VISUALIZATION WITH VOCABULARY TRACKING FOR ARABIC WORD RECOGNITION AND READING COMPREHENSION

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ABSTRACT

Comprehending text is the aim of reading; however, there is the phenomenon of non-Arabic speakers in Malaysia reading the Qur'an, written in Arabic, without comprehension. Word recognition (WR) theory, through word frequency effect (WFE) and word superiority effect (WSE), are used as a basis to achieve reading comprehension (RC) of the Qur'an. The Eye of Qur'an (EoQu) interface was developed, to visualise word occurrences and word morphology. This is achieved through parallel plot and word segmentation visualization. EoQu can track a user's personal vocabulary with a presentation of percentage and word position in the Qur'an. Consequently, users know their ability to recognize Arabic words in relation to the whole Qur'an to achieve RC. An experimental study was set up with 90 Malaysian participants, starting with a pre-test, followed by a stratified sampling to divide participants into control and experimental groups (who used EoQu) for the post-test. Results showed evidence of improvement in WR based on scores and time taken to complete the Arabic Word Recognition Test.

Keywords: ***Information visualization, reading, vocabulary, comprehension, Arabic word recognition***

1.0 INTRODUCTION

Reading is a process aimed at comprehension, often resulting in enjoyment, that involves complex cognitive processes and mapping of orthographical elements of the text to phonological elements [1]. There is also the case of reading enjoyably, extensively and fluently with little comprehension of the material, which represents reading the *Qur'an* for many Muslims. The *Qur'an* is written in Arabic; however, Muslims in Malaysia are native Malay speakers. One obvious reason for non-comprehension in this case is a vocabulary deficiency [2–4], or a simple lack of word knowledge [5–7]. This contrasts to the suggestion that at least 95% of the words in a text passage should be known [8] to comprehend a sentence.

Reading without comprehension also occurs because of the nature of the Arabic language. Many consider the language challenging to learn. There are many factors, such as the Arabic writing script being different from the familiar Malay and English Latin scripts used in Malaysia. In addition, Arabic script is cursive, thus one who does not know the language would see the writing as a continuous character, making it difficult to differentiate words. This is especially apparent for the writing system used to write the *Qur'an*. Additionally, Arabic has a vast vocabulary and a lack of knowledge of Arabic's root word system makes it difficult for non-Arabic speakers to deal with the language's complex morphological structure. Without knowledge of vocabulary and root words, one would struggle to search for the meaning of the word in a dictionary.

In Qur'anic reading classes (known as *Tajwid*), emphasis is on correct pronunciation of the written text, which is based on the requirement to preserve the *Qur'an* in its original form [9]. Qur'anic lessons to increase Islamic knowledge are attained separately throughout life. These lessons provide acquisition of knowledge of topics and themes, which are important for parts of the reading comprehension (RC) process, such as making inferences, word knowledge, and word relations. Although many Muslims cannot interpret the Arabic text, they may be familiar with many words in the *Qur'an* without realising it, since Malay language has many loan words from Arabic such as *waktu* (time) and *abjad* (alphabets).

Attending Arabic classes provides variable levels of achievement in Arabic proficiency, which is similar to second-language learning for English. Other language learning support to overcome comprehension problems includes pictorial sketches [10], learning frequent words [11] and word by word lessons [12]. These solutions suggest relations to several theoretical studies related to visualization, general RC and word recognition (WR). In theory, WR skills are important elements of achieving RC [13–14], where *word superiority effect* (WSE) [15–18] and *word frequency effect* (WFE) [19–20] help to solve the phenomenon of reading without comprehension. The WSE shows that a letter is easier to be recognize in known words compared to non-words; while the WFE shows that more frequent words are responded to more rapidly. Visualization of the WFE and WSE can be supported by learning technology using information visualization techniques.

We therefore envisaged that this study, which relates to visualization and WR, will support comprehension for those who have challenges comprehending classical Arabic words from the *Qur'an*. It is the aim of this study to develop a visualization system with vocabulary tracking to supports word recognition and then evaluate the effectiveness of the system through an experimental study.

The subsequent part of this paper is as the followings: the related literature based upon how the problem was approached through cognitive processes and proposed integrated model. Then, this paper outlines the methodology, results, discussion and finally conclusion.

2.0 APPROACHING THE PROBLEM

2.1 Cognitive Learning, Information Processing and Visualization

Cognitive learning views learning as restructuring and integration of pre-existing knowledge with newly acquired knowledge. Sensory (SM), short-term (STM) and long-term (LTM) memories are all involved throughout the process and are referred to as the information processing stages [21–22]. To acquire and integrate new knowledge into the LTM, it is required to first attract the attention of the SM from items of interest and recognisable patterns that may lead to new knowledge into the STM. Information is then passed on from the STM to the LTM through repeatable actions or rehearsal.

It is known that information from the SM transfers to the STM [23], also commonly known as active memory, where information is held for a short period. As an example, people tend to remember seven digit numbers more easily than to those with 10 digits. This information is easily forgotten if not rehearsed and organized in a meaningful manner to be more readily assimilated. In the context of learning, any action or movement, such as relating, explaining, or discussing, leads to active learning and reinforced learning [24]. Consequently, this results in improved recall of the learning material. This is the basis of the theory that students retain 90% of what they say as they do something.

