

IMPLEMENTATION OF EYE TRACKING TECHNIQUE FOR
HUMAN BEHAVIOR QUANTIFICATION

NUR ATIKAH BINTI MOHAMMAD KHEDZER

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

Malaysia-Japan International Institute of Technology
Universiti Teknologi Malaysia

MARCH 2022

DEDICATION

This thesis is wholeheartedly to my beloved parents and my sisters, who have been my source of inspiration and gave me strength, who continually provide their moral, spiritual, emotional and financial support.

ACKNOWLEDGEMENT

Bismillahirrahmanirahim. All praises and thanks to Allah SWT for his bless. Foremost, I would like to express my sincere gratitude to my supervisor Dr. Muhamad Kamal bin Mohammed Amin and Dr. Fauzan bin Ahmad, for the continuous support of my thesis, for his motivation and immense knowledge. Without his assistance and dedicated involvement in every step throughout the process, this thesis would have never been accomplished. His guidance helped me in all the time of research and writing of this thesis.

Besides, I am also indebted to Universiti Teknologi Malaysia (UTM) for funding my Master's study. I would like to thank members of Bio Cognition Laboratory of Bio-Inspired System Technology research group, Malaysia – Japan International Institute of Technology (MJIIT) for helping me out to complete my research.

Nevertheless, my great appreciation dedicated to all of my fellow postgraduates students and those whom involve directly or indirectly with this study.

Most importantly, my appreciation also goes to my dearest parents and siblings for all your motivation and support throughout the entire process of project. All of you are the best and I am considered myself lucky to have you. This thesis stands as a testament to your unconditional love and encouragement.

ABSTRACT

In this modern era of technology, numerous eye-mind relationship studies have dominated discussion on the ability of computer to interpret human personality traits. This phenomenon shows that eye tracking technique is becoming an important area of study. However, the study of eye movement system on validating the interpretation of actual human behaviour is still deficient. Thus, this study designs an experiment to detect human behaviour of Big Five personality traits - extraversion, agreeableness, neuroticism, openness and conscientiousness - through eye tracking system. It investigates the correlation between eye movement and human behaviour, and evaluates and validates the observational response and human personality traits. To test the hypothesis that there is a significant relation between eye movement and human behaviour, a personality test of Big Five model and experiment were conducted with 30 engineering undergraduates from one premier public university in Malaysia. The respondents were randomly picked, and the personality test was distributed to the respondents before starting the experiment. The fixation duration stimulated by film clips of different arousal contents and graphic health warning labels on cigarette packs were explored using Tobii TX300 eye tracker device. Each subject was analysed by studying their eye movement using five types of emotional video stimuli including joy, amusement, neutral, fear and sad, as well as six graphic health warning labels that are currently used by government of Malaysia. The results of eye gazing of emotion-related clips and warning labels stimuli were compared with Big Five personality test to study the relationship of eye movements and human behaviour. The results were analysed using statistical analysis of variance (ANOVA) which indicated there is no significant relation between fixation duration and human behaviour. As the actual results of positive emotion scored the longest fixation at 2570ms while negative emotion scored 2380ms, were unexpectedly different from the expected outcome based on previous studies. The data also indicated that the validation of eye-tracking technique from the emotion clips and warning labels did not have the consistent response from each subject personality, related towards their behaviour. These results suggest that their eye movement did not likely portray the participant behaviour. Hence, the concepts of validating system from eye tracker device should be further analysed in future studies for better understanding of human – computer interaction.

ABSTRAK

Dalam era teknologi moden kini, banyak kajian hubungan mata-minda telah mendominasi perbincangan mengenai keupayaan komputer untuk menafsirkan ciri-ciri personaliti manusia. Fenomena ini menunjukkan bahawa teknik mengesan mata menjadi satu bidang kajian yang penting. Walau bagaimanapun, kajian sistem pergerakan mata untuk pengesahkan tafsiran tingkah laku manusia yang sebenar masih kurang. Oleh itu, kajian ini mereka bentuk eksperimen untuk mengesan tingkah laku manusia melalui ciri-ciri personaliti Big Five – ‘extraversion, agreeableness, neuroticism, openness dan conscientiousness’ melalui sistem pengesanan mata. Ia menyiasat korelasi antara pergerakan mata dan tingkah laku manusia, dan menilai serta mengesahkan tindak balas pemerhatian dan ciri personaliti manusia. Untuk menguji hipotesis bahawa terdapat hubungan yang signifikan antara pergerakan mata dengan tingkah laku manusia, satu ujian personaliti model Big Five dan eksperimen telah dijalankan dengan 30 pelajar kejuruteraan dari sebuah universiti awam terkemuka di Malaysia. Responden telah dipilih secara rawak, dan ujian personaliti diedarkan kepada responden sebelum memulakan eksperimen. Tempoh penetapan yang dirangsang oleh klip filem ransangan yang berbeza dan label amaran kesihatan grafik pada pek rokok telah diterokai menggunakan peranti penjejak mata Tobii TX300. Setiap subjek dianalisis dengan mengkaji pergerakan mata mereka menggunakan pergerakan mata mereka menggunakan lima jenis ransangan video emosi termasuk kegembiraan, keseronokan, neutral, ketakutan dan kesedihan, serta enam label amaran kesihatan yang digunakan oleh kerajaan Malaysia. Keputusan pandangan mata klip berkaitan emosi dan label ransangan amaran dibandingkan dengan ujian personaliti Big Five untuk mengkaji hubungan pergerakan mata dan tingkah laku manusia. Keputusan dianalisis menggunakan analisis statistik varians (ANOVA) yang menunjukkan tidak terdapat hubungan yang signifikan antara tempoh penetapan dan tingkah laku manusia. Oleh kerana keputusan sebenar emosi positif mencatatkan penetapan terpanjang pada 2570ms manakala emosi negatif mendapat 2380ms, secara tidak dijangka berbeza daripada hasil yang dijangkakan berdasarkan kajian terdahulu. Data juga menunjukkan bahawa pengesanan teknik penjejukan mata daripada klip emosi dan label amaran tidak mempunyai tindak balas yang konsisten daripada setiap personaliti subjek, berkaitan dengan tingkah laku mereka. Keputusan ini menunjukkan bahawa pergerakan mata mereka tidak mungkin menggambarkan tingkah laku peserta. Oleh itu, konsep sistem pengesanan daripada peranti penjejukan mata harus dianalisis lebih lanjut dalam kajian masa depan untuk pemahaman yang lebih baik tentang interaksi manusia – komputer.

