Understanding Decision-Making Processes via Digital Means: Evidence from an Eye Tracking Study

Khazriyati Salehuddin[1]
Universiti Kebangsaan Malaysia

Nur Ain Amni Ahmad Bokhari[2]
Sek. Men. Keb. Senai, Johor Darul Takzim, Malaysia

Abstract

Decision making is a complex process which involves multiple cognitive and linguistic abilities. Studies have shown that language does play a role in decision making; yet, not much is known about how decision making, language, and culture are intertwined. This paper presents the preliminary findings of a research investigating how English as a Second Language (ESL) undergraduates make decisions from a set of Malay and English situational questions that are embedded in Malay and English cultural elements via digital means. Sixty ESL undergraduates participated in this study. Their eye movements, as they read twelve situational questions in Malay and twelve in English, were tracked using the TOBII TX300 eye tracking machine. A retrospective interview was then conducted on one-third of the participants to qualitatively explain how they read the situational questions and answer options with the help of the playback function on the eye tracking machine. Preliminary findings obtained in digital forms such as fixation counts, fixation duration, visit counts, heat maps, and scan paths act as evidence that the eye tracking machine is a useful tool for researchers to further understand the cognitive processes involved in making decisions.

Keywords

Cognitive processes, decision making, English as a second language, eye movement, Malay-English bilinguals, psycholinguistic experiment, reading pattern

[1] **Khazriyati Salehuddin** is Associate Professor at Universiti Kebangsaan Malaysia (UKM). She has led several research groups related to psycholinguistics and has published several journal articles, books, and book chapters in the area. She has a book chapter in *South and Southeast Asian Psycholinguistics* (Cambridge University Press, 2013). She is the author of *Psikolinguistik: Penerokaan Minda Berlandaskan Bahasa* (UKM Press, 2018). Email: khazudin@ukm.edu.my.

[2] **Nur Ain Amni Ahmad Bokhari** teaches at Sekolah Menengah Kebangsaan Senai (SMK Senai), Johor Darul Takzim, Malaysia. She completed her Bachelor of Education in Teaching of English as a Second Language (TESL) and her Master of Arts in English Language Studies at Universiti Kebangsaan Malaysia (UKM). Email: nurainamni@gmail.com

Introduction

Decision making involves selecting items from two or more potential options so that a resolution to a given problem can be achieved (Panpatte and Takale 76). Human beings make decisions differently. Some individuals make decisions based on chance (like flipping coins). The majority, however, make decisions based on a commitment to a course of action that is intended to serve the interests and values of particular people (Yates and Potorowski 200). In other words, in most cases, when making decisions, human beings tend to proceed with a course of action that is in line with their liking or preference.

The decisions that the second type of individuals above make suggest that making decisions is actually a complex cognitive process. As elaborated by Panpatte and Takale, decision making is actually a process of judging various versions of available options followed by narrowing down the choices, depending on the problems and situations that are to be addressed (73). In other words, the term decision making calls upon the image of making choices among alternative courses of action in a way appropriate to the demand of the situation (Obi and Agwu 10).

Human beings are bound to constantly make decisions. According to Wai Li et al., people have to deal with decisions related to the monetary and nonmonetary resources that are available in their everyday life in a wide range of domains (1066); some may be as simple as choosing whether to have a toast or a half-boiled egg for breakfast; some can be as critical as deciding whether or not to proceed with movement control order when a pandemic occurs. When making decisions, our brains will actively process the information about the available choices or options. For example, in deciding what to have for breakfast, individuals might include information regarding the calorie intake, the amount of time they have to employ to prepare the meal, and perhaps, when their next meal will be. Based on such information, the options are carefully weighed – depending on how critical the decisions are made – and eventually processed until the preferred choice is made.

Regardless of how big or small the decision is, good decision making depends on the decision makers' ability to recognise whether and when the decision needs to be made (Yates and Oliveira 108; Obi and Agwu 16). Whether they like it or not, the decision makers are accountable for their decisions, whether the decisions made are for themselves or for others.

According to Nunes et al., decision making takes place in four different processing stages in the brain (14). The first stage is known as the pre-processing stage. This is the stage when the decision makers build their understanding from the compiled information that are gathered from different sources. The second stage is the explication stage, where the decision makers update the established understanding based on the information gathered earlier. The third stage is the elimination stage; it is when the decision makers eliminate the options that bring

no advantages when compared with other options. The final stage, or the selection stage, takes place after the decision makers complete the decision-making process by selecting the best option from the choices.

In the realm of research related to psychology, researchers have postulated that decision-making mechanism entails the components of intuitive and deliberate thinking. The former develops in the mind very quickly, effortlessly, and unconsciously – which Kahneman (11) describes as through gut feelings and norms – like which shoes to wear on a wet day; the latter results from prolonged and meticulous thinking, which is done rather slowly, rationally, analytically, and systematically (Kruglanski and Giegerenzer 97), such as solving mathematical problems.

Despite the fact that decision making is an inherent act across the human population, the decision-making process might be carried out differently in different cultures in the world. Past studies (e.g., Wai Li et al.) have shown that different cultures have their own ways of making decisions. For instance, individuals from collectivistic or interdependent communities make decisions differently from individuals from individualistic or independent communities. In contrast, individuals who are holistic in thinking make decisions differently from individuals who are analytic in thinking (1066).

Lucas et al., for example, suggest that people from the collectivist culture tend to feel more connected to those around them; they are tied to friends, family, and workgroups and take into consideration all possible aspects and consequences that are related to these individuals (456). They reflect the Eastern communities (Giacomin and Jordan 2319) who take into account the well-being of others around them and process information in a holistic manner when making decisions. People from the individualistic or independent culture, as the name suggests, tend to be more absorbed with themselves. They reflect the Western communities (Giacomin and Jordan 2319) who would execute analytic processing when making decisions. A study by Wai Li et al., for example, found that their Hong Kong Chinese participants tended to be more holistic than their European Canadian counterparts, who were more focused and analytical when making decisions (1071). Because of this, the claim that humans are bound to be influenced by their culture when making decisions to some extent can be true (see Zhang et al. [110] on holistic vs. analytic thinking).

Decisions, however, may be made involuntarily; in most cases, individuals do not realise that the culture in which they are brought up plays a role in their decision making. Culture refers to the practice or belief that is passed down from one generation to another and this distinguishes one group of people from another as well as shapes how behaviour, symbols, and customs are interpreted by different people in different cultures (Shimizu et al. 79). The practice is embedded naturally in the people within the same community that it gradually transforms into a habit. Ideally, individuals' culture should not influence

the decisions that the individuals make; in reality, culture seems to have influenced how decisions are made, as shown in studies by Giacomin and Jordan (2319), and Wai Li et al. (1071). In other words, there is a strong need to understand whether factors such as culture and language influence people in their decision-making processes. Therefore, it is worth investigating how different cultures shape the perceptions or opinions of individuals within these cultures and how these differences would affect their decision-making process.