Information visualization on the other hand aims to transform data into a perceptually efficient visual format [25]. However, mere static image visualization does not seem as effective when compared to information that is more interactive in nature. For example, interactivity operations that are tightly coupled with visualization fields can help users gain insight of data to be analysed. The act of exploring, interpreting and making deductions of data related to vocabulary visualization somehow relates to the rehearsal action that allows information to follow through the memory path from SM to STM and subsequently to the LTM.

2.2 Reading Comprehension and Word Recognition

Reading comprehension or RC involves several information processing steps that can be divided into three stages [13, 27]. Several opinions on RC exist; however, many point out that the first and lowest level in RC involves the process of decoding orthography (text) to phonology (sound) [1]. The second stage involves associating the text with its meaning. Lastly, the third and topmost level involves combining words to form ideas. In between the top and bottom levels, the process towards achieving RC involving word recognition or WR, known as the word level process, is considered important [13]. The WSE [15–18] and WFE [19–20] are the two most well-established theories related to achieving WR.

The WSE shows that a letter is easier to recognize in known words than in unknown words; whereas the WFE shows that more frequent words are responded to more rapidly. This implies that the SM and STM are involved in stages 1 and 2 in Fig. 1, as WFE and WSE are elements that attached to each other. Additionally, the word shape model [28] found that words are recognized as a whole in some studies. Studies also showed that letters are easier to recognize in known words [15–16] that lower case letters are read faster than uppercase letters [28], and that there was difficulty reading in alternating cases (such as the word AlTeRnAtInG) [29]. Many studies on WSE were conducted in languages using Latin alphabets, such as English and Dutch [8] This includes studies by McClelland and Johnson [18], Borowsky, Owen & Masson [30] and Estes and Brunn [31]. WSE has also been studied in non-latin writing scripts languages, such as Chinese and Arabic [31].

Forster and Chambers [20] and Starrfelt, Petersen and Vangkilde [15] conducted influential studies on WFE, found that words seen more frequently are responded to more rapidly. There are numerous studies adopting this model, such as Taft and Russell [33], Segui, Mehler, Frauenfelder and Morton [34] and Oweini and Hazoury [35]. Based on these studies, many researchers had developed a set of frequently used words that are taught in early stages of reading, especially to children [33][36]. For example, the Dolch list [37], consisting of 220 basic recognisable conjunctions, prepositions, pronouns, adverbs, adjectives and verbs, and the Fry list [38], consisting of 95 common nouns, where the first 100 words make up 50% of written material and the first 10 words of the 100 words make up 24 % of printed material. However, these lists are for the English language. Frequent words can also be obtained for other languages such as Arabic [34].

The crucial ingredient in developing comprehension is knowledge of the syntactical forms and word meanings, more commonly referred to as vocabulary development or semantic knowledge. This involves the active working memory, or the STM and the LTM, with the ability to remember and retrieve words in a sentence (step 3 in Fig. 1). Reading is also referred as a combination of processes in making inferences with knowledge, comprehension with monitoring and domain knowledge [1][13]. Understanding the literal meaning of text is highly integrated with inference ability and is developed with knowledge. This refers to the top-level process of reading, which needs significant input from the bottom level, such as from word level processes, WR and vocabulary. External factors towards achieving RC may involve general knowledge and aspects of the text's linguistic system, such as its orthography, phonology, morphology, syntax and lexicon.

2.3 The Proposed Model: Vocabulary Visualization for Word Recognition in Quranic Verses

Vocabulary is important, thus tracking and visualising it can be an essential part of the reading processing stage. Fig. 1 shows the word processing stages approach towards RC, while Fig. 2 shows our approach to solving the problem of RC for non-Arabic speakers when reading the *Qur'an* through visualization and vocabulary tracking. We propose an integrated model (Fig. 2) for WR in Qur'anic verses based on theoretical findings, summarised in Figure 1. This contains four main components: 1) WFE; 2) WSE; 3) vocabulary tracker with cognate words; and 4) visualization. The proposed model is based on 4 main foundations which are the repetitive nature of the Qur'anic words, the complex morphological structure of Arabic words, similarities of Arabic words and scripts to the local language and interactive vocabulary visualization as means of information processing for WR and RC. Detailed description of these are as follows:

First, the *Qur'an* contains many repeated words. There are 77,430 words in the *Qur'an*, and analysis of information gathered through the Qur'an Arabic Corpus [40] shows that there are about 5155 non-repeated words amounting to only 6.7% of all the words in the *Qur'an*. This fact could be used as a learning strategy in relation to WFE. Our approach is to attract the visual memory with a visualization of word frequency. For example, users might be more interested in learning words that occur more frequently. When users see a visualization of word frequency in the Qur'anic verses, they may be motivated to explore the meaning and location of those words. Therefore, information visualization of word meaning, word count and word position would be relevant in this context. Parallel plot was found to be a suitable visualization technique to facilitate this exploration [41].

Second, the WSE implies that those who are fluent in their recitation of the *Qur'an* would recognize most of the words. As discussed previously, the process of recognising Arabic words is complex compared to English due to the complex morphological structure of Arabic words, especially with regard to the following:

- An Arabic word token can contain more than a word consists of a preposition, pronoun and noun. For example the word معهم (ma ahum = with them) consists of two words مع (with) + هم (them)
- Arabic words, especially verbs, can exist in many forms based on their root words by adding prefixes, suffixes and infixes. For example the word جهد (jahada = "he strove") while اجتهد ("ijtihada"), a derivative word from جهد with a prefix " ا " and infix " ت" means "he worked hard".