TABLE OF CONTENTS

	TITLE	PAGE
	DECLARATION	iii
	DEDICATION	iv
	ACKNOWLEDGEMENT	v
	ABSTRACT	vi
	ABSTRAK	vii
	TABLE OF CONTENTS	viii
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF ABBREVIATIONS	xv
	LIST OF APPENDICES	xvi
CHAPTER 1	INTRODUCTION	1
	1.1 Problem Background	1
	1.2 Problem Statement	4
	1.3 Research Hypothesis	5
	1.4 Research Question	5
	1.5 Research Objectives	5
	1.6 Scope of Study	6
	1.7 Significant of Study	6
	1.8 Thesis outline	7
CHAPTER 2	LITERATURE REVIEW	9
	2.1 Introduction	9
	2.2 Limitation	9
	2.3 Research Gap	10
	2.4 Eye Tracking	10
	2.5 Eye Gazing	19
	2.6 Eye Tracking on Human Behavior	29

2.7	Personality Traits	31
2.8	Big Five Personality Traits through Images and Videos	36
2.9	Summary	39
CHAPTER 3	RESEARCH METHODOLOGY	41
3.1	Introduction	41
3.2	Stimuli	41
3.3	Subject	47
3.4	Hardware	49
3.5	Software	50
3.6	Statistical Analysis	52
3.7	Experimental Procedure	53
3.8	Experimental Workflow	55
3.9	Summary	57
CHAPTER 4	RESULTS AND DISCUSSION	58
4.1	Introduction	58
4.2	Big Five Personality Test	58
4.3	Gaze Plot and Heat Map	66
4.4	Mean Fixation Duration towards Personality Traits	73
4.5	Individual Fixation Duration towards Personality Traits	83
4.6	Summary	87
CHAPTER 5	CONCLUSION AND RECOMMENDATIONS	91
5.1	Introduction	91
5.2	Research Outcomes	91
5.3	Contributions to Knowledge	92
5.4	Future Works	93
	REFERENCES	95
	LIST OF PUBLICATIONS	147

LIST OF TABLES

TABLE NO.	TITLE	PAGE
Table 2.1	Eye tracking method	15
Table 2.2	Eye tracking devices	17
Table 2.3	Cornea five distinct layers of tissue	21
Table 2.4	Eye structure of sclera	23
Table 2.5	Eye muscles	24
Table 2.6	Previous studies on eye movement and gazing behaviour	27
Table 2.7	Previous studies on eye gazing on human behaviour	30
Table 2.8	Big Five model on high and low score	32
Table 2.9	Previous studies on eye tracking on personality	35
Table 2.10	Previous studies on human behaviour towards stimuli	37
Table 3.1	Types of cigarette warning stimuli used	42
Table 3.2	Types of emotional clips stimuli used	44
Table 3.3	Previous studies using around 30 samples.	48
Table 3.4	Previous studies using within-subject design.	48
Table 4.1	Gaze plot and heat map obtained from image stimuli	67
Table 4.2	Gaze plot and heat map obtained from video stimuli	69
Table 4.3	Analysis of variance of fixation duration on emotion stimuli	74
Table 4.4	Comparison of fixation duration on emotion clips	75
Table 4.5	Analysis of variance of fixation duration on warning label stimuli	80
Table 4.6	Comparison of fixation duration on graphic warning labels	81
Table 4.7	Individual score of Big Five personality traits for Subject A and B	84

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
Figure 2.1	Pioneer on evaluation of eye tracking	11
Figure 2.2	Apparatus used for photographing eye movements	12
Figure 2.3	Eye tracker device and data obtained from Yarbus eye tracker	13
Figure 2.4	Eye tracker device in 1990s	14
Figure 2.5	Human eye	21
Figure 2.6	Five distinct layers of corneal tissue	21
Figure 2.7	Muscles of human eye	24
Figure 3.1	Tobii TX300 eye tracker	49
Figure 3.2	Tobii TX300 setup for experiment	50
Figure 3.3	Position of the subject during experiment	50
Figure 3.4	Data acquisition and analysis of eye tracker device	51
Figure 3.5	Example of eye level of a subject	54
Figure 3.6	Example of calibration result	54
Figure 3.7	Experimental workflow	56
Figure 4.1	Percentage distribution of subject score on extraversion	59
Figure 4.2	Percentage distribution of subject score on agreeableness	61
Figure 4.3	Percentage distribution of subjects score on conscientiousness	62
Figure 4.4	Percentage distribution of subjects score on neuroticism	64
Figure 4.5	Percentage distribution of subjects score on openness	65
Figure 4.6	Gaze plot of premature warning label	67
Figure 4.7	Heat map of premature birth warning label	67
Figure 4.8	Gaze plot of stillbirth warning label	67
Figure 4.9	Heat map of stillbirth warning label	67
Figure 4.10	Gaze plot of lung cancer warning label	67

Figure 4.11	Heat map of lung cancer warning label	67
Figure 4.12	Gaze plot of mouth cancer warning label	67
Figure 4.13	Heat map of mouth cancer warning label	67
Figure 4.14	Gaze plot of tongue cancer warning label	68
Figure 4.15	Heat map of tongue cancer warning label	68
Figure 4.16	Gaze plot of neck cancer warning label	68
Figure 4.17	Heat map of neck cancer warning label	68
Figure 4.18	Gaze plot of Joy1 video stimuli	69
Figure 4.19	Heat map of Joy1 video stimuli	69
Figure 4.20	Gaze plot of Joy2 video stimuli	70
Figure 4.21	Heat map of Joy2 video stimuli	70
Figure 4.22	Gaze plot of Amusement1 video stimuli	70
Figure 4.23	Heat map of Amusement1 video stimuli	70
Figure 4.24	Gaze plot of Amusement2 video stimuli	70
Figure 4.25	Heat map of Amusement2 video stimuli	70
Figure 4.26	Gaze plot of Neutral video stimuli	70
Figure 4.27	Heat map of Neutral video stimuli	70
Figure 4.28	Gaze plot of Fear1 video stimuli	70
Figure 4.29	Heat map of Fear1 video stimuli	70
Figure 4.30	Gaze plot of Fear2 video stimuli	71
Figure 4.31	Heat map of Fear2 video stimuli	71
Figure 4.32	Gaze plot of Sad1 video stimuli	71
Figure 4.33	Heat map of Sad1 video stimuli	71
Figure 4.34	Gaze plot of Sad2 video stimuli	71
Figure 4.35	Heat map of Sad2 video stimuli	71
Figure 4.36	Mean fixation on emotion video stimuli	73
Figure 4.37	Mean fixation on types of emotion	74
Figure 4.38	Fixation on graphic warning stimuli	80
Figure 4.39	Fixation duration on emotion video stimuli (Subject A)	83

Figure 4.40	Fixation duration on emotion video stimuli (Subject B)	84
Figure 5.1	Subjects score on first question of extraversion	111
Figure 5.2	Subjects score on second question of extraversion	112
Figure 5.3	Subjects score on third question of extraversion	112
Figure 5.4	Subjects score on fourth question of extraversion	113
Figure 5.5	Subjects score on fifth question of extraversion	114
Figure 5.6	Subjects score on sixth question of extraversion	114
Figure 5.7	Subjects score on seventh question of extraversion	115
Figure 5.8	Subjects score on eighth question of extraversion	116
Figure 5.9	Subjects score on ninth question of extraversion	116
Figure 5.10	Subjects score on tenth question of extraversion	117
Figure 5.11	Subjects score on first question of agreeableness	118
Figure 5.12	Subjects score on second question of agreeableness	118
Figure 5.13	Subjects score on third question of agreeableness	119
Figure 5.14	Subjects score on fourth question of agreeableness	120
Figure 5.15	Subjects score on fifth question of agreeableness	121
Figure 5.16	Subjects score on sixth question of agreeableness	121
Figure 5.17	Subjects score on seventh question of agreeableness	122
Figure 5.18	Subjects score on eight question of agreeableness	122
Figure 5.19	Subjects score on ninth question of agreeableness	123
Figure 5.20	Subjects score on tenth question of agreeableness	124
Figure 5.21	Subjects score on first question of conscientiousness	125
Figure 5.22	Subjects score on second question of conscientiousness	125
Figure 5.23	Subjects score on third question of conscientiousness	126
Figure 5.24	Subjects score on fourth question of conscientiousness	127
Figure 5.25	Subjects score on fifth question of conscientiousness	127
Figure 5.26	Subjects score on sixth question of conscientiousness	128
Figure 5.27	Subjects score on seventh question of conscientiousness	129
Figure 5.28	Subjects score on eighth question of conscientiousness	129