Decision-making and Language

Language, as a component of culture, functions as a means that reflect the views of cultures and culture-specific epistemologies (Imai et al. 72). Since language and culture are intertwined, the language used to make decisions may influence the decisions speakers of different speech communities make. Consequently, because language may play a role in shaping individual's decision making, the decisions that human beings make may be different depending on the language the individuals use when making decisions. In other words, there is a possibility that the decisions that bilingual individuals make may differ depending on the language they are operating in (Athanasopoulos et al. 1)

Keysar et al. claim that the challenges that bilingual speakers encounter in making decisions are different depending on whether the language in which the decisions have to be made is the speakers' first language or their second/foreign language. They suggest that making decisions in a language other than their own requires more cognitive load (664).

When individuals make decisions in their native (or first) language, the tendency to make biased decisions increased as opposed to when they make decisions in a language other than their mother tongue. The same study by Keysar et al., for example, showed that decision-making biases among their Asian participants regarding Asian disease problems were reduced when the situations that require them to make decisions on monetary form, loss-gain, and live-die conditions were presented in a foreign language (662). This, according to them, is because framing effects (i.e., a cognitive bias of tendency to be risk-averse in a gain frame and risk-seeking in a loss frame) disappear when the choices are presented in a foreign language. Conversely, when the choices are presented in one's first language, participants tended to be risk-averse for gains and risk-seeking for losses. A study by Winskel et al. (434) also suggests that language is a factor that contributes to the decisions that their participants made.

A study by Li, for example, addresses the conviction of language effect on decision-making process using ten games, including dictatorship, jealousy and generosity (16). Findings from Li's study showed different decision-making attitudes when participants had to make decisions in different languages. Their participants, for instance, tended to give less money when the questions appeared

in a foreign language, supporting the notion that language plays a role in decision making (27).

It is commonly accepted that decision making is indeed a complex process to explain and that past studies have concluded that language appears to play a role in decision making. However, this conclusion was based on studies that were conducted using pen and paper (e.g., Keysar et al. 662; Winskel et al. 429) and game simulation (e.g., Li 17), and was based on the answers given (i.e., the choices made) by the participants in the study. What we do not know is what happens in the participants' cognition as the decision-making process takes place, i.e., *before* the actual selection is made. Since decision making is a cognitive process and this process is not visible to the naked eye, conducting studies using digital means may be the way forward. Such studies on the brain waves of decision makers (e.g., Giorgetta et al. 38) have shown that many processes take place in different brain regions as decisions are made. State-of-the-art brain-imaging techniques such as *functional magnetic resonance imaging* (fMRI), *positron emission tomography* (PET), *magnetoencephalography* (MEG), and *electroencephalography* (EEG) have been used to investigate decision-making processes. Perera-W.A. et al. also explain how EEG can be used to understand the processes that take place in decision making through *event-related potentials* (ERPs) (1).

Unfortunately, despite the fact that the brain-imaging techniques mentioned above either have high spatial or temporal resolution, they are not only expensive and difficult to use; they are also difficult to explain in a layperson's term. One less complex and more affordable digital means of investigating what happens in the cognition as the decisions are being made is through the use of the eye-tracking technology. The eyes can be regarded as a window to investigate what actually happens in the cognition (Salehuddin 142). A medical study also suggests that the "eye is the window to the brain in central nervous system diseases" (Waduthantri 376).

Technically, the eye tracking machine is a digital tool to understand human cognitive behaviour through eye movements. This instrument can digitally and accurately track moment-to-moment processing action in natural settings without relying on participants' conscious responses to given tasks (Tham 21). The infrared lights in the eye tracker track the pupils' eye movements and compute the data into various variables called matrices. These include fixation (when the eyes maintain the visual gaze on a single location), saccade (when the eyes jump from one spot to another), pupil dilation (the pupil size shrinks or enlarges), and gaze plot (the sequence of the gazes).

Eye trackers enable researchers to track even subtle changes in eye movement behaviour due to the difficulties the users face when dealing with certain tasks (Costa et al. 239). In Malaysia, for example, the use of the eye tracking machine in investigating issues in linguistics, cognition, and education is flourishing. Among them are research on vocabulary learning (e.g., Sulaiman et

al. 60), on Qur'anic memorisation strategies (e.g., Salehuddin et al. 318), and on the interpretation of metaphorical expressions (e.g., Tengku and Salehuddin 18).

According to Stewart et al., there is a strong link between the eye movement and decision-making (117). Studies by Schotter et al. (1112) and Shi et al. (1022), for example, show that decision makers tend to sample and look at answer choices that were favourable to them compared to the rest. However, Stewart et al. argue that there are two possible explanations to such "attention." The decision makers look at an option more because they like it more, or they like the option more, hence, they look at it more (117). In other words, it is still unknown whether the fixation of the eyes drives the decision makers' choice or reflects their choices. To our knowledge, up till now, no studies have investigated how the decisions are made prior to the act of the decision making itself.

Given the above observations, the present study was conducted to investigate how decisions are made by bilinguals when they read situational questions in two different languages. This is presented through preliminary findings from a larger study conducted on a group of Malay-English bilingual undergraduates.

Methodology

This study was originally conducted to understand how decisions are made by Malay-English bilingual individuals (who are native speakers of Malay) when they were given written stimuli in both languages. However, given the quantity and range of the data, the focus of this paper is solely on demonstrating that the eye tracker can be used as a digital means to understand the decision-making process. This section presents the methodology that was used to collect the data.

Participants

The snowball sampling recruitment technique was used in selecting the participants for this study because it was difficult to get participants to go to the eye tracking lab. The participants, whose age ranged between nineteen and twenty-four years, were in different academic years at a research university in Malaysia. This, however, does not affect the validity of the study because the participants' level of proficiency in the English language, which matters most, was determined by their Malaysian University Entrance Test (MUET) band levels. All participants were considered proficient in Malay, as it is the national language of Malaysia. It is formally taught in schools from preschool onwards. To enrol as undergraduates at a Malaysian public university, individuals must obtain at least a pass in the Sijil Pelajaran Malaysia (SPM) or the Malaysian Certificate of Education Examination (somewhat equivalent to the International General Certificate Secondary Examination [IGCSE]).