Thus, when learning to recognize Qur'anic Arabic words, one should be exposed to various word forms and stems that originate from a root. It is thus considered essential to visualise Arabic word structures. In this way, learners can learn to recognize words in many forms. These words can include nouns, pronouns, prepositions and conjunctions as well as verbs.

Third, Arabic language is considered as an important language in the Muslim community; therefore, Arabic writing scripts have been adopted by many Muslim nations. For example, the Urdu script for writing Urdu or Tamil language and Jawi script for writing the Malay language are both originated from the Arabic script. In addition, many Arabic words have been adopted as part of the local language. Due to that, familiarizing users to cognate words through the Arabic Scripts should help in the word recognition and the reading comprehension process.

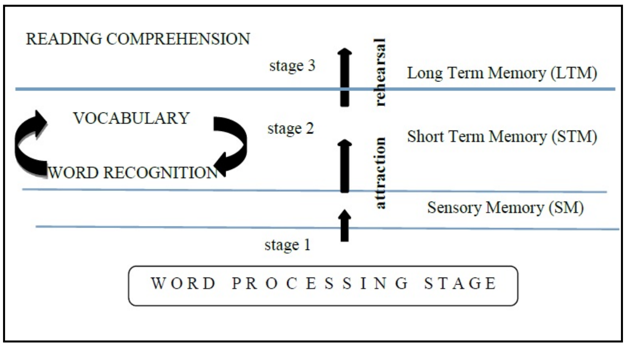


Fig 1: Word processing stages for reading comprehension

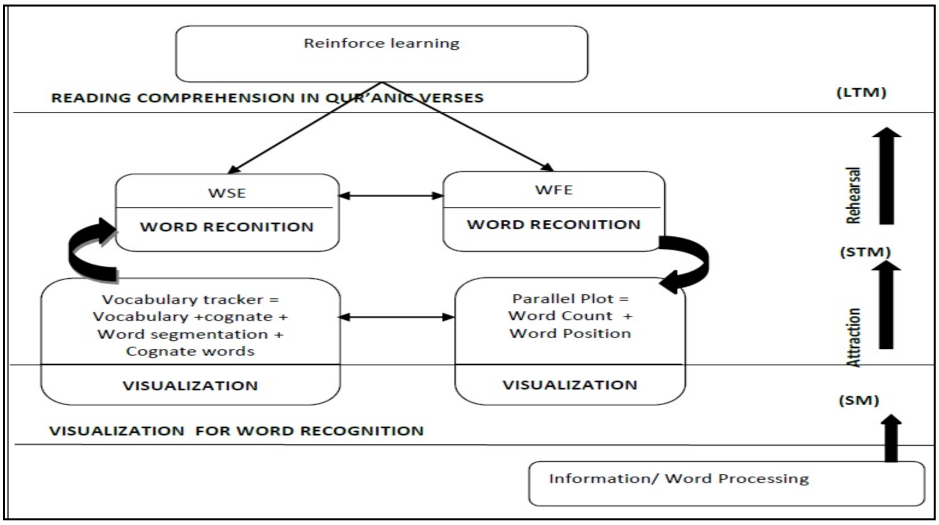


Fig 2: Integrated model

Lastly, many integrated processes related to cognitive information processing are required to achieve RC [13]. Word and information visualization as part of dynamic interaction is hypothesized to be able to help in achieving RC. The exploration of the visual display as part of the interactive system can contribute significantly to effectively data interpretation. Operations such as zooming, panning, selecting and rearranging contribute to how effectively one integrates pre-existing knowledge with new ones, subsequently resulting in the understanding of certain concepts [39]. This process can be seen as a mental exercise that facilitates the cognitive process by attracting SM and rehearsing information to get it into LTM.

If users have the options to keep track of, be reminded of and be shown their own vocabulary with respect to all the words contained in the *Qur'an*, then the vocabulary tracking system should lead to a better strategy for learning Arabic words in the *Qur'an*. The effects of word relation and predicting words within their context in a sentence, with the addition of existing knowledge of the theme or topic of the Chapters (*sura*) in the Book (*Qur'an*)*,* helps the integrated process and should be considered in the implementation.

3.0 THE METHODOLOGY

The specific objective of this research focuses on WR and is based on the hypothesis that visualization with a vocabulary tracking mechanism supports WR in the reading process to achieve RC. We adopted an experimental study set-up such as addressed by the Human-Computer Interaction (HCI) community [42]. The integrated model (in the previous section) was used as part of the hypothesised solution. The *Eye of Quran* or *EoQu* was designed and implemented, with embedded theoretical concepts from the integrated model. Finally, we evaluated 90 participants with an experimental setup based on the Arabic Word Recognition Test (AWRT).

With the focus of this study centred on the hypothesis that visualization with vocabulary tracking supports word recognition (H), we posed the following research questions:

- **Research Question 1**: Is there any significant effect on non-Arabic speakers in recognising the Arabic words with regard to:
- Before and after using the EoQu interface?
    - Groups using the EoQu interface and groups not using it?

- **Research Question 2**: Does age effect the performance of recognising Arabic words?

- **Research Question 3**: Does time to complete the test effect performance?