Figure 5.29	Subjects score on ninth question of conscientiousness	130
Figure 5.30	Subjects score on tenth question of conscientiousness	131
Figure 5.31	Subjects score on first question of neuroticism	132
Figure 5.32	Subjects score on second question of neuroticism	132
Figure 5.33	Subjects score on third question of neuroticism	133
Figure 5.34	Subjects score on fourth question of neuroticism	134
Figure 5.35	Subjects score on fifth question of neuroticism	134
Figure 5.36	Subjects score on sixth question of neuroticism	135
Figure 5.37	Subjects score on seventh question of neuroticism	136
Figure 5.38	Subjects score on eighth question of neuroticism	136
Figure 5.39	Subjects score on ninth question of neuroticism	137
Figure 5.40	Subjects score on tenth question of neuroticism	138
Figure 5.41	Subjects score on first question of openness	139
Figure 5.42	Subjects score on second question of openness	139
Figure 5.43	Subjects score on third question of openness	140
Figure 5.44	Subjects score on fourth question of openness	141
Figure 5.45	Subjects score on fifth question of openness	142
Figure 5.46	Subjects score on sixth question of openness	142
Figure 5.47	Subjects score on seventh question of openness	143
Figure 5.48	Subjects score on eighth question of openness	144
Figure 5.49	Subjects score on ninth question of openness	145
Figure 5.50	Subjects score on tenth question of openness	145

LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
GHWL	-	Graphic Health Warning Label
HCI	-	Human – Computer Interaction
IOP	-	Intraocular Pressure
MJIIT	-	Malaysia – Japan International Institute of Technology
PCCR	-	Pupil Centre Corneal Reflection
UTM	-	Universiti Teknologi Malaysia

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
Appendix A	Big Five Personality Traits	107
Appendix B	Consent Form	109
Appendix C	Big Five Personality Traits of Subjects	111

CHAPTER 1

INTRODUCTION

1.1 Problem Background

Human behaviour is an individual pattern of typical features in building a person's personality traits including thinking skills and emotion feeling as well. Behaviour were known as the way on how human act and interact with other person that affected by several factors along with genetic make-up, culture and individual attitude (Malle et al., 2021). For instance, in certain cases, people may change on their attitude in order to align similar with their behaviour at that particular moment; people tend to alter their attitude to reverse their other beliefs (Cherry, 2021).

Behaviour plays a very important role in our daily lifestyle, interaction and socializing, while the factors that affected someone's behaviour were related on their personality, motivation, values, abilities and environment (Bird, 2017). In the developing world, with ubiquitous computer interfaces, technologies have recommended these relation between users and their devices as human – computer interaction (HCI). However, this interaction have become main subjects of intensive academic research as the system were inadequate in forming human behavioural condition and utilize the knowledge in demonstrating real actions to implement (What is Human-Computer Interaction?, 2021). Researches performing in the area firmly trust that HCI potentially upgraded outstandingly by social process integration (Maskeliunas and Raudonis, 2016).

Previous research have showed that the eye approach in face-to-face interaction were the crucial part as several eye motion were presented and predict various behaviour (Maskeliunas and Raudonis, 2016). In order words, the computer devices with capability to interact directly with user's eyes were expected to process the signal information apart from only attendant with users or scanning the environment (Kweku,

2018). Effective computing innovations able to analyse behavioural state of a user by theoretically utilizing certain method including gesture, voice recognition, facial expression or biometrics (Brigham, 2017). Apart from these method, another simple yet practically accurate approach used nowadays is the eye tracking technique, which identify the appearance, attention and focus of the user (Improving your research with eye tracking since 2001 - Tobii Pro, 2021). This procedure was recently establish by huge companies in order to determine on the best way to advertise and attract customer attention in marketing products. Therefore, eye tracking study is still new method in psychology researches. Moreover, graphic and video – based eye tracking technique was one of the most suitable method in studying the eye gaze interaction, as this approach were able to elicitate on range of human behavioural state.

Decades of research have demonstrated the involvement of eye tracker in diverse perceptual and cognitive process related to eye movement behaviour towards visual interaction stimulus. The eye tracking studies involves a sensor technology that able to detect the exact point on where the eyes are focused on. A large volume of data had acquire relating to human behaviour in diverse researches and eye tracking technique, as the academic and commercial researches are focusing on broader understanding of human behaviour. With advance technology along with procedure for multi-modal data acquisition and analysis nowadays have empowered researches globally to explore and discern more on human behaviour linked with eyes attention. In addition, with this advanced practical procedure of eye tracker, much studies on visual attention, decision making and gazing behaviour were studied in detailed. As the eye activities facilitate effective sampling of visual information globally even in daily routine of social interaction. Giving the results are highly linked to cognition goals and suggested that our personality have influenced on how eyes were moved.

The reliable involvement of this eye tracking technique have increases the encouragement for validation of eye tracking in determining human behaviour. With the details of validate data from this study, it may prove for researches and clinical practitioners interest in monitoring and maintaining proficiency, developing informatics tractable studies strategies in future. Furthermore, this research will study and develop a large set of data input that able to convince the ability of eye tracker to

validate human behaviour by eye movement, as the eye tracker is a direct measure of eye activities that are more detailed and less prone to be bias than verbal report (Meernik, et al., 2016). As the eye tracker device was useful to deliver valuable insight into gaze pattern of eye movements, the study observation were expected to lead an interpretation of eyes attention and human behaviour.

In addition, this current study aims to investigate and determine the effectiveness of eye movements in identifying human behaviour by graphical and video stimuli. This study is made possible as the ground-breaking of eye tracking method was fully automated and user friendly. By using the eye tracking device, the fixation duration which is the observation during eye rest on an object for certain period of time were identified on how it relates towards the stimuli and behavioural state during experiment (Galley, Betz and Biniossek, 2015) were studied. With the application of the eye tracking matrices, it able to help on understanding on how human attributes affected, from the data obtained. Moreover, the eye motion were analysed by statistical analysis of analysis of variance (ANOVA). Besides, the correlation analysis between observational response and human personality traits by eye tracking and Big Five model were implemented in order to show the relationship between eye gazing and human behaviour. The data from these eye activities were extracted from Tobii TX300 eye tracker device.

