figure 2. Noticing Threshold*




Depending on the multiple spline curve plot, it was observed that the gap between pre-test and post-test started to expand and learning gains increased after approximately 450ms. Regarding test scores, attention levels of 400ms and below resulted with isomorphic vocabulary performance, yet the difference accumulated linearly with the increasing total fixation duration. Lower scores were more prone to the fixation effect; learners with lower scores fixated more and scored more in post-test. In this respect, the cut-off point for the total fixation value was about 450ms. According to these findings, an activation threshold for noticing exists which is slightly over 450ms.

## DISCUSSION

The aim of the current research was to use eye tracking to examine any familiarity effect on fixation values, to investigate the facilitative role of attention in incidental vocabulary acquisition during L2 reading and to scrutinize any potential activation threshold for noticing in SLA. Firstly, familiarity in word recognition is a strong predictor of attention during reading in L2. According to the findings, the amount of a reader's gaze duration, second pass time and total fixation duration on a word was predicted by word familiarity; knowing a word led to less attention being applied while not knowing it caused longer fixation values. Unknown vocabulary items were attended more, revisited more and required more total time to process. According to Staub and Rayner (2007), word frequency and word familiarity are two different factors of eye movements. While frequency is a fixed corpus based effect, familiarity is more reader oriented and is determined by a norming procedure in which participants rate how familiar they are with a given word. Indeed infrequent words are less prone to be recognized, however, a number of studies showed that familiarity effect during reading may be independent of frequency and readers tend to fixate less on words that they are familiar with (Chaffin et al., 2001; Juhasz and Rayner, 2003; Williams and Morris, 2004). When compared to these studies in L1, the results of the current research is confirmatory for L2 by indicating a similar notion of familiarity in a second language: L2 learners fixated less on the words they know, more on the words they did not know.

When learners meet a word, cognitive sources allocate attention according to the cognitive demands of the input. Robinson (2003) found that the attentional difference is a response to task demands, and attention is therefore allocated to meet these cognitive requirements. As a result, for an unknown word, learners' encoding is slower and demands more attention to be effective in working memory operationalization. Known words require relatively fewer cognitive resources and attention as they are already part of an encoded mental lexi-



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con. This difference in current research is not yet strong enough to draw conclusions about awareness in SLA but it can be assumed that learners somehow distinguish between unknown and known words. This perception can be regarded as "visual awareness" towards L2 linguistic stimuli.

On the other hand, no significance was observed for the first fixation duration - the first eye contact with a vocabulary item. This result contradicts the findings of research by Godfroid et al (2013) who found significant differences between novel and known words regarding first fixation duration. The main reason for the contradiction might be the nature of the stimuli used; while they used pseudo-words with different conditions, this research included natural words as stimulus. For this research, the natural words used contributed to fluency and caused different first fixation values. However, it should be noted that orthography has a remarkable impact on initial processing of words. First fixation duration is closely associated with the very initial phases of word recognition, including orthographic processing. The findings of the current research indicate that first fixation duration was not always necessarily associated with word familiarity but it might be affected by orthography-dependent factors. A number of eye tracking studies have shown that orthographic familiarity in reading was a crucial predictor of first fixation duration. Unfamiliar orthography or letter sequences cause longer first fixation duration (Lima and Inhoff, 1985) and initial letters of long words can influence first fixation values (Hyönä, 1995; Radach, Inhoff, & Heller, 2004; White & Liversedge, 2004, 2006). In this research, such orthographic manipulation did not exist and all learners were assumed to have proper orthographic familiarity even for the unknown words. Thus, first contacts with unknown and known words were identical. However, when learners progressed through the unknown words and became involved in text and discourse integration processes, they could not recognize morphological, syntactic and semantic features, and so gaze duration and re-reading times were inflated. These inflated values also inflated total fixation duration. In such cases, word recognition is at minimal level.

Secondly, the findings of the current research indicated an association between attention and learning gains; learners who gave more attention to unknown vocabulary items were found to have scored better in post-test. In the case of 1 second more attention, each fixation value was observed to have a significant effect on further recognition: total time by 11%, first fixation duration by 9%, gaze duration by 13% and re-reading time by 5%. Relatively, re-reading times were found to have the least effect on further recognition. Hence, early phases of word recognition were found to be critical. The results showed that when learners try to analyze an unknown word, their first and following successive fixations to the right mostly predicted further recognition. Possibly, learners' lack of lexical and syntactic skills led them to regress or look for clues in the following textual construct. However, turning back and re-reading an unknown word were found to have a minimal effect on further recognition. These findings supplement research by Godfroid et al (2013) who also found significance for total fixation duration but not for other measures, due to limited sample size (p. 507).