3.1 Participants

We selected 90 volunteers 19–60 years of age as participants in our study. 35 of the participants were 19–25 years old, 9 were 26–30 years old, 6 were 31–35 years old, 13 were 36–40 years old, 10 were 41–45 years old and 17 were more than 45 years old. Only those who could read but not comprehend the meaning of the *Qur'an* were selected. Participant educational backgrounds were: 4 with primary school as highest education, 18 with a secondary certificate, 8 with an upper secondary certificate, 8 with a diploma, 34 with a bachelor's degree, 12 with a master's degree and 6 with a Ph.D. Most participants had a medium level of Arabic proficiency. This was the case for all educational backgrounds except for the primary and upper secondary groups. There were 48 female and 42 male participants. The participants were divided into two groups: a control group with participants that did not use the EoQu interface (C) and an experimental group with participants that used the EoQu interface (X).

In the C group, there were 10 males and 9 females under the age of 35 and 12 males and 14 females over 35. In the X group, there were 10 males and 15 females under 35 and 10 males and 10 females over 35. We chose a pre-test score of 45% as the cutting point between above average and below average, to balance the distribution of participants in the C and X group.

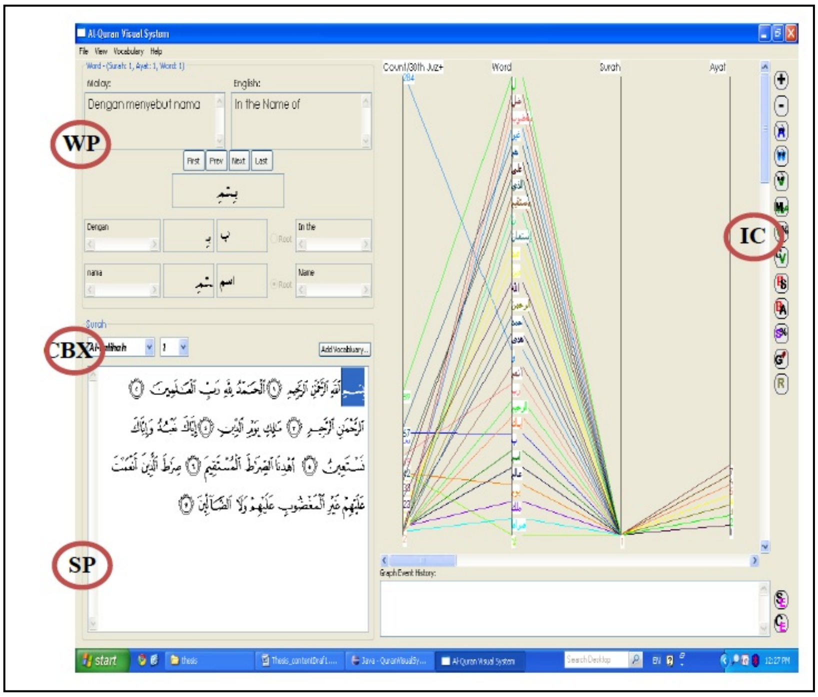
3.2 System Development

The EoQu interface was designed and implemented with embedded theoretical concepts based on the integrated model. It contains functions that support the hypothesis that visualization with a vocabulary tracking mechanism supports meaningful WR. Functional modules based on the requirement were designed to consist of a function related to visualization and vocabulary tracking in Qur'anic verses. A three-tier architecture consisting of related components was implemented using the Java SE runtime environment with the Eclipse integrated development environment. MySQL community version was used as the database.

3.3 The EoQu Interface

The EoQu interface contains two main parts, the Sura (Chapter) panel and the Graph panel. Fig. 3 shows the window interface. The Sura panel contains several modules: sura, vocabulary and Arabic word visualizer. The Graph panel contains functions that can be divided into several module categories: word view, vocabulary view, add Malay-Arab Word and Graph controllers (Fig. 3). The main feature of EoQu is to let users go through all the *sura* of the *Qur'an,* and while reading the *sura*, they are able to learn the Arabic meaning of each word in English and Malay. However, the reading flow is not restrictedly sequential. Users can jump from one *sura* to another without finishing to read one specific other *sura*. Once users know the meaning of the new Arabic word, they can click on the Add Vocabulary button to add the word to their vocabulary list.

Users can also view the percentage of their known vocabulary for each sura in the Graph panel. The word and vocabulary view comes with the word count and position. For example, EoQu visualises the word وَ(*wa'*/translated as 'and'*)* as having a word count of 283 in several sura and ayah (sentences). Users can search for words and word meanings through both panels.



WP:Word panel, **CBX**: Combo box, **SP**: Sura panel, **IC**: Icons

Fig 3: Window interface of EoQu

3.4 Arabic Word Recognition Test (AWRT)

The AWRT consist of three sets of questions validated by three panels from the department of Islamic and Quranic studies. Each set consists of two sections, the reference and the question.

The reference section contains one sura/Arabic word list from the *Qur'an* written with the meaning of each Arabic word at the bottom or side. The question section consists of a different sura written with a blank space beneath the Arabic word. The test is designed for users to read the reference section and try to recognize words and remember their meanings. The question section consists of another sura that contains some of the words that can be found in the reference section. Users will score one mark each if they can recognize and recall a word found in the reference section that is contained in the question section. Fig. 4 a) and b) are examples of the sections in AWRT.