Overall, in current study, the research therefore aim to design an experiment for detecting human behaviour by Big Five personality through eye tracking system; to investigate the correlation between eye movement and human behaviour; and to evaluate and validate the observational response and human personality traits. The outcome expect each fixation duration on emotion stimuli share the same outcomes as the personality traits test, negative stimuli expect to fixate more compared to positive stimuli. In addition, graphic warning labels expect to have similar high visual attention on each image, showing that more negative impact will increase the health risk information.

1.2 Problem Statement

Over the past decade, plenty of eye tracking research had dominated the discussion of gazing behavior by studying the human visual behavior and fine eye movements. With this precise measured equipment, research on investigating and analysis of eye gazing shift has focused on the eye movement during range of activities including as user experience, marketing research and scientific research (Improving your research with eye tracking since 2001 - Tobii Pro, 2021). Thus, with these benefits, research relating on decision making and learning eye tracker were usually conducted in order to study on how does the visual perception linked towards strategic behavior in decision process based on the primary tools, eyes.

However, the effectiveness on how does the eye movements tells the same story as how people actually behave are still deficient. Without the functional method in measuring the effectiveness of eye tracking technique, this inefficiency will likely to continue and retard the achievement of further studies in learning human behavior by human – computer interaction. Furthermore, with the increase usage of eye tracking technologies in improvising learning process, the new studying method able to presented nearly precise, as it deliver information by capturing the attention on how the feature were seen.

Therefore, this study then analyzed the connection of eye movements features towards human behavior that were neglected beforehand. As the computer alone has no capability to acknowledge on how human feels, whether they are happy, excited, neutral, sad or fear. Proving that, this field of study are still new as the improvement is beginning to become recognizable, ranging from boosting the uniqueness of interfaces to treatment. In addition, focusing on student perspective can help to develop more robust theories on current tobacco control movement in order to educate the health risk on younger generation, as well as potentially informing and producing more effective policy regarding tobacco control in future (Benjamin, 2012). Thus, with the improvement of automatic recognition and interpretation, the efficiency of interaction and personalization, natural user behavior are able to be capture with the innovative design of human-computer system.

1.3 Research Hypothesis

- 1.3.1 There is significant relation between human behaviour by eye movements and Big Five personality traits.
- 1.3.2 There is significant improvement between eye movement and human behavior.
- 1.3.3 There is significant enhancement for validation of human behavior through observational response.

1.4 Research Question

The research question are:

- 1.4.1 How does human behavior affected by eye tracking system within Big Five personality traits?
- 1.4.2 What are the impact do eye activities had on human behavior?
- 1.4.3 How can eye tracking system validate human behavior through eye tracking technique?

1.5 Research Objectives

The objectives of the research are:

- 1.5.1 To design an experiment to detecting human behaviour with Big Five personality through eye tracking system.

1.5.2 To investigate the correlation between eye movement and human behaviour.

1.5.3 To evaluate and validate the observational response and human personalities traits.

1.6 Scope of Study

The reliable involvement of eye tracking technique have increases the encouragement for validation in determining human behaviour. With details of validate data from this study, it may prove from researcher and clinical practitioners interest in monitoring and maintaining proficiency, developing informatics tractable studies strategies in future. The function of eye tracker in this study is to measure the eye activity including eye position and eye movement that used to determine which feature are seen and part that capture the attention. Therefore, this study focuses on the eye tracking technique in validating human behaviour quantification, by investigating the correlation between eye movement and human behaviour, as the scope of study is limited to warning labels and emotion clips. All the eye gaze data will be record while performing the task using Tobii TX300 eye tracker, involving 30 Malaysia – Japan International Institute of Technology (MJIIT) students. The eye tracker device includes a sensor technology that enables to identify the exact point of eye focused on. The experiment will be organized in a closed room in Bio Cognition Laboratory in MJIIT. This study is also a try test theory, while focusing on human behaviour using two different methods, personality test on people behaviour and tracking eye movement relating towards human behaviour. Both of this experiment will be compare and validate, whether does the obtain eye movement data tells the exact same story as our thought of ourselves in quantification set of data.

1.7 Significant of Study

The study of implementation of eye tracking technique for human behaviour quantification was capable to presented as a source or learning paradigm in research

community in order to enhance the human computer interaction. The stimuli of warning labels will allow people to gain more attention, recall the health warning messages in order to acquire knowledge for the risk of smoking from eye gaze. Meanwhile emotion clips that include 5 different types of videos were able to trigger people's emotion that are suitable for arousing emotion, which measured by eye activity, with a view to correlate the relationships of eye focus and brain. Eye tracker effectiveness in validating human behaviour were able to evaluate by analysing the quantification of these sets of data in beneficial to experience the device with great measurement and accuracy. Furthermore, this eye tracking study able to provide valuable insight on subjects preference that other method unable to cover. With subjects consciously have high attention on stimuli during experiment, the pupil dilation occur as the subject are intrigue by having intense emotion and critical response towards the stimuli. The audience reaction can be better predict as each line of data pattern are observe across test subject. Thus this study were expected to enhance the validation technique of human behaviour from previous studies through eye movement analysis.

1.8 Thesis outline

This thesis is divided into five chapter to ensure a clear presentation of the human behaviour and eye tracking technology put forward, which includes introduction, literature review, methodology, results and discussion and conclusion.

Chapter 1 is the introduction of the thesis providing the summary of the background of eye tracking technique in determining human behaviour, which including the background of study, statement of problem, objectives of study and scope of research. The significant of study and thesis organization are also provided.

Chapter 2 describes the literature review of eye tracking and the methods related, eye gazing, human behaviour and how eye tracking related on personality traits method from the previous studies that related with this thesis. This extensive review starts with its own introduction and followed by conceptual clarification of eye tracking and its historical background.

Chapter 3 discusses on the methodology in order to complete this thesis in details and also in flow chart form. The methodology including stimuli, subject, hardware and software along with procedure and operational framework were describe in detail.

Chapter 4 then focuses on the results and its discussion from the Big Five personality traits test, followed by data of observation and analysis of gazing behaviour that acquired during the experiment of the study. As the quantitative data collected and presented. Then discussion starts with a brief definition and introduction on the methods used in getting the results of eye tracking based on the graphical warning labels and emotion clips. In addition, this chapter also described extensive part of the discussion of the results and feedback from the study.

Finally, chapter 5 states the conclusions drawn from the study as well as the problems and recommendation were described based on the study that suggests the possible direction for future research.