Sixty undergraduates (fifty females; ten males) participated in this study. They were grouped into two categories: thirty in the high proficiency group

(MUET Bands 4-6) and thirty in the low proficiency group (MUET Bands 1-3). This categorisation of students follows Amutan's and Hee's (4) categorisation of high and low proficiency students based on MUET band levels.

Instruments

a. Demographic Questionnaire

Ten demographic questions were prepared for the participants to fill in as they signed up to participate in the study. This demographic questionnaire was intended to obtain information about the participants' background and their language usage.

b. The Eye Tracking Machine

The eye tracker that was used to collect the data in this study was TOBII TX300. It has a refresh rate of 300 Hz with a large head movement box for a more natural position and less restricted head movement. Because of its high temporal resolution, the eye tracker can provide a good moment-to-moment indication of cognitive processing during reading (Khedher et al. 53). After tracking the eye movements, TOBII TX300 can digitally present the quantitative data gathered in the forms of fixation counts (how many times they pause at a particular area), fixation duration (how long they paused at the area), and visit counts (how many times they go back to a particular area). Qualitative data were also obtained in the form of heat maps, i.e., "visualization that uses different colors to show fixation count or duration" (Bergstrom and Schall 363) and scan paths, i.e., "a trace of a participant's eye-movements in space and time – and its events and representations" (Holmqvist et al. 363). These qualitative data were used not only in the analysis process but also in the retrospective interview; they were used as cues via the playback function that is available in the eye tracking machine.

c. The Stimuli

A set of twenty-four multiple-choice situational questions were prepared as the stimuli to prompt reading and eventually track the decision-making process. Twelve of these questions were in the Malay language and the other twelve in English. This set of twenty-four situational questions was adopted and adapted from the ten games employed by Li (16). However, only three games were adopted in this study as the other seven were deemed not suitable for Malaysian culture. The situational questions were formulated into three themes to reflect the three games – dictatorship, jealousy, and generosity – to simulate the decision-making process. There were four questions for each theme and each of these themes was presented in both languages. For each theme, two questions were injected with "cultural" elements to reflect the Malay- and English-speaking cultures. For example, the situational questions on the dictatorship theme had the noun phrases "Haziq-*duit raya*" and "Alex-*tips*" to simulate the Malay and English identity and culture, respectively.

Each situational question was accompanied by three options (i.e., answer choices) that were presented horizontally beneath each question (Figure 1). The three options were provided following Meißner et al.'s suggestion not to use more than three options in a choice task. According to Meißner et al., a three-option answer choice is more stable and can save much more time in reading than answer choices that have more alternatives (33).

There was no right or wrong answer to these situational questions. However, participants were asked to click the left mouse button as they placed the cursor on the bullet next to their preferred answer. A single click of the mouse would lead them to the subsequent page on the eye tracking monitor.

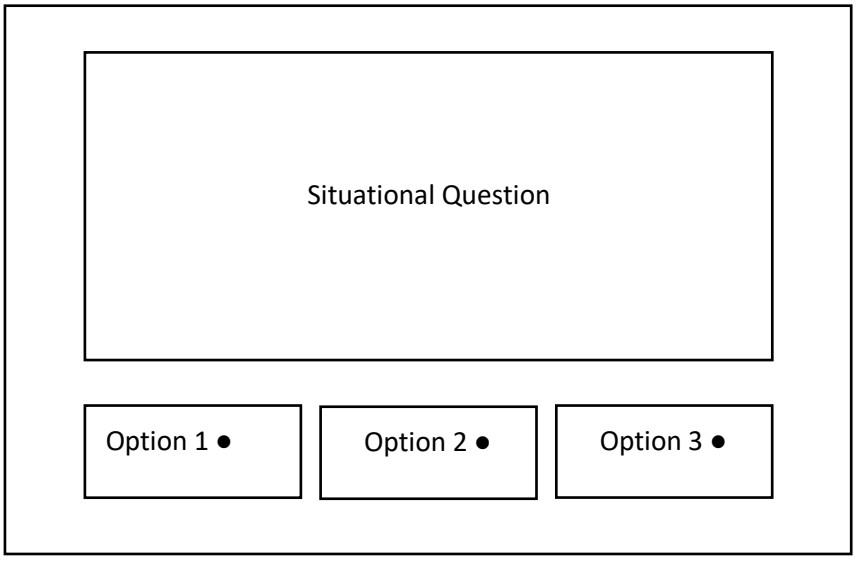

Figure 1. The layout of the situational questions and answer choices

The twenty-four situational questions were presented in a random but fixed order. This type of ordering was chosen because of its systematicity which eventually can facilitate data analysis. Since the situational questions were presented in two different languages, the questions in both languages were presented alternately between English and Malay. All twenty-four questions were validated prior to the experiment by two experts in both Malay and English languages. These experts teach at the tertiary level, and have published academic works, in both languages. Their feedback on the initial drafts of the situational questions were addressed and revisions were made on the language aspect to

make all twenty-four questions more comprehensible to the participants. Table 1 shows how the situational questions were different from each other.

Table 1
Elements that form the 24 situational questions

	ENGLISH	BAHASA MELAYU
Dictator	Alex	Alex
Given 100. Other:You – 50:50	Haziq	Haziq
Given 100. Other:You – 40:60	Alex + *tip*	Alex + *upah*
Given 100. Other:You – 60:40	Haziq + *duit raya*	Haziq + *duit raya*
Jealousy	Brendan	Brendan
Given 150	Badrul	Badrul
You: 40;	Brendan + *Halloween*	Brendan + *Halloween*
Other:20,40,60	Badrul + *baby*	Badrul + Cahaya Mata
Generosity	Cheerleading Club	Pasukan Sorak
Given RM40	Red Crescent	Bulan Sabit Merah
Other: 0, 20, 40	Cheerleading Club + *prom*	Pasukan Sorak + tari menari
You: keep remaining	Red Crescent + *gotong royong*	Bulan Sabit + gotong royong

d. Retrospective Interview Question

Although the eye tracking machine is able to quantitatively describe what actually happens in the cognition when reading takes place, the machine cannot verify if the descriptions were accurate. Therefore, another instrument – a set of Retrospective Interview Questions – was used as a tool to collect data. The Retrospective Interview Questions were in the form of three semi-structured interview questions that were developed to seek the participants' initial responses regarding their experience in reading the situational questions and making decisions. In particular, the questions were designed to seek further clarifications from the participants as to why their eye movements behaved differently in different situations or when reading texts in different languages. These three questions led to follow-up questions, depending on the answers given by the participants. The three questions include:

1. Did you realise that there were different names and events used in the questions? Did these differences affect your decision-making?
2. The questions were either in English and Malay. Were your answers to the questions in Malay the same as or different from the ones in English?
3. (As the playback session was taking place) Why did you look at the words (show the difference) differently when you read the questions?