The tests consist of six sets of questions related to three main word categories: WFE, WSE and recognising cognate words from one sura. Questions can be answered by referring to their own set except for Set 6, which is used to test WSE of all words introduced in Sets 1 to 5.

3.5 Data Collection and Procedure

To test the hypothesis H, we set up an experiment for the integrated model embedded within the EoQu interface. We used an experimental design approach in this study involving a control (C) and experimental (X) group. The C group attempted the AWRT without going through the EoQu interface while the X group attempted the AWRT after using the EoQu interface.

Fig. 5 shows the experimental setup. The score of the pre-test (Sets 1, 2 and 3) is used to divide the 90 participants into the C and X groups. There are equal number of participants with below and above average scores in C and X. In the post-test, the X group was given the same sets of questions as in the pre-test after using EoQu (Sets 1AB, 2AB and 3AB).

Also included in these questions are instructions on how to use EoQu to answer the post-test questions. Both groups were given another set of questions—Sets 4, 5 and 6 for the C group and Sets 4AB, 5AB and 6 for the X group—that incorporated instructions on how to use EoQu to answer the questions.

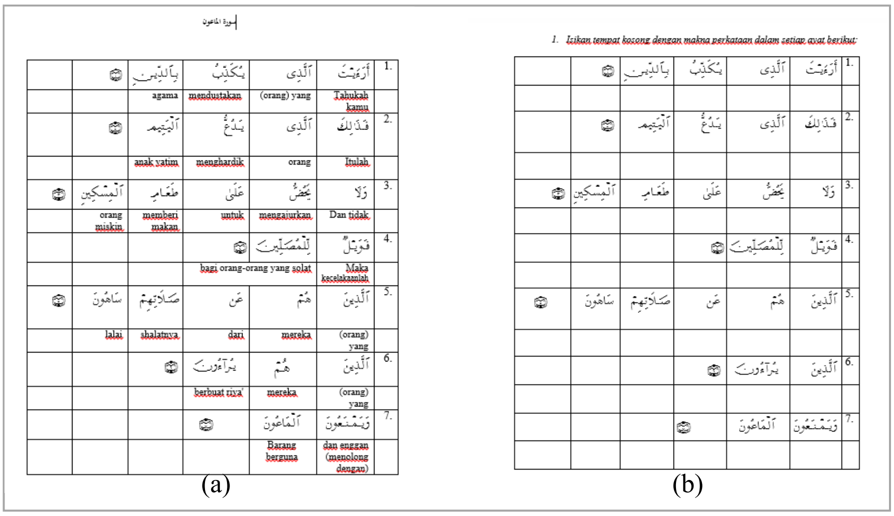
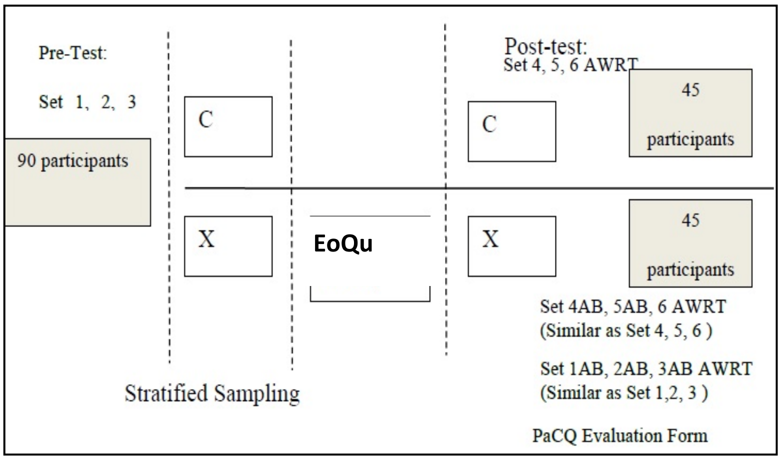


Fig 4: (a) The Reference section of the Arabic Word Recognition Test (AWRT); and (b) the Question section of AWRT



AWRT= Arabic Word Recognition Test

Fig 5: The experimental setup

3.5.1 The Stratified Sampling, The C Group and X Group AWRT Procedure

The experimental sessions were started with the general explanation of the aim of the intended study. Then, the participants were briefed on the privacy of the personal data collected which will not be made public. Participants were told that they can choose to stop participating in the study at any time if they choose to do so. The consent form were distributed for the participants to sign. Participants were asked to also fill in the demographic information and record their start and end time of answering the AWRT. A small token of appreciation was given to the participants at the end of the experiment.

The stratified sampling AWRT procedure

Before the participants were divided into the C and X group, they were given the pre-test consisting of Sets 1, 2 and 3. The AWRT questions were distributed individually or conducted with a maximum of five people in a lab until all 90 participants answered the questions. This session were completed within one month. After this session, the AWRT were analysed and the score of all participants were recorded. They were then divided into groups according to Table 1.

The C group AWRT procedure

The AWRT questions were distributed individually or conducted with a maximum of five people in a lab. This session was continued until all 45 participants from the C group attempted Sets 4, 5 and 6.