REFERENCES

- Abadi, R. (2002). Mechanisms Underlying Nystagmus. *Journal Of The Royal Society Of Medicine*, 95(5), 231-234. <https://doi.org/10.1177/014107680209500504>
- Ali, Z., & Bhaskar, S. (2016). Basic statistical tools in research and data analysis. *Indian Journal Of Anaesthesia*, 60(9), 662. <https://doi.org/10.4103/0019-5049.190623>
- Anatomy of the Eye | Kellogg Eye Center | Michigan Medicine*. Umkelloggeye.org. (2020). Retrieved 5 March 2021, from <https://www.umkelloggeye.org/conditions-treatments/anatomy-eye>.
- Andersen, P. A. (2015). Eye Behavior. *The International Encyclopedia of Interpersonal Communication*, 1–7. doi: 10.1002/9781118540190.wbeic152
- Baillon, A., Selim, A. and van Dolder, D., 2013. On the social nature of eyes: The effect of social cues in interaction and individual choice tasks. *Evolution and Human Behavior*, 34(2), pp.146-154.
- Bateson, M., Callow, L., Holmes, J., Redmond Roche, M., & Nettle, D. (2013). Do Images of ‘Watching Eyes’ Induce Behaviour That Is More Pro-Social or More Normative? A Field Experiment on Littering. *Plos ONE*, 8(12), e82055. <https://doi.org/10.1371/journal.pone.0082055>
- Bednarski, J. (2012). *Eliciting Seven Discrete Positive Emotions Using Film Stimuli*. Ir.vanderbilt.edu. Retrieved 2 January 2022, from <https://ir.vanderbilt.edu/handle/1803/5081?show=full>.
- Benjamin, R., 2012. A New Surgeon General's Report: Preventing Tobacco Use among Adolescents and Young Adults. *Public Health Reports*, 127(4), pp.360-361.
- Berkovsky, S., Taib, R., Koprinska, I., Wang, E., Zeng, Y., Li, J. and Kleitman, S., 2019. Detecting Personality Traits Using Eye-Tracking Data. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*.
- Bhandari, P. (2021). *Within-Subjects Design | Explanation, Approaches, Examples*. Scribbr. Retrieved 4 January 2021, from <https://www.scribbr.com/methodology/within-subjects-design/>.

- Bird, V., 2017. *Eight Reasons Why Behaviour Is Important*. [online] Belbin.com. Available at: <<https://www.belbin.com/resources/blogs/eight-reasons-why-behaviour-is-important>> [Accessed 17 September 2020].
- Blignaut, P., Rensburg, E. J. V., & Oberholzer, M. (2019). Visualization and quantification of eye tracking data for the evaluation of oculomotor function. *Heliyon*, 5(1). doi: 10.1016/j.heliyon.2019.e01127
- Boyd, K. (2020). What Is Nystagmus?. Retrieved 19 September 2020, from <https://www.aao.org/eye-health/diseases/what-is-nystagmus>
- Bojanić, Ž., Nedeljković, J., Šakan, D., Mitić, P., Milovanović, I. and Drid, P., 2019. Personality Traits and Self-Esteem in Combat and Team Sports. *Frontiers in Psychology*, 10.
- Boomsma, C. (2013). *Visual Images as a Motivational Bridge to Pro-Environmental Behaviour: A Cognitive Approach*. Pearl.plymouth.ac.uk. Retrieved 29 December 2021, from <https://pearl.plymouth.ac.uk/handle/10026.1/1546>.
- Boundless. (n.d.). Boundless Physics. Retrieved November 25, 2019, from <https://courses.lumenlearning.com/boundless-physics/chapter/the-human-eye/>
- Boyd, K. (2020). *What Is Nystagmus?*. American Academy of Ophthalmology. Retrieved 8 June 2021, from <https://www.aao.org/eye-health/diseases/what-is-nystagmus>.
- Bradley, M., Houbova, P., Miccoli, L., Costa, V. and Lang, P., 2011. Scan patterns when viewing natural scenes: Emotion, complexity, and repetition. *Psychophysiology*, 48(11), pp.1544-1553.
- Brigham, T., 2017. Merging Technology and Emotions: Introduction to Affective Computing. *Medical Reference Services Quarterly*, 36(4), pp.399-407.
- Brune, A., & Eggenberger, E. (2018). Disorders of Vergence Eye Movements. *Current Treatment Options In Neurology*, 20(10). <https://doi.org/10.1007/s11940-018-0528-z>
- Brunyé, T. T., Drew, T., Weaver, D. L., & Elmore, J. G. (2019). A review of eye tracking for understanding and improving diagnostic interpretation. *Cognitive Research: Principles and Implications*, 4(1). doi: 10.1186/s41235-019-0159-2
- Budiu, R. (2018). *Between-Subjects vs. Within-Subjects Study Design*. Nielsen Norman Group. Retrieved 13 November 2020, from <https://www.nngroup.com/articles/between-within-subjects/>.

- C. Hain, T. (2021). *Eye movement recording devices*. Dizziness-and-balance.com. Retrieved 18 May 2021, from <https://dizziness-and-balance.com/practice/eyemove.html>.
- Cañigüeral, R. and Hamilton, A., 2019. The Role of Eye Gaze During Natural Social Interactions in Typical and Autistic People. *Frontiers in Psychology*, 10.
- Charness, G., Gneezy, U., & Kuhn, M. (2012). Experimental methods: Between-subject and within-subject design. *Journal Of Economic Behavior & Organization*, 81(1), 1-8. <https://doi.org/10.1016/j.jebo.2011.08.009>
- Cherry, K., 2020. *What Are the Big 5 Personality Traits?*. [online] Verywell Mind. Available at: <https://www.verywellmind.com/the-big-five-personality-dimensions-2795422#conscientiousness> [Accessed 10 July 2020].
- Cherry, K., 2021. *How Can Our Attitudes Change and Influence Behaviors?*. [online] Verywell Mind. Available at: <https://www.verywellmind.com/attitudes-how-they-form-change-shape-behavior-2795897> [Accessed 6 April 2021].
- Conscientiousness Personality Trait*. Thomas International. (2021). Retrieved 5 August 2021, from <https://www.thomas.co/resources/type/hr-blog/conscientiousness-personality-trait>.
- Cuncic, A., 2020. *Understanding the Impact of Neuroticism From the Big Five Traits*. [online] Verywell Mind. Available at: <https://www.verywellmind.com/how-neuroticism-affects-your-behavior-4782188> [Accessed 10 July 2020].
- Dash, S., & Thier, P. (2014). Cerebellum-Dependent Motor Learning. *Progress In Brain Research*, 121-155. <https://doi.org/10.1016/b978-0-444-63356-9.00006-6>
- Diener, E. and Lucas, R., 2021. *Personality Traits*. [online] Noba. Available at: <https://nobaproject.com/modules/personality-traits> [Accessed 10 May 2021].
- Durupinar, F., 2020. *Personality-Driven Gaze Animation With Conditional Generative Adversarial Networks*. [online] Arxiv.org. Available at: <https://arxiv.org/pdf/2012.02224.pdf> [Accessed 10 October 2020].
- E-Prime Extensions - Tobii Pro. (2015, June 26). Retrieved from <https://www.tobiiopro.com/product-listing/e-prime-extensions/>
- Eye Muscles: Attachment, Nerve Supply & Action - Anatomy Info. Anatomy Info. (2021). Retrieved 13 June 2021, from <https://anatomyinfo.com/eye-muscles/>.