The direction of the subsequent questions in this semi-structured Retrospective Interview was directed by the participants themselves.

Data Collection Procedure

Fifty-five .jpg files were prepared for this study. Among these fifty-five files, four were images of practice trial pages, twenty-eight transitional pages, one instruction page, one opening page, twenty-four situational question pages (with three-option answers on the same page) and one thank-you page. All fifty-five files were uploaded to the TOBII TX300 eye tracker before the data collection process began.

a. Pilot Study

Prior to the actual experimental session, a pilot study was conducted. Four participants (two of high English proficiency and two of low) who matched the targeted age group that participated in the pilot study, which began with answering the demographic questionnaire followed by the reading of all twenty-four situational questions at the eye tracking machine. This session at the eye tracking machine was then followed by the retrospective interview session. The pilot study was conducted to test the suitability of the questions, the environment and to estimate the time needed to run the actual experimental session. All four participants in the pilot study reported that the questions designed in the test materials were clear and unambiguous, and the environment within which the pilot study took place was conducive. The time each person took when participating in the pilot was averaged so that plans for the number of participants to participate in the actual experiment per day could be made.

b. The Data Collection Stage

Practice Trial

Once the pilot session was found to be satisfactory, a call for participation was made to a group of undergraduates at the eye tracking lab in a research university in Malaysia. Those who signed up to participate in the study were also asked to invite their friends to participate. Since only one person can participate in the data collection procedure at any one time, each participant was given different appointment slots so that the data collection procedure would be systematic. Upon reaching the eye tracking lab, participants were first informed about the nature of the study; after consent was obtained from them, the participants were asked to fill in the demographic questionnaire.

Once the demographic questionnaire was filled, they were ushered to the eye tracking corner. All participants were instructed to adjust their sitting position and posture, and were told to remain in the same position to ensure that their eyes could be easily detected by the eye tracking device. They underwent a nine-point eye calibration procedure to ensure that their eye movements were accurately tracked by the eye tracker. The practice trial began once the calibration

process was completed. All participants were asked to answer four practice trial questions and each of these questions came with a set of three answer choices for the participants to choose from. The practice trial format was identical to the experimental session format, which included a combination of situational questions and answer choices in Malay and English. The questions in the practice trial revolved around daily situations, as shown in Figure 2.

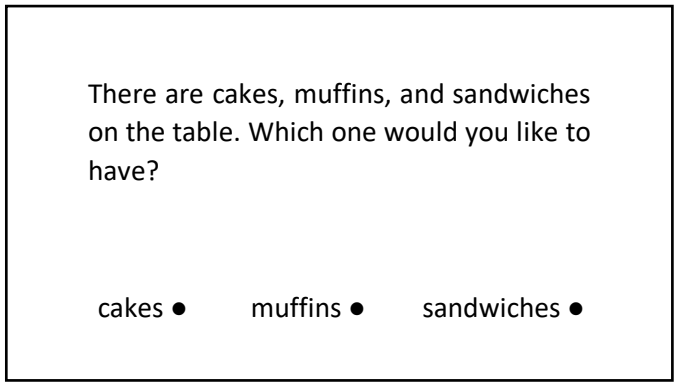

Figure 2. A stimulus in the practice trial session. This layout is similar to the one in the experimental session.

All participants were informed that the entire procedure was to be recorded and although they did not have to read the situational questions and answer choices aloud, they were asked to read aloud their choice so that their answers can be captured by the recorder that is built in the eye tracking machine. The participants were also asked to point the cursor at the bullet next to the chosen answer and click the left mouse button to proceed to the next page. The mouse click led to a transitional page, on which a "+" sign could be seen at the centre of the screen. This "+" sign was there to bring the participant's focus back to the centre of the screen to prepare them for the next stimulus. Another mouse click would take the participant to the next stimulus, which is the subsequent situational question with a different set of three answer choices. This practice trial is important to ensure that the participants were familiar with the data collection procedure involving the eye tracker. After completing the Practice Trial session, the Experimental session began.

Experimental Session

The experimental session immediately followed the practice trial at the eye tracker and began with an instruction page. Each participant was reminded again that there were neither right nor wrong answers in all the situational questions. This

instruction page was followed by an opening page, which, in turn, was followed by a transitional page with a "+" sign at the centre of the page. Each of the twenty-four situational questions that came together with three answer choices was followed by the transitional page (Figure 3). The overall behaviour of each participant, which was video recorded by the eye tracker's in-built recorder, was also monitored by one of the researchers. The observation was done to assist the researchers with the retrospective interview session following the experimental session. The entire experimental trials concluded in five to eight minutes.