Table 1: The stratified sampling

Experimental Group (45 participants)	Male/ (<35 years)	Above average AWRT score (>=45 %)
		Below average AWRT score (<45 %)
	Female (<35 years)/	Above average AWRT score (>=45 %)
		Below average AWRT score (<45 %)
	Male (>=35 years)/	Above average AWRT score (>=45 %)
		Below average AWRT score (<45 %)
	Female (>=35 years)	Above average AWRT score (>=45 %)
		Below average AWRT score (<45 %)
Control Group (45 participants)	Male/ (<35 years)	Above average AWRT score (>=45 %)
		Below average AWRT score (<45 %)
	Female (<35 years)/	Above average AWRT score (>=45 %)
		Below average AWRT score (<45 %)
	Male (>=35 years)/	Above average AWRT score (>=45 %)
		Below average AWRT score (<45 %)
	Female (>=35 years)	Above average AWRT score (>=45 %)
		Below average AWRT score (<45 %)

The X group AWRT procedure

The X group had to answer two sets of AWRT questions (Set 1A, 2A, 3A, 4A, 5A and 6) after using the EoQu interface. The EoQu interface was installed on a few Windows laptops with a 1280 x 800-pixel resolution and 32-bit colour quality.

The X group interacted with the system using a mouse. The session was conducted with a maximum of 5 people per session in a lab environment. Approximately 20 sessions of the post-test were conducted until all the targeted participants had gone through the training. Each post-test session took approximately 90–120 minutes and was completed within one month.

3.6 Data Analysis

Before extracting the results using SPSS, the datasets needed to be tested for normality. All datasets are significantly different from the normal distribution except for the average AWRT score for Sets 4, 5 and 6 (post-test). This research uses a non-parametric test for the datasets containing non-normal distributions. The original data was in scale form because AWRT test scores are the marks of the participants answering the test. Before proceeding to the non-parametric test, the data were changed to an ordinal type.

Table 2 describes this transformation. The scale data for AWRT scores were transformed into a ranked form between 1 to 5. Scores from 0%–20% were given a rank of 1 for very poor, 21%–40% was ranked 2 for poor and so on. Data related to the time taken to complete Sets 4, 5 and 6 were also transformed into a ranked form between 1 to 5. Times of 1–4 minutes were ranked very fast, 5–9 minutes were ranked fast and 10–14 minutes were ranked average and so on.

The parametric independent t-test is used to analyse the average AWRT score for Sets 4, 5 and 6 (post-test). A significance level of 0.05 was used for all statistical tests.

We used three tests and boxplots to analyse the data:

- Wilcoxon signed-rank test, for testing paired samples of non-parametric data
- Mann-Whitney U test for testing independent samples of non-parametric data
- Independent t-test for testing independent samples of parametric data
- Boxplots to see the mean of the data

4.0 RESULTS

The results are organized according to the research questions posed in the introduction. Centring on the hypothesis that visualization with vocabulary tracking supports WR, we divide the results section into performance scores for the C and X groups (RQ1), performance based on age (RQ2) and time's effect on performance (RQ3). The result of each test set and the average of all the test sets are reported.

4.1 Research Question 1: Significant Impact to Non-Arabic Speakers in Recognising Arabic Words

Before and after using EoQu interface

We conducted a Wilcoxon signed-rank test to evaluate whether the AWRT scores for Sets 1, 2 and 3 were different before and after using the EoQu interface for the X group. The results indicate a significant difference for all sets, as shown in Table 2. Details are as follows:

- The results for Set 1 of the AWRT scores after using EoQu are significantly higher, with z =-2.27, p < 0.05 (p = 0.023). The mean rank of Set 1 AWRT scores after using the EoQu was 18.14, whereas the mean rank of the Set 1 AWRT scores before using it was 13.36.

- The results for Set 2 after using EoQu are significantly higher, with $z = -3.89$, $p < 0.05$ (p = 0.000). The mean rank of Set 2 AWRT scores after using the EoQu interface was 11.25, whereas the mean rank before using it was 6.00.

- The results for Set 3 of the AWRT scores after using EoQu are significantly higher, with $z = -2.24$, $p < 0.05$ (p = 0.025). The mean rank of Set 3 after using the EoQu interface was 12.56, whereas its mean rank before using it was 12.33.

Table 2: Transformation of data from scale to ordinal

Data type	Transformed data	Description
1. Scale data for AWRT scores on Sets 1, 2, 3, 4, 5 and 6	Ordinal data with rank between 1 and 5	1–very poor (0%–20%) 2–poor (21%–40%) 3–average (41%–60%) 4–good (61%–80%) 5–very good (81%–100%)
2. Scale data for the time to complete Sets 4, 5 and 6 of AWRT 3. Scale data for the average time to complete Sets 4, 5 and 6 of AWRT	Ordinal data with rank between 1 and 5	1–very fast (1–4 minutes) 2–fast (5–9 minutes) 3–average (10–14 minutes) 4–slow (15–19 minutes) 5–very slow (20–24 minutes)