- Eye, T., & Brimhall, B. (2019). *The Six Muscles of the Eye*. Brimhall Eye. Retrieved 5 June 2020, from <https://brimhalleyecenter.com/ophthalmology-tips/the-muscles-of-the-eye/>.
- Eyesee. 2014. *Eye Tracking Through History*. [online] Available at: <<https://medium.com/@eyesee/eye-tracking-through-history-b2e5c7029443#:~:text=In%201908%2C%20Edmund%20Huey%20built,the%20movements%20of%20the%20eye.>> [Accessed 9 August 2020].
- Farnsworth, B. (2019, July 4). Human Behavior: The Complete Pocket Guide. Retrieved from <https://imotions.com/blog/human-behavior/>
- Farnsworth, B. (2019, January 8). Types of Eye Movements [Saccades and Beyond]. Retrieved January 25, 2020, from <https://imotions.com/blog/types-of-eye-movements/>
- Fernández-Caballero, A., Miguel Latorre, J., Martínez-Rodrigo, A., Rodríguez-Jimenez, R., & Hussain, A. (2019). Editorial: Physiological Computing of Social Cognition. *Frontiers In Human Neuroscience*, 13. <https://doi.org/10.3389/fnhum.2019.00326>
- Fukushima, K., Fukushima, J., Warabi, T. and Barnes, G., 2013. Cognitive processes involved in smooth pursuit eye movements: behavioral evidence, neural substrate and clinical correlation. *Frontiers in Systems Neuroscience*, 7.
- Galley, N., Betz, D. and Biniossek, C., 2015. Fixation durations - Why are they so highly variable?. *ResearchGate*, [online] Available at: <https://www.researchgate.net/publication/296906377_Fixation_durations_-_Why_are_they_so_highly_variable> [Accessed 18 March 2020].
- Giesel, M., Yakovleva, A., Bloj, M., Wade, A., Norcia, A. and Harris, J., 2019. Relative contributions to vergence eye movements of two binocular cues for motion-in-depth. *Scientific Reports*, 9(1).
- Gold, D. (2019). Eye Movement Disorders. *Liu, Volpe, And Galetta's Neuro-Ophthalmology*, 549-584. <https://doi.org/10.1016/b978-0-323-34044-1.00016-x>
- Gordon, S., 2021. *Understanding How Conscientiousness Affects Your Behavior*. [online] Verywell Mind. Available at: <<https://www.verywellmind.com/how-conscientiousness-affects-your-behavior-4843763>> [Accessed 16 June 2021].

- Goyal, S., Miyapuram, K. P., & Lahiri, U. (2015). Predicting Consumers Behavior Using Eye Tracking Data. *2015 Second International Conference on Soft Computing and Machine Intelligence (ISCMI)*. doi: 10.1109/iscmi.2015.26
- Guntuku, S., Lin, W., Carpenter, J., Ng, W., Ungar, L., & Preoțiu-Pietro, D. (2017). Studying Personality through the Content of Posted and Liked Images on Twitter. *Proceedings Of The 2017 ACM On Web Science Conference*. <https://doi.org/10.1145/3091478.3091522>
- Haddock, A., & Rutkowski, A. (2014). *Psychology of extraversion* (pp. 107-120). Nova Publishers.
- Halim, Z., & Zouq, A. (2021). On identification of big-five personality traits through choice of images in a real-world setting. *Multimedia Tools And Applications*, 80(24), 33377-33408. <https://doi.org/10.1007/s11042-021-11419-5>
- Hancock, E. (2016). *Keeping an Eye on Human Behavior - UConn Today*. UConn Today. Retrieved 5 February 2022, from <https://today.uconn.edu/2016/02/keeping-an-eye-on-human-behavior/>.
- Harrison, C., Binetti, N., Coutrot, A., Johnston, A., & Mareschal, I. (2018). Personality Traits Do Not Predict How We Look at Faces. *Perception*, 47(9), 976-984. <https://doi.org/10.1177/0301006618788754>
- Hayhoe, M., & Ballard, D. (2005). Eye movements in natural behavior. *Trends in Cognitive Sciences*, 9(4), 188–194. doi: 10.1016/j.tics.2005.02.009
- Health Kura. 2020. *White Part of the Eye: Sclera Function, Definition & Anatomy | Health Kura*. [online] Available at: <<https://healthkura.com/white-part-of-eye-sclera/>> [Accessed 3 March 2021].
- Helmenstine, A. (2019). *Here's How the Human Eye Works*. ThoughtCo. Retrieved 6 January 2021, from <https://www.thoughtco.com/how-the-human-eye-works-4155646>.
- Hessels, R. S., Benjamins, J. S., Cornelissen, T. H. W., & Hooge, I. T. C. (2018). A Validation of Automatically-Generated Areas-of-Interest in Videos of a Face for Eye-Tracking Research. *Frontiers in Psychology*, 9. doi: 10.3389/fpsyg.2018.01367
- Hietanen, J., 2018. Affective Eye Contact: An Integrative Review. *Frontiers in Psychology*, 9.

- Holleman, G., Hessels, R., Kemner, C. and Hooge, I., 2020. Implying social interaction and its influence on gaze behavior to the eyes. *PLOS ONE*, 15(2), p.e0229203.
- Hooge, I. T. C., Holleman, G. A., Haukes, N. C., & Hessels, R. S. (2018). Gaze tracking accuracy in humans: One eye is sometimes better than two. *Behavior Research Methods*, 51(6), 2712–2721. doi: 10.3758/s13428-018-1135-3
- Hoppe, S., Loetscher, T., Morey, S. A., & Bulling, A. (2018). Eye Movements During Everyday Behavior Predict Personality Traits. *Frontiers in Human Neuroscience*, 12. doi: 10.3389/fnhum.2018.00105
- Hwang, J. and Cho, S., 2020. The association between new graphic health warning labels on tobacco products and attitudes toward smoking among south Korean adolescents: a national cross-sectional study. *BMC Public Health*, 20(1).
- J Soto, C. (2018). Big Five personality traits. Retrieved 2 October 2020, from https://www.researchgate.net/publication/324115204_Big_Five_personality_traits
- Jaslow, R., 2012. *Study: Graphic tobacco warning labels more effective at delivering anti-smoking message.* [online] Cbsnews.com. Available at: <https://www.cbsnews.com/news/study-graphic-tobacco-warning-labels-more-effective-at-delivering-anti-smoking-message/> [Accessed 6 February 2020].
- Johns, M., Tucker, A., Chapman, R., Crowley, K. and Michael, N., 2007. Monitoring eye and eyelid movements by infrared reflectance oculography to measure drowsiness in drivers. *Somnologie - Schlafforschung und Schlafmedizin*, 11(4), pp.234-242.
- Jones, O., 2020. The Extraocular Muscles. *TeachMeAnatomy*. Available at: <https://teachmeanatomy.info/head/organs/eye/extraocular-muscles/> [Accessed March 2, 2021].
- Jones, S. (2019). *The Importance of Face-to-Face Communication in the Modern Workforce - Lifesize.* Lifesize. Retrieved 11 November 2020, from <https://www.lifesize.com/en/blog/importance-face-to-face-communication/>.
- Jongerius, C., Hessels, R., Romijn, J., Smets, E. and Hillen, M., 2020. The Measurement of Eye Contact in Human Interactions: A Scoping Review. *Journal of Nonverbal Behavior*, 44(3), pp.363-389.
- Klaib, A., Alrehin, N., Melhem, W., Bashtawi, H. and Magableh, A., 2021. Eye tracking algorithms, techniques, tools, and applications with an emphasis on