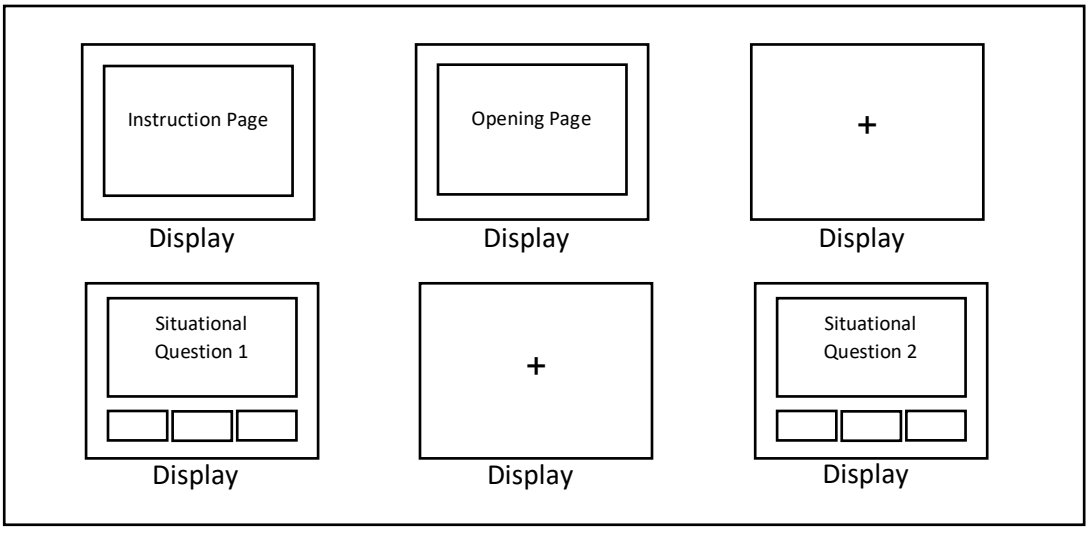

Figure 3. The presentation sequence of the first 6 of the 55-page stimuli

Retrospective Interview

This session took place once the experimental session was completed. In this session, the video recordings of the participants' eye movements and reading behaviour were played back to the participants using the in-built playback function. The playback function was utilised to assist the participant in recalling what they did when performing the experimental task. Through the playback function, the participants could see their own scan paths and heat maps, which were digitally generated by the eye tracker, as they read the situational questions and answer options during the experimental session. From this, they were able to recall their reading behaviours (i.e., what they actually focused on and looked at) as they were performing the task. The interview, however, was not conducted with all participants; the interview session concluded once the same response pattern emerged from the interview. This is because, as mentioned earlier, the retrospective interview session was conducted to get some clarifications from the

participants' point of view about why their eye movements behaved differently in different situations and in different languages. Therefore, only the first twenty (ten high- and ten low-proficiency) participants participated in this Retrospective Interview session. Other than the three questions mentioned earlier in the research instrument section, the participants in this retrospective interview were also asked questions such as "Why were you looking at the word 'xxx' many times / for a long time?" or "Why did you go back to the word 'yyy' before you answered the questions?" or "Why did you go back-and-forth between the words 'www' and 'zzz' after reading the question?" The information gathered from the retrospective interview was used to triangulate the quantitative (i.e., fixation counts, fixation durations, and visit counts) and qualitative (i.e., heat maps and scan paths) data obtained from the eye tracking machine to specifically explain the eye movement behaviour.

Analysis of Data

The analysis of data began with the process of determining the Areas of Interest (henceforth AOI) in all the situational questions and answer choices. The AOIs are specific parts of visual stimuli that are put under investigation by manually marking those parts. In this study, the AOIs were the names of individuals (e.g., Haziq and Alex), events (e.g., *duit raya* and tip), monetary amount in the situational questions (e.g., RM20 and RM40) and monetary amount in the answer options (e.g., RM20 and RM40) as these are potential areas that may help the participants to make their choices (refer to Figure 4 for an illustration of AOI).

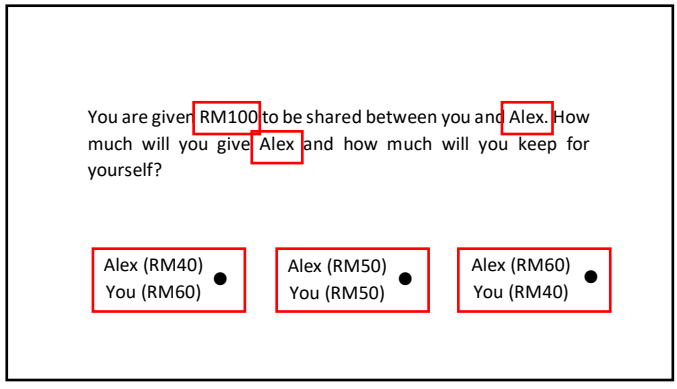

Figure 4. Six AOIs in one English situational question on the "Dictatorship" theme

As can be seen in Figure 4, there are six AOIs (marked by the red boxes) in the situational question. The red boxes, however, were not visible when the participants were reading the stimuli – they were only marked during the data analysis stage. Data that fall in these AOIs were generated into different variables determined by the researchers, namely: fixation counts, fixation duration, visit counts, scan paths, and heat maps. The quantitative data (i.e., fixation counts, fixation duration, and visit counts) gathered from the TOBI TX300 were then exported to excel files, whereas the qualitative data (i.e., scan paths and heatmaps) were transferred into images (.jpg) files. Only the mean of the quantitative data was taken from each AOI for all questions. To find the significant differences between the high and low English proficiency groups, *t*-test was conducted using the SPSS software. The scan paths and heat maps were used to support the findings. The scan paths, in particular, were used to visually show the back-and-forth movements of the eyes that are quantitatively recorded as "visit counts."

Data from the retrospective interview, which were collected during the interview, were transcribed and analysed qualitatively to support the quantitative findings mentioned in the preceding paragraph.

In this study, the answer choices that the participants made were not analysed; what was analysed however, were the eye movement behaviours before the answers were chosen, that is, the part of the stimuli that the participants focused their attention more on before the 'click of the mouse'. For this paper, however, only results from the situational questions on the Dictatorship theme was analysed not only due to the extensive nature of the original study but also because the focus of this paper is to highlight the fact that the eye tracking instrument can be used to digitally show what decision makers do as they were in the process of making their decisions.

Results and Discussions

Quantitative Data

Results show that participants with high English proficiency significantly focused more on the name 'Alex' (Fixation Count p=0.013; Visit Count p=0.013) compared to the low proficiency group when the situational questions were presented in the English language. In contrast, participants with low proficiency in English focused more on the name 'Haziq' (Fixation Duration p=0.022; Visit Count p=0.046) compared to the high proficiency group when the stimuli were presented in Malay.

Results on the participants' attention on the answer choices were also mixed. As shown in Table 2, both high and low proficiency groups gave attention to all the answer options before deciding which answer to choose, regardless of whether the questions were in Malay or English. However, participants with high English proficiency spent less time on the answer choices; their visit counts on the 50-50 and 60-40 answer choices were significantly more than those by their

low proficiency counterparts, p=0.045 for Question 6 and p=0.040 for Question 16. Low proficiency participants spent significantly more time on all answer choices, which is seen in all Malay situational questions.

Table 2
The p value of AOI that shows significant difference between high and low proficiency groups.