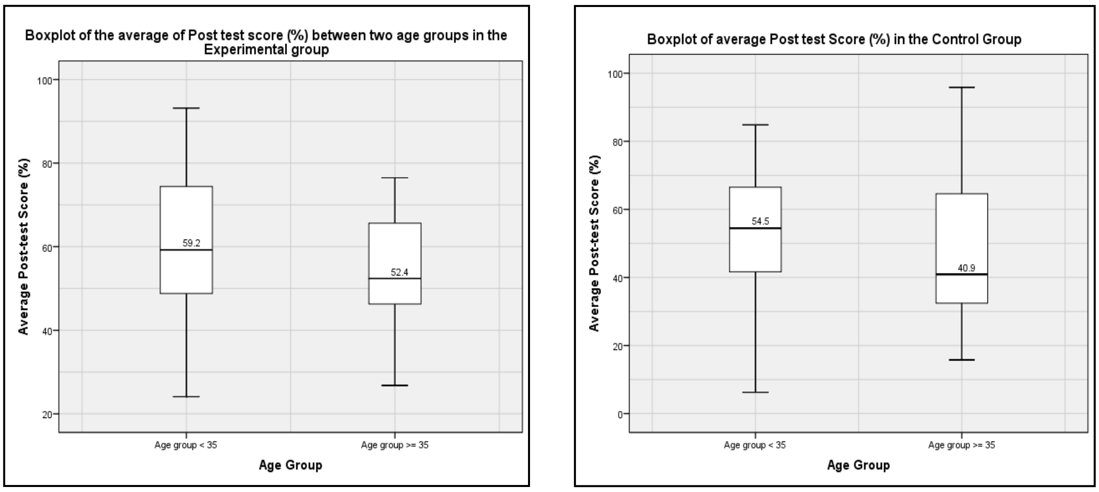
Groups that use the EoQu interface (X) and groups that did not use (C)

We conducted an independent t-test to test the significance difference of the average AWRT percentage scores for Sets 4, 5 and 6 between groups C and X. The average AWRT scores for Sets 4, 5 and 6 for the X group (M = 64.44, SD = 21.58) are higher than those for the C group (M = 54.85, SD = 23.55), t (88) = -2.014, $p < 0.05$ (p = 0.047).

4.2 Research Question 2: Performance Based on Age

Fig. 6 shows the boxplot for the average AWRT scores. The average scores were higher (59.2 and 54.5) for the L categories in the X and C groups and lower (52.4 and 40.9) for the M categories in the X and C groups.

Fig. 7 shows the boxplot of average AWRT scores before and after using the EoQu interface for the L and M categories. Scores were higher (82.1 and 75.1) after using the EoQu interface both for the L and the M categories, respectively, than before using EoQu (71.0 and 56.0).



(a) (b)

Fig 6: Boxplot of Arabic Word Recognition Test scores based on age group for age < 35 (L) and >= 35 (M) in the experimental (X) group (a) and in the control (C) group (b)

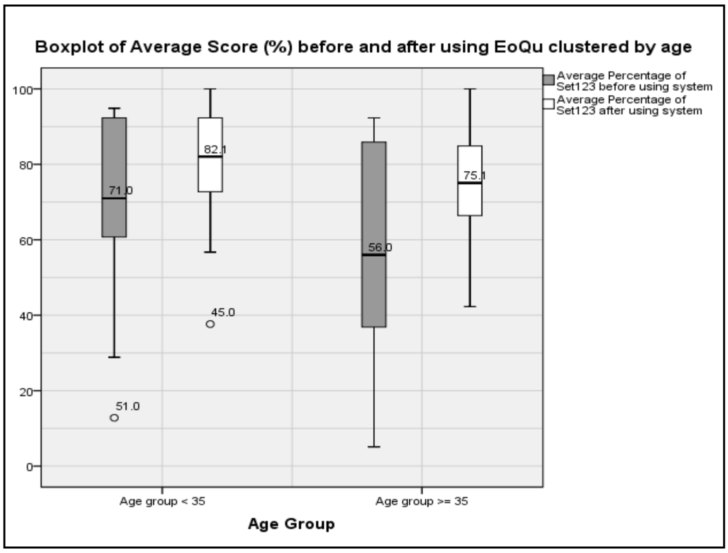


Fig 7: Boxplot of the Arabic Word Recognition Test (AWRT) scores for age < 35 and >= 35 in the experimental group (X).

4.3 Research Question 3: Time Taken to Complete The AWRT

We conducted a Mann-Whitney U test to test the significance of the average time taken to complete Sets 4, 5 and 6 in the C and X groups.

The average time taken to complete Sets 4, 5 and 6 for the X group (*Mdn* = 2) was faster than that of the C group (*Mdn* = 2), with U = 542.0, p = 0.006 and z =- 2.769. The results for the L category in the C group (*Mdn* = 2) were faster than those in the M category (*Mdn* = 2), with U = 104.0, p = 0.002 and z =- 3.144. The result for the L category in the X group (*Mdn* = 2) does not differ significantly from that for the M category (*Mdn* = 3), U = 175.5, p = 0.922 and z=-0.098. See Table 3 for results.

Table 3: Time taken to complete Arabic Word Recognition Test (AWRT)

1	Average time to complete Sets 4, 5 and 6 between control (C) and experimental (X) groups		X Group	C Group	Results
		Sets 4,5 and 6	(*Mdn*=2)	(*Mdn*=2)	U=542.0, p= 0.006, z=-2.769
2	Average time to complete AWRT in C group for age <35 (L) and age >=35 (M) categories		L Category	M Category	Results
		Sets 4, 5 and 6	(*Mdn*=2)	(*Mdn*=2)	U=104.0, p = 0.002, z=-3.144
3	Average time to complete AWRT in X group for L and M category	Sets 4, 5 and 6	(*Mdn*=2)	(*Mdn*=3)	U=175.5, p = 0.922, z=-0.098

Fig. 8 shows a boxplot of time taken to complete the AWRT for the L and M categories in the X and C groups. We found that in both groups, the times were faster (5.7 and 5.2 minutes) in the X group than in the C group (6.3 and 10 minutes).