- machine learning and Internet of Things technologies. *Expert Systems with Applications*, 166, p.114037.
- Kumar, G. and Chung, S., 2014. Characteristics of Fixational Eye Movements in People With Macular Disease. *Investigative Ophthalmology & Visual Science*, 55(8), p.5125.
- Kuniecki, M., Wołoszyn, K., Domagalik, A. and Pilarczyk, J., 2017. Effects of Scene Properties and Emotional Valence on Brain Activations: A Fixation-Related fMRI Study. *Frontiers in Human Neuroscience*, 11.
- Kweku, O., 2018. *The Potential for Human-Computer Interaction and Behavioral Science*. [online] Behavioral Scientist. Available at: <<https://behavioralscientist.org/potential-human-computer-interaction-behavioral-science/>> [Accessed 13 February 2021].
- Lim, A., 2020. *Big Five Personality Traits | Simply Psychology*. [online] Simplypsychology.org. Available at: <<https://www.simplypsychology.org/big-five-personality.html>> [Accessed 28 January 2021].
- Lim, J., Mountstephens, J., & Teo, J. (2020). Emotion Recognition Using Eye-Tracking: Taxonomy, Review and Current Challenges. *Sensors*, 20(8), 2384. <https://doi.org/10.3390/s20082384>
- Lou, Y., Cai, H., Liu, X. and Li, X., 2019. Effects of Self-Enhancement on Eye Movements During Reading. *Frontiers in Psychology*, 10.
- M. Nitzschner, M., K. J. Nagler, U., & F. Rauthmann, J. (2015). The Role of Personality in Advertising Perception: An Eye Tracking Study. *Psychology Of Everyday Activity*, 8(1). Retrieved from https://www.researchgate.net/publication/275770993_The_role_of_personality_in_advertising_perception_an_eye-tracking_study
- Manesi, Z., Van Lange, P. and Pollet, T., 2016. Eyes Wide Open. *Evolutionary Psychology*, 14(2), p.147470491664078.
- Malle, B., Fortin, J., Leblanc, M., Brunet, A., Chen, X., Beltran, D., Haroon, E., Hewitson, C., Shukur, S., Kaplan, D., Lee, K., Lee, H., Kim, S., Zacharopoulos, G., Sella, F., Kadosh, R., Fühner, T., Granacher, U., Kliegl, R., Malle, B., Reardon, S., Brod, G. and Patel, M., 2021. *Human behaviour - Latest research and news | Nature*. [online] Nature.com. Available at: <<https://www.nature.com/subjects/human-behaviour>> [Accessed 6 June 2021]

- Martin, J. G., Davis, C. E., Riesenhuber, M., & Thorpe, S. J. (2018). High Resolution Human Eye Tracking During Continuous Visual Search. *Frontiers in Human Neuroscience*, 12. doi: 10.3389/fnhum.2018.00374
- Martinez-Conde, S., Macknik, S., Troncoso, X., & Hubel, D. (2009). Microsaccades: a neurophysiological analysis. *Trends In Neurosciences*, 32(9), 463-475. <https://doi.org/10.1016/j.tins.2009.05.006>
- Maskeliunas, R. and Raudonis, V., 2016. Are you ashamed? Can a gaze tracker tell?. *PeerJ Computer Science*, 2, p.e75.
- McCrackin, S., Soomal, S., Patel, P., & Itier, R. (2019). Spontaneous eye-movements in neutral and emotional gaze-cuing: An eye-tracking investigation. *Heliyon*, 5(4), e01583. <https://doi.org/10.1016/j.heliyon.2019.e01583>
- Meernik, C., Jarman, K., Wright, S. T., Klein, E. G., Goldstein, A. O., & Ranney, L. (2016). Eye Tracking Outcomes in Tobacco Control Regulation and Communication: A Systematic Review. *Tobacco Regulatory Science*, 2(4), 377–403. doi: 10.18001/trs.2.4.9
- Messner, K., 2010. *Tobii Technology Launches 300 Hz Eye Tracker That Gives Subjects Room to Move, Opens Up Possibilities for New Fields of Research*. [online] News Powered by Cision. Available at: <<https://news.cision.com/tobii-ab/r/tobii-technology-launches-300-hz-eye-tracker-that-gives-subjects-room-to-move--opens-up-possibilities-for-new-fields-of-research,c524563>> [Accessed 9 February 2021].
- Nettle, D., Harper, Z., Kidson, A., Stone, R., Penton-Voak, I. and Bateson, M., 2013. The watching eyes effect in the Dictator Game: it's not how much you give, it's being seen to give something. *Evolution and Human Behavior*, 34(1), pp.35-40.
- NKCF.org. 2020. *How the Human Eye Works | Cornea Layers/Role | Light Rays*. [online] Available at: <<https://nkcf.org/about-keratoconus/how-the-human-eye-works/>> [Accessed 10 August 2021].
- Nummenmaa, L., Hyönä, J. and Calvo, M., 2009. Emotional scene content drives the saccade generation system reflexively. *Journal of Experimental Psychology: Human Perception and Performance*, 35(2), pp.305-323.

- Ostertagova, E., & Ostertag, O. (2013). Methodology and Application of One-way ANOVA. *American Journal Of Mechanical Engineering*, 1(7), 256-261. <https://doi.org/10.12691/ajme-1-7-21>
- Otero-Millan, J., Macknik, S. and Martinez-Conde, S., 2014. Fixational eye movements and binocular vision. *Frontiers in Integrative Neuroscience*, 8
- Pan, B., Hembrooke, H. A., Gay, G. K., Granka, L. A., Feusner, M. K., & Newman, J. K. (2004). The determinants of web page viewing behavior. *Proceedings of the Eye Tracking Research & Applications Symposium on Eye Tracking Research & Applications - ETRA2004*. doi: 10.1145/968363.968391
- Peterson, E., Thomsen, S., Lindsay, G. and John, K., 2010. Adolescents' Attention to Traditional and Graphic Tobacco Warning Labels: An Eye-Tracking Approach. *Journal of Drug Education*, 40(3), pp.227-244.
- Picó, A., Espert, R., & Gadea, M. (2020). How Our Gaze Reacts to Another Person's Tears? Experimental Insights Into Eye Tracking Technology. *Frontiers In Psychology*, 11. <https://doi.org/10.3389/fpsyg.2020.02134>
- Rauthmann, J. F., Seubert, C. T., Sachse, P., & Furtner, M. R. (2012). Eyes as windows to the soul: Gazing behavior is related to personality. *Journal of Research in Personality*, 46(2), 147–156. doi: 10.1016/j.jrp.2011.12.010
- Research to Prevent Blindness. 2018. *How the Eye Works*. [online] Available at: <<https://www.rpbusa.org/rpb/resources-and-advocacy/resources/rpb-vision-resources/how-the-eye-works/>> [Accessed 10 February 2021].
- Rosengren, W., Nyström, M., Hammar, B., Rahne, M., Sjö Dahl, L., & Stridh, M. (2020). Modeling and quality assessment of nystagmus eye movements recorded using an eye-tracker. *Behavior Research Methods*, 52(4), 1729-1743. <https://doi.org/10.3758/s13428-020-01346-y>
- Sarsam, S., Al-Samarraie, H. and Alzahrani, A., 2021. Influence of personality traits on users' viewing behaviour. *Journal of Information Science*, p.016555152199805.
- Schneider, T. (2004). The role of neuroticism on psychological and physiological stress responses. *Journal Of Experimental Social Psychology*, 40(6), 795-804. <https://doi.org/10.1016/j.jesp.2004.04.005>
- Searle, A. and Rowe, F., 2016. Vergence Neural Pathways: A Systematic Narrative Literature Review. *Neuro-Ophthalmology*, 40(5), pp.209-218.