AOI / Variables	Name		Answer Choice		
	Alex	Haziq	50%-50%	40%-60%	60%-40%
Fixation Duration		0.022 M23 - L		0.024 E16 - L	0.000 M23 – L**
Fixation Count	0.013 E1 - H*				0.001 M18 – L
Visit Count	0.021 E1 - H	0.046 M23 - L	0.045 E6 – H 0.021 M20 – L 0.016 M21 - L		0.040 E16 – H 0.009 M18 - L

**0.013 E1 – H means that the fixation count for the name Alex is significantly higher (p = 0.013) among the high proficiency participants (H) compared to the low proficiency participants for situational question 1 that was presented in the English language (hence, marked E1).*
***0.000 M23 – L means the fixation duration for the answer choice 60%-40% is significantly shorter (p = 0.000) among the low proficiency participants (L) compared to the high proficiency participants for situational question 23 that was presented in the Malay language (hence, marked M23)*

Qualitative Data from the Eye Tracking Experiment
The scan paths of the participants were qualitatively analysed. The point-to-point movements were numbered by the eye tracker to indicate the sequence of the eye movement. As shown in Figure 5, the scan path of readers with high English proficiency is somewhat different from those with low proficiency. High proficiency readers moved back-and-forth more from all the answer options to the situational questions that were presented in English before making their decisions; low proficiency readers showed fewer back-and-forth movements when reading English situational questions. High proficiency readers showed fewer back-and-forth movements when reading situational questions in Malay

before making decisions, whereas low proficiency readers showed more back-and-forth movements when reading the Malay situation questions. The eye movement patterns of low proficiency participants were almost similar when reading situational questions in Malay and English, whereas the eye movement patterns of high proficiency participants were distinct between the questions in Malay from those in English. The eye movement patterns of high proficiency participants when reading Malay situational questions was more systematic (less back-forth movement) compared to the low proficiency participants. The heat maps (Figure 6) of the reading further support the findings from the scan paths. There were more warm colours (yellow and red colours to show more and longer fixations) on the name 'Alex' among the high proficiency readers compared to those by the low proficiency readers.

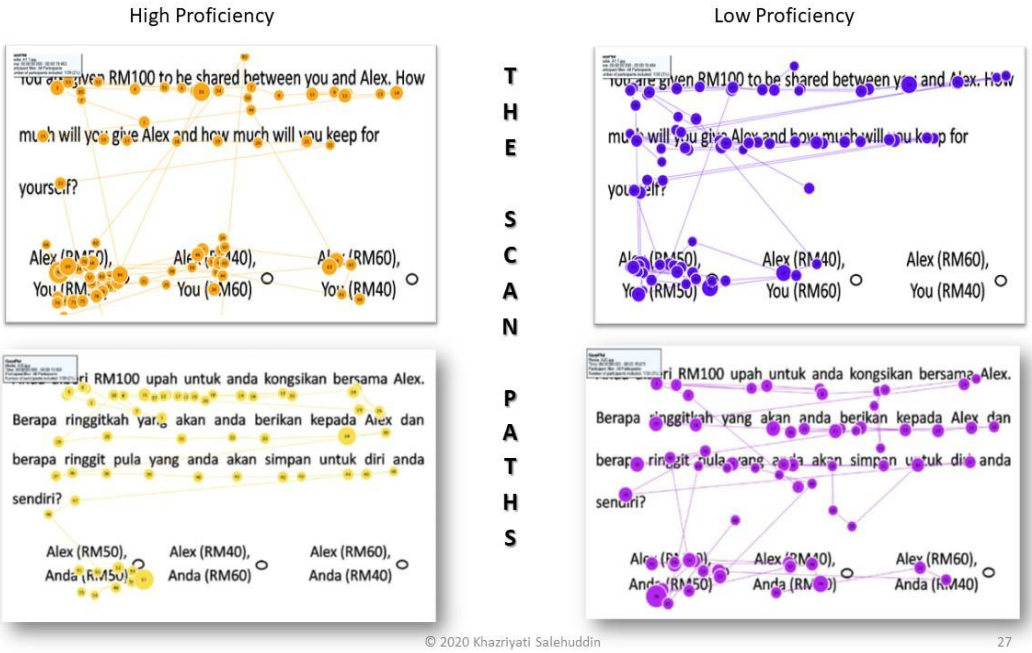

Figure 5. The scan path of high English proficiency readers (left) and low proficiency readers (right) when reading English situational questions and answer choices (top) and Malay (bottom)

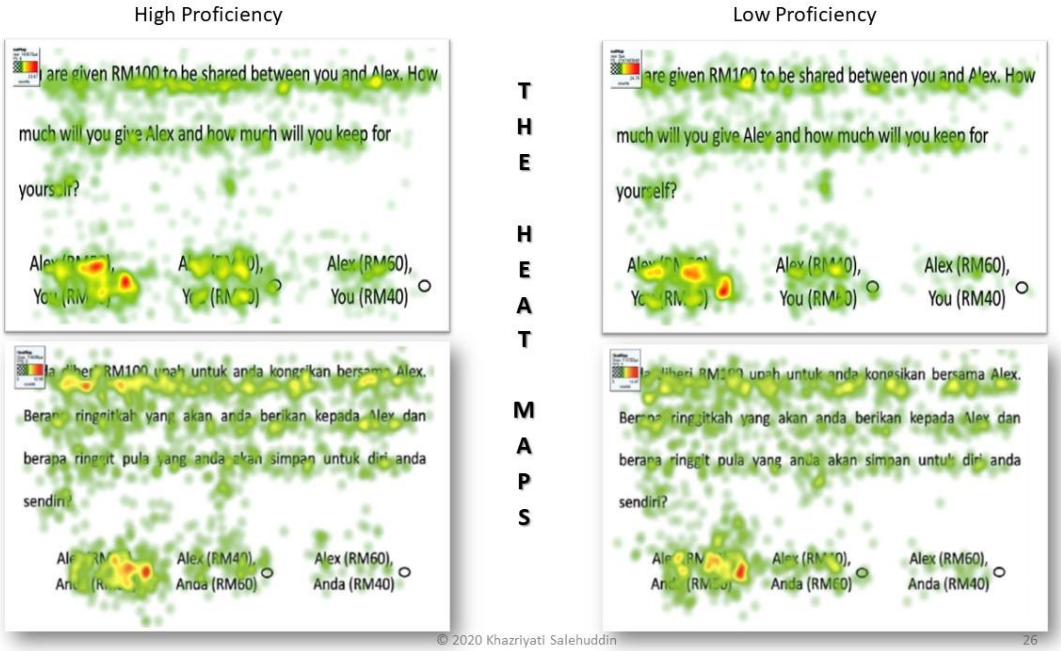

Figure 6. The heat maps of high English proficiency readers (left) and low proficiency readers (right) when reading English situational questions and answer choices (top) and Malay (bottom)

Qualitative Data from the Retrospective Interview

Analysis from the Retrospective Interview generally supports the eye movement patterns of the participants. Examples of their answers (some were originally in Malay and later translated into English) are as follows (L1 refers to Low English proficiency reader 1 and H2, to High English proficiency reader 2):

1. "I read the questions first, later then answer" (L1)
2. "I prefer (to read) in English, had to read twice in Malay" (H2)
3. "I read faster in Malay" (L3)
4. "I tend to miss many words (in Malay) so I have to read (the Malay questions) again but English is fine" (H2)

However, it is not known whether or not their responses were influenced by what they saw from the playback function. There is also a possibility that the participants were not aware of their eye movements when they read the stimuli; the responses they gave were different from what their eye movements showed. For example, one participant said the following after realising that he actually skipped words when reading the situational questions.

