THE EFFECT OF CROWDING IN SMARTPHONE AND PRINTED MATERIALS ON ACCOMMODATIVE RESPONSE AND LAG OF ACCOMMODATION

BY

NUR AMANI IZZATI BINTI MAT GHANI

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International Islamic University Malaysia

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ABSTRACT

This study aimed to investigate the effect of crowding letters in smartphone and printed reading materials on accommodative response and lag of accommodation. The effect of crowding letters presented in printed reading material and smartphone were uncrowded target A (two letter width letter separation), uncrowded target B (reading material with standard letter separation) and crowded target C (reading material with abutting letter) at viewing distances of 33 cm, 40 cm and 50 cm corresponding to the accommodative stimulus of 3.00 D, 2.50 D and 2.00 D. Accommodative response was found increased significantly with closer viewing distances, regardless of crowded or uncrowded target. Printed materials showed significantly higher accommodative response in all distances compared to smartphone. There were no significant differences for both reading materials at 50cm. Changes in the accommodation lag showed statistically higher as accommodation demand increased for uncrowded target A (smartphone). There were no significant changes in the lag of accommodation regardless of targets and distances between smartphone and printed material. These findings suggested that the smartphone reading materials produced lesser accommodative response than printed. Smaller changes of accommodative lag seem to prevent visual fatigue with closer working distance in both smartphone and printed material.

Key Words: accommodation, accommodation response, accommodative lag, crowding, near target, viewing distance

خلاصة البحث

يهدف هذا البحث إلى إلقاء الضوء على تأثير الحروف المزدحمة في الهواتف الذكية ومواد القراءة المطبوعة على استجابة المتكيف والتأخر التكييفي. تقدم الحروف في مواد القراءة المطبوعة والهواتف الذكية في ثلاثة المواقف المختلفة لبحث عن الفروق بينها وهي الموقف A، هدف غير مزدحم (تباعد الأحرف موسع)، الموقف B، هدف غير مزدحم (تباعد الأحرف عادي) والموقف C، هدف مزدحم (تباعد الأحرف مكثف) عند عرض مسافات المشاهدة ٣٣ سم و ٤٠ سم و ٥٠ سم مقابل للحافز التكيفي ٣,٠٠ D و ٢,٥٠ D و ٢,٠٠ D. فهذه التجربة تكشف بأن استجابة المتكيف نزداد مع انخفاض مسافات المشاهدة، بغض النظر عن هدف مزدحم أو غير مزدحم. واستجابة المتكيف على المواد المطبوعة يكون أعلى من الهواتف الذكية في جميع مسافات المشاهدة إلا في ٥٠ سم أي لم تكن هناك فروق ذات دلالة إحصائية لكلا مواد القراءة المطبوعة والهواتف الألكترونية. أظهرت التغييرات في التأخر التكيفي ارتفاعًا إحصائيًا مع ارتفاع طلب المتكيف لهدف غير مزدحم A (الهواتف الذكية). لم تكن هناك تغييرات كبيرة في التأخر التكييفي بين الهواتف الذكية والمواد المطبوعة بغض النظر عن اختلاف الأهداف (target) المستخدمة. فالنتائج من هذا البحث تشير إلى أن مواد القراءة في الهواتف الذكية نتتج استجابة المتكيف أقل ملاءمة من تلك المطبوعة. فالتغييرات الصغيرة في التأخر التكييفي قادرة على وقاية الإجهاد البصري في مسافة المشاهدة القريبة لكلا مواد القراءة المطبوعة والهواتف الألكترونية.

الكلمات المفتاحية: الإقامة، استجابة المتكيف، تأخر الإقامة، الازدحام، قرب الهدف، مسافات المشاهدة

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Health Sciences in Optometry

.....……
Asst. Prof. Dr.Norsham binti Ahmad
Supervisor

……..
Asst. Prof. Dr. Mohd Hafidz bin Ithnin
Co-Supervisor

……..
Asst. Prof. Dr. Muhammad Afzam Shah bin Abdul Rahim (Co-Supervisor)

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Health Sciences in Optometry

……..
Asst. Prof. Dr. Mohd Radzi bin Hilmi
Internal Examiner

……..
Assoc. Prof. Dr. Lily Asma binti Ismail
External Examiner

This thesis was submitted to the Department of Optometry and Visual Sciences and is accepted as a fulfilment of the requirement for the degree of Master of Health Sciences in Optometry

……..
Asst. Prof. Dr. Norsham binti Ahmad
Head DOVS

This thesis was submitted to the Kulliyyah of Allied Health Sciences and is accepted as a fulfilment of the requirement for the degree of Master of Health Sciences in Optometry

…….…….
Prof. Dr. Suzanah binti Abdul Rahman
Deputy Dean of Postgraduate, KAHS

DECLARATION

I hereby declare that this thesis is the result of my own investigation, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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LIST OF ABBREVIATIONS AND SYMBOLS

-	Nearsightedness (myopia)
%	Percentage
+	Farsightedness (hypermetropia)
<	less than
±	Plus, minus sign
√	Square root
≥	equal or more than
◦	Degree
©	Copyright
®	Registered trademark
AA	Amplitude of accommodation
ANOVA	Analysis of Variance
BFA	Binocular facility of accommodation
cm	Centimeter
cm2	Square centimeter
CVS	Computer Vision Syndrome
D	Diopter
D	Depth
DC	Diopter cylinder
dpi	Dots per inch
et.al.	(et alia); others
FA	Facility of accommodation
g	Gram
H	Height
i.e.,	that is
II	Roman numerals 1
II	Roman numerals 2
III	Roman numerals 3
IIUM	International Islamic University Malaysia
in	inches
IPS LCD	In-Plane Switching Liquid Crystal Display
IREC	IIUM Research Ethics Committee
IV	Roman numerals 4
jpeg	Joint Photographic Experts Group
LA	Lag of accommodation
LCD	Liquid Crystal Display
m	Meter
M	M-units
M	million
MEM	Monocular Estimation Method
MFA	Monocular facility of accommodation
mm	Millimeter
N	N-notation
NPC	Near point of convergence

oz	Ounce
pdf	Portable document format
ppi	Pixels per inch
pt	Point
RAF	Royal Air Force
RGB	Red-Green-Blue
RM-ANOVA	Repeated Measures Analysis of Variance
SD	Standard deviation
SE	Spherical equivalent