Finally, a potential threshold for noticing in SLA was examined. According to the findings, fixation values less than 400ms did not have a



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substantial effect on learning gains. After the 450ms cut-off point, learning gains started to accumulate. It can be assumed that a total fixation value over 500ms facilitates learning. However it should be noted that such a threshold is fragile and vulnerable to individual differences and task demands (Robinson et al., 2012). Factors such as aptitude, working memory capacity and task difficulty would surely have an impact on this cut-off point.

## CONCLUSIONS

This study examined the role of noticing as a form of attention in L2 vocabulary acquisition during reading, by using eye tracking methodology. The primary finding of the current research is that a direct relationship exists between attention and learning gains. Given that deeper attention leads to more learning (Schmidt, 1995, 2001), this research provides empirical evidence for the relationship between noticing and incidental vocabulary acquisition. Furthermore, different spatial and temporal values on known and unknown words indicated a kind of selectivity during reading. This selectivity strengthens the role of attention in learning; not only attention but also subsystems of attentional mechanisms are active in working memory during L2 reading. In addition, any potential threshold for noticing was explored and the findings indicated a possible consistent cut-off point over 450ms. Due to capacity limitations of working memory, noticing was found to be pedagogically facilitative roughly after 500ms. This threshold may vary due to individual differences and cognitive abilities (see Robinson et al, 2012). However, as eye tracking methodology is a quantitative technique measuring physiological features in response to linguistic stimuli, making strong claims about consciousness and awareness in SLA would be too phenomenological. Indeed such an assertive claim requires accumulating related physiological research triangulated with well-designed qualitative procedures. Consistent with research by Godfroid et al (2013), the key claim arising from these findings is that “learners are visually aware of the linguistic input”.

Beside all these findings, consistent results in current research showed that eye tracking is a suitable technique enabling in-depth analysis of attention with advanced spatial and temporal resolution in second language research. As eye movement data acquisition processes do not require any concurrent procedures, obtained data is free from reactivity and cognitive overload limitations. Unlike other conventional techniques measuring attention (e.g. note taking, underlining, concurrent verbalizations and retrospective procedures), eye tracking provides objective, robust and accurate data without being interfered with by memory decay, reactivity or subjectivity. On the other hand, using eye tracking is demanding and has a number of limitations. Technical challenges are always waiting for the second language researcher such as acquiring a fast system, recalibrating, monitoring participant eye movements with a remote software during the experiment to avoid drifts and offsets, being ready to face unexpected data loss and high noise levels due to external factors. Dealing with higher sample sizes regarding data acquisition and analysis especially requires considerable time. However, when cons and pros are scaled, the technique of eye tracking provides most robust and accurate attentional data. Surely, as related SLA research accumulates, future research is promising in which eye tracking can be triangulated with relevant tech-



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niques such as ERP and fMRI. With such cross-validation supported by qualitative findings, more will be revealed about the role of attention, consciousness and awareness in SLA.

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## APPENDICES

*Appendix 1: Text Stimulus (AOIs in bold)*

AUSTRALIA

Have you ever travelled to another part of your country and stayed for a few days? **Travel** within one's own country is popular throughout the world. And, according to a **survey** carried out in Australia in 2002, **travelers** are tending to spend more and more money on their holidays.

The **Domestic** Tourism Expenditure Survey showed that domestic travelers – those travelling within the country – injected $23 **billion** into the Australian economy in 2002. As a result, domestic tourism became the **mainstay** of the industry, accounting for 75 per cent of total tourism expenditure in Australia. International tourism, on the other hand, added $7 billion to the economy. Overall, in present dollar terms, Australians spent $7 billion more on domestic tourism in 2002 than they did when the first survey of tourist spending was completed in 1991.

Thus, tourism has become one of Australia's largest industries. The **combined** tourist industry now accounts for about 5 per cent of the nation's gross domestic product, compared with **agriculture** at 4.3 per cent and **manufacturing** at 8 per cent. Tourism is therefore an important earner for both companies and individuals in a wide range of industries. For example, the transport industry benefits from the extra money **poured into** it. Hotels **spring up** in resort areas to provide **accommodation**, and the **catering** industry gains as tourists spend money in restaurants. The **retail** sector benefits as well, as many tourists use their holidays to shop for clothes, accessories and **souvenirs**.

*Appendix 2: Sample pre-test and post-test*

| WORD | OPTIONS | TURKISH MEANING |
|---|---|---|
| AGRICULTURE | ☐ I KNOW THIS WORD! | |
| | ☐ I AM FAMILIAR BUT NOT SURE. | |
| | ☐ I HAVE NO IDEA! | |



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