5. "I did not skip (the words) but still read the same questions more than one time" (L2)

A number of participants from both the high and low proficiency groups claimed that the names mentioned in the stimuli did not play a role in their decision-making process. One high proficiency participant said "no biases in terms of names" (H1) and that "names do not affect my decision-making" (H6). However, one high proficiency participant was more biased towards the English names and events; for example, "Malay names, I tend to give lesser, but English names, I give more" (H2). Similarly, one low proficiency participant was more biased towards the Malay names and events; for example, "as for Malay names, I tend to give more" (L5); another added that "Names and purposes do affect my decision-making" (L4).

Generally, our initial findings from the quantitative data suggest that there are significant differences between the data gathered from the high proficiency group and the low proficiency group. The high proficiency participants focused more on the name 'Alex' whereas the low proficiency group focused more on the name 'Haziq'. This suggests that both groups of participants focused more on the names, perhaps to assist them in making decisions. More attention was given to the English name by the high proficiency group, probably because they were more familiar with this name. All these suggest that participants' proficiency level in the language influences their decision making. Perhaps, the high exposure to English names that the high proficiency participants have from their readings and other forms of media makes them more attracted to the English names. Conversely, the low proficiency participants' lack of exposure to English names makes them more attracted to the Malay names. This echoes Stewart et al.'s claim that participants could have looked more at the names they liked because they are familiar with the names, or because the more they looked at the names, the more likely they are to be more biased towards the names (117).

There was a higher number of back-and-forth movements from the answer options to the situational questions among high proficiency participants compared to the low proficiency participants when the stimuli were in English. This back-and-forth movement, however, does not mean that the participants had difficulty in understanding the situational questions and the answer choices, as what findings from other reading research using the eye tracker have found (e.g., Sulaiman et al. 69). The higher number of back-and-forth movements in the high proficiency group could be because high proficiency learners were more biased towards the English language compared to low proficiency learners. Hence, because of the tendency to be biased, they had to read and reread the situational questions and answer choices before making any decisions. Since English is not a language that the low proficiency participants are equally familiar with, they tended to be less biased when reading in English; hence, they did not

resort to going back and forth between reading situational questions and the answer choices before making decisions. The opposite was also seen when the stimuli were presented in Malay; there were fewer back-and-forth movements among the high proficiency readers compared to the low proficiency readers. Low proficiency participants could be more biased to the Malay stimuli that this could have influenced their eye movement behaviour when they had to make decisions in the Malay language compared to the high proficiency readers.

Both high and low proficiency groups were reported to have given attention to all options provided in the stimuli before deciding on the choices, regardless of whether the situational questions were in Malay or in English. Low proficiency participants, however, spent significantly more time on all answer choices because as individuals from the Eastern community, they probably holistically took into account more perspectives of the world before decisions were made (e.g., Giacomin and Jordan 2319). As for the high proficiency participants, perhaps because they are more exposed to the Western way of thinking through the language, they were more analytical in their thinking; they wanted to solve issues quickly and as a result, they spent less time considering all options as shown in the data. This echoes previous studies suggesting that bilinguals behave distinctly depending on the language in operation and that "cognitive restructuring may occur through increasing experience with L2" (Athanasopoulos et al. 1).

Thus far, we have presented our preliminary findings with regard to investigating the decision-making process through digital means using the eye tracking machine. The analysis is still ongoing, and the other findings will be discussed in our future publications. However, what we would like to highlight in the paper is that the use of the eye tracking machine in research on decision making can help researchers further understand the complexity of the processes that take place in the minds of the decision makers as the decisions are being made.

In general, as a cognitive process, decision making is an activity that cannot be captured via the naked eye. Yet, it is important for researchers to understand the process, particularly because various factors influence how particular decisions are made. Pinpointing which factor determines which decision is necessary because past studies that used pen and paper as well as game simulations have indicated that certain factors usually influence the decisions made. However, these past studies only looked at the outcome of the decision-making process, which is the final of the four stages of the decision-making process. In these studies, none of the first three stages mentioned in Nunes et al. (14) was addressed.

The current study has illustrated that the use of digital means such as the eye tracking machine in reading experiments involving decision-making process has made investigation into the first three phases of decision-making process

possible. The experiment conducted in the current study has shown that the pre-processing stage (i.e., stage 1, which is the stage when the decision-maker builds his/her understanding from the compiled information that are gathered from different sources) could be detected by the eye tracking experiments. This was when the participants spent more time looking at certain words, which was translated by the eye tracker as fixation count and fixation duration, to gather information. The explication stage (i.e., the second stage, which is the stage when the decision maker updates the established understanding based on the information gathered earlier) was also reported by the eye tracker. This was when the participants' eyes moved back and forth from one point to another, which was translated by the eye tracker as visit counts. The elimination stage (i.e., the third stage, which is the stage when the decision maker eliminates the options that bring no advantages when compared with other options) can also be reported by the eye tracker. This was when the participants totally ignored or spent the least amount of time on one or two of the three options provided; this was translated by the eye tracker both quantitatively, in the forms of fixation counts, fixation durations, and visit counts, and qualitatively, in the forms of heat maps and scan paths. All these show that the use of a digital means such as the eye tracker can make it possible for researchers to further understand some aspects of the cognitive processes as the decision makers make decisions.

Conclusion

This paper has shown that the level of proficiency in a particular language plays a role in decision making. The eye movement patterns of participants when reading bilingual situational questions and answer choices prior to decision making showed that the names and the language used in the stimuli received different forms of attention depending on whether or not the readers are proficient in the language. This echoes recent studies suggesting that bilinguals who are proficient in their second language can actually view the world in different ways due to the specific language they are operating in (Athanasopoulos et al. 1).

Although the findings are preliminary, this paper shows that the eye tracking machine can be used to advance our understanding of what actually happens in the cognition of the decision makers through the digital data recorded by the eye tracking machine. Despite its preliminary nature, this paper has presented a rather detailed methodology that can be replicated in future studies to further identify factors that may influence the decision-making process. Through such studies, researchers may be able to make further inferences, on the basis of objective data, as to why the diverse human population reacts differently in situations that are seemingly universal in nature.