- Sekhon, R., Cabrero, F. and Deibel, J., 2021. Nystagmus Types. *National Center for Biotechnology Information*, [online] Available at: <<https://www.ncbi.nlm.nih.gov/books/NBK539711/>> [Accessed 18 January 2021].
- Shojaeizadeh, M., Djamasbi, S., Paffenroth, R. C., & Trapp, A. C. (2019). Detecting task demand via an eye tracking machine learning system. *Decision Support Systems*, *116*, 91–101. doi: 10.1016/j.dss.2018.10.012.
- Shokrkon, A., & Nicoladis, E. (2021). How personality traits of neuroticism and extroversion predict the effects of the COVID-19 on the mental health of Canadians. *PLOS ONE*, *16*(5), e0251097. <https://doi.org/10.1371/journal.pone.0251097>
- Simola, J., Torniainen, J., Moisala, M., Kivikangas, M. and Krause, C., 2013. Eye movement related brain responses to emotional scenes during free viewing. *Frontiers in Systems Neuroscience*, *7*.
- Singh, H., & Singh, J. (2012). Human Eye Tracking and Related Issues: A Review. *International Journal Of Scientific And Research Publication*, *2*(9). doi: 10.29322
- Smillie, L. (2017). *Openness to Experience: The Gates of the Mind*. Scientific American. Retrieved 3 January 2022, from <https://www.scientificamerican.com/article/openness-to-experience-the-gates-of-the-mind/>.
- Sridhar M. S. 2018. Anatomy of cornea and ocular surface. *Indian journal of ophthalmology*, *66*(2), 190–194. https://doi.org/10.4103/ijjo.IJO_646_17
- Stuart, S., Parrington, L., Martini, D., Peterka, R., Chesnutt, J., & King, L. (2020). The Measurement of Eye Movements in Mild Traumatic Brain Injury: A Structured Review of an Emerging Area. *Frontiers In Sports And Active Living*, *2*. <https://doi.org/10.3389/fspor.2020.00005>
- Subramanian, R., Shankar, D., Sebe, N. and Melcher, D., 2014. Emotion modulates eye movement patterns and subsequent memory for the gist and details of movie scenes. *Journal of Vision*, *14*(3), pp.31-31.
- Sun, Y., & Smith, L. (2018). Retinal Vasculature in Development and Diseases. *Annual review of vision science*, *4*, 101–122. <https://doi.org/10.1146/annurev-vision-091517-034018> (Retraction published Annu Rev Vis Sci. 2020 Oct 15;0:)

- Tarnowski, P., Kołodziej, M., Majkowski, A., & Rak, R. (2020). Eye-Tracking Analysis for Emotion Recognition. *Computational Intelligence And Neuroscience*, 2020, 1-13. <https://doi.org/10.1155/2020/2909267>
- Termsarasab, P., Thammongkolchai, T., Rucker, J. and Frucht, S., 2015. The diagnostic value of saccades in movement disorder patients: a practical guide and review. *Journal of Clinical Movement Disorders*, 2(1).
- The Interaction Design Foundation. 2021. *What is Human-Computer Interaction (HCI)?*. [online] Available at: <<https://www.interaction-design.org/literature/topics/human-computer-interaction>> [Accessed 19 July 2021].
- Thier, P., & Ilg, U. J. (2005). The neural basis of smooth-pursuit eye movements. *Current Opinion in Neurobiology*, 15(6), 645–652. doi: 10.1016/j.conb.2005.10.013
- Thomas International. 2021. *What Are The Big 5 Personality Traits?*. [online] Available at: <<https://www.thomas.co/resources/type/hr-guides/what-are-big-5-personality-traits>> [Accessed 16 May 2021].
- Tobii TX 300. Tsgdoc.socsci.ru.nl. (2019). Retrieved 20 March 2020, from https://tsgdoc.socsci.ru.nl/images/e/eb/Tobii_TX_300.pdf.
- Tobiiipro.com. 2021. *Improving your research with eye tracking since 2001 - Tobii Pro*. [online] Available at: <<https://www.tobiiipro.com/>> [Accessed 6 April 2021].
- Tobiiipro.com. 2019. *Learn about the different types of eye movement - Tobii Pro*. [online] Available at: <<https://www.tobiiipro.com/learn-and-support/learn/eye-tracking-essentials/types-of-eye-movements/>> [Accessed 10 August 2020].
- Tobiiipro.com. (2014). Retrieved 20 August 2020, from <https://www.tobiiipro.com/siteassets/tobii-pro/user-manuals/tobii-pro-tx300-eye-tracker-user-manual.pdf>.
- Tobii Pro Lab. (2015, June 23). Retrieved from <https://www.tobiiipro.com/product-listing/tobii-pro-lab>
- Tobii Tech. 2021. *What is eye tracking?*. [online] Available at: <<https://tech.tobii.com/technology/what-is-eye-tracking/>> [Accessed 19 May 2020].

- Valtakari, N., Hooge, I., Viktorsson, C., Nyström, P., Falck-Ytter, T. and Hessels, R., 2021. Eye tracking in human interaction: Possibilities and limitations. *Behavior Research Methods*.
- Van Thiel, E. (2020). *What are the Big Five Personality Test Traits? - Learn all about the Theory | 123test*. 123test.com. Retrieved 5 August 2020, from <https://www.123test.com/big-five-personality-theory/>.
- Veerapa, E., Grandgenevre, P., El Fayoumi, M., Vinnac, B., Haelewyn, O., Szaffarczyk, S., Vaiva, G. and D'Hondt, F., 2020. Attentional bias towards negative stimuli in healthy individuals and the effects of trait anxiety. *Scientific Reports*, 10(1).
- Vision Initiative. 2020. *How your eyes work - Vision Initiative*. [online] Available at: <<https://www.visioninitiative.org.au/common-eye-conditions/how-your-eyes-work>> [Accessed 2 March 2021].
- Wachler, B. (2019). *Corneal cross-linking for keratoconus*. All About Vision. Retrieved 20 September 2020, from <https://www.allaboutvision.com/conditions/corneal-crosslinking.htm>.
- What is Visual Fixation?. (2020). Retrieved 12 October 2020, from https://www.seevividly.com/info/Binocular_Vision/Visual_Skills/Visual_Fixation
- Widiger, T. and Oltmanns, J., 2017. Neuroticism is a fundamental domain of personality with enormous public health implications. *World Psychiatry*, 16(2), pp.144-145.
- Zhang, X., Liu, X., Yuan, S.-M., & Lin, S.-F. (2017). Eye Tracking Based Control System for Natural Human-Computer Interaction. *Computational Intelligence and Neuroscience*, 2017, 1–9. doi: 10.1155/2017/57393