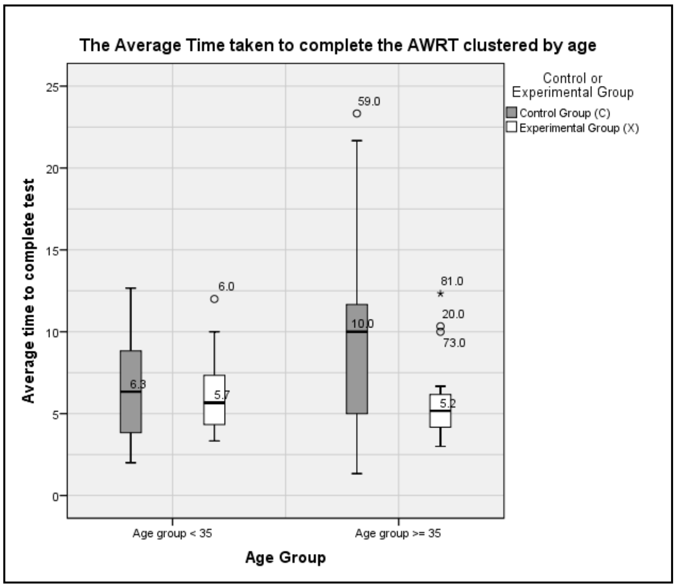


Fig 8: Boxplot of time taken to complete the Arabic Word Recognition Test (AWRT) for age < 35 (L) and age >= 35 (M) in the experimental (X) and control (C) groups.

5.0 DISCUSSION

Our results implied several issues. The AWRT score percentage rank for X group participants after using EoQu interface is significantly higher than before using EoQu. This implies that the integrated components of the hypothesised model, which integrates visualization, have a positive effect on WR performance. Similarly, Tozcu & James [5] found that learning frequent words significantly affects reading and word recognition in the treatment group. These findings are consistent with those from other studies, such as Perfetti, Landi and Oakhill [13], Rayner, Schotter, Masson, Potter and Treiman [14], Reicher [16], Wheeler [17], McClelland and Johnson [18] and Forster and Chambers [20].

The average AWRT percentage scores for Sets 4, 5 and 6 for the X group show significantly different rank scores compared to those of the C group. The results also show that the average times to complete Sets 4, 5 and 6 for the X group were significantly faster than for the C group. This indicates that the EoQu interface has a positive effect on user scores and times. This implies that intrapersonal communication within the user's cognitive space was triggered to result in better performance in terms of scores and time to complete the AWRT. Lin and Chen [43] and Park, Yang and Hsieh [44] had similar findings.

The performance in terms of AWRT scores for the L and the M categories were found not to differ significantly in either the C or X groups. However, the average time taken to complete the test differed significantly between these categories. Within the C group, the L category showed a faster completion time then the M. This may be related to younger people having a generally faster information processing ability. However, for the X group, average times were found not to differ between the age groups. Therefore, there is evidence showing that the information processing ability of the older group was improved by using the EoQu interface.

These findings also highlighted a few issues regarding the effectiveness of the component of the hypothesised model. The EoQu interface was tested for the effectiveness of the visualization of parallel plot and the Arabic word visualizer through AWRT Sets 1–5. Therefore, it can be implied that the EoQu interface's visualization components support Arabic word recognition. A similar study was also found based on a graphical user interface for Indian words [45]. Although the parallel plot visualization is used for multivariate and more abstract data analysis [46], the usage of this plot can be further investigated in the context of language learning.

6.0 CONCLUSION

In the EoQu interface, users can learn words in the Qur'anic verse to achieve word recognition. This is supported through visualization for WSE and WFE. Semantic word visualization through vocabulary, cognate words and word segmentation support WSE, whereas parallel plot visualization of the word count, word position and percentage information support WFE. For example, users can start to explore more frequent words that can be found easily using the parallel plot visualization. Information on word frequency can more intuitively attract visual memory than a list of statements written in a text format. Users can strategise their learning by starting to learn frequently occurring words shown through the parallel visualization and add new words to their personal vocabulary list.

In answering the research questions, we achieved all the objectives of this research in relation to RC problems, WR, visualization, information processing, system development, experiments and performance measures. The EoQu interface was developed to incorporate visualization with a vocabulary tracking mechanism to support Arabic WR. Our performance evaluation (through an experimental study) was based on meaning retrieval of Arabic words and results show that the performance of users using the EoQu interface improved in terms of performance scores and time taken to complete the AWRT.

In conclusion, the results show an improvement in AWRT performance for those using the EoQu. The hypothesis that visualization with a vocabulary tracking mechanism supports Arabic WR in the reading process can therefore be accepted, although the determinant components could not accurately be identified. To do so, further experiments based on specific components of the integrated system can be carried out.

Lastly, in the general context of learning languages, it can be implied that there are evidences (in the context of Arabic language) showing positive outcome in terms of performance and time taken if a learning tool is developed to support the learning process. There is also evidence that the older age group had slightly positive results after using the tool. These evidences could serve as a motivation to develop tools for learning languages even for the older groups in the context of word recognition and reading comprehension.

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