Works Cited

Amutan, Krishnan Isai, et al. "How do Non-Native Speakers of English Process Self Repair and Improve Language Proficiency and Explicitness in F2F Conversation: A Case Study." *Journal of Language and Communication* 5.1 (2018): 1-13.

Athanasopoulos, Panos, et al. "Learning to Think in a Second Language: Effects of Proficiency and Length of Exposure in English Learners of German." *Modern Language Journal* 99.1 (2015): 138-53.

Bergstrom, Jeniffer Romano, and Andrew Jonathan Schall. *Eye Tracking: In User Experience Design*. Burlington, MA: Morgan Kaufmann, 2014.

Costa, Albert, et al. "'Piensa' Twice: On the Foreign Language Effect in Decision Making." *Cognition* 130.2 (2014): 236-54.

Giacomin, Miranda, and Christian H. Jordan. "Interdependent and Independent Self-Construal." *Encyclopedia of Personality and Individual Differences,* edited by Zeigler-Hill V and T. Shackelford T. Springer, 2017. 2319-25.

Giorgetta, Cinzia, et al. "Waves of Regret: A MEG Study of Emotion and Decision-Making." *Neuropsychologia* 51.1 (2013): 38-51.

Holmqvist, Kenneth, et al. *Eye Tracking: A Comprehensive Guide to Methods and Measures*. Oxford University Press, 2011.

Imai, Matsumi, et al. "The Relation Between Language, Culture, And Thought." *Current Opinion in Psychology* 8 (2016): 70-77.

Kahneman, Daniel. *Thinking Fast and Slow*. Penguin, 2011.

Keysar, Boaz, et al. "The Foreign-Language Effect: Thinking in A Foreign Tongue Reduces Decision Biases". *Psychological Science* 23.6 (2012): 661-68.

Khedher, Asma Ben, et al. "Tracking Students' Analytical Reasoning Using Visual Scan Paths." *Proceedings of IEEE 17th International Conference on Advanced Learning Technologies*, 2017. 53-54.

Kruglanski, Arie W., and Gerd Gigenrenzer. "Intuitive and Deliberate Judgments Are Based on Common Principles." *Psychological Review* 118.1 (2011): 97-109.

Li, King King. "How Does Language Affect Decision-Making in Social Interactions and Decision Biases?" *Journal of Economic Psychology* 61.C (2017): 15-28.

Lucas, Richard E., et al. "Cross Cultural Evidence for the Fundamental Features of Extraversions." *Journal of Personality and Social Psychology* 79.3 (2000): 452-68.

Meißner, Martin, et al. "How Many Options? Behavioral Responses to Two Verses Five Alternatives Per Choice." *Proceedings of the 19th Sawtooth Software Conference,* 2019. 19-36.

Nunes, Ingrid, et al. "Decision Making with Natural Language Based Preferences and Psychology-inspired Heuristics," *Engineering Applications of Artificial Intelligence* 42 (2015): 13-16.

Obi, James Nwoye, and Edwin Agwu. "Effective Decision-Making and Organizational Goal Achievement in a Depressed Economy." *International Journal of Research and Development Studies* 8.1 (2017): 1-21.

Panpatte, Suraj, and V.D. Takale. "To Study the Decision Making Process in an Organisation for Its Effectiveness." *The International Journal of Business Management and Technology* 3.1 (2019): 73-78.

Perera-W.A., Hiran., et al. "EEG Sebagai Satu Kaedah Berkesan untuk Memahami Aktiviti Neural Berkaitan Kemisikinan" *Akademika: Journal of Southeast Asia Social Sciences and Humanities* 91.1 (2021): 165-79.

Salehuddin, Khazriyati. "Can the Eye Tracker Reveal How the Qur'an can be Learned by Heart?" *Al-Shajarah: Journal of the International Institute of Islamic Thought and Civilisation* 23.1 (2018): 125-47.

Schotter Elizabeth R., et al. "Heuristics and Criterion Setting During Selective Encoding in Visual Decision-Making: Evidence From Eye Movement." *Visual Cognition* 20.9 (2012): 1110-29.

Shi, Savannah Wei, et al. "Information Acquisition Online Decision Making: A Model-Based Exploration Using Eye Tracking Data." *Management Science* 59.5 (2013): 1009-26.

Shimizu, Yuki, et al. "Culture as Automatic Processes for Making Meaning: Spontaneous Trait Inferences." *Journal of Experimental Psychology* 69 (2017): 79-85.

Stewart, Neil, et al. "Eye Movement in Risky Choices." *Journal of Behavioral Decision Making* 29 (2016): 116-36.

Sulaiman, Nur Ainil, et al. "Reading English Academic Texts: Evidence from Eye Movement Data." *3L: The Southeast Asian Journal of English Language Studies* 26.1 (2020): 60-78.

Tengku, Fariqul Haq, and Khazriyati Salehuddin. "Pembacaan Ungkapan Literal dan Metafora Melayu: Satu Kajian Penjejakan Mata." *GEMA Online Journal of Language Studies* 20.2 (2020): 18-35.

Tham, Adam I. "An Eye-Tracking Study of Bilinguals' Processing of Lexical Cues in L1 and L2". MA Thesis. University of Malaya, 2016.

Waduthantri, Samanthila. "Eye as a Window to the Brain in Central Nervous System Diseases." *Medical Journal of Dr Y Patil University* 12.4 (2019): 376-77.

Wai Li, Liman Man, et al. "Culture and Decision Making: Influence of Analytic Versus Holistic Thinking Style on Resource Allocation in a Fort Game." *Journal of Cross-Cultural Psychology* 49.7 (2018): 1066-80.

Wang, Wuhong, et al. "Driver's Various Information Process and Multi-Ruled Decision-Making Mechanism Fundamental of Intelligent Driving

Shaping Model." *International Journal of Computational Intelligence Systems* 4.3 (2011): 297-305.

Winskel, Heather, et al. "Decision-Making and the Framing Effect in a Foreign and Native Language." *Journal of Cognitive Psychology* 28.4 (2016): 427-36.

Yates, J. Frank, and Georges A. Potorowski. "Evidence-based Decision Management." *The Oxford Handbook of Evidence-Based Management,* edited by Denis M. Rousseau. Oxford University Press, 2012. 198-222.

Yates, J. Frank, and Stephanie Oliveira. "Culture and Decision Making." *Organisational Behaviour and Human Decision Process* 136 (2016): 106-18.

Zhang, Xin, et al. "Thinking More Holistically as We Grow Older? Results from Different Tasks in Two Cultures." *Culture and Brain* 2.2 (2014): 109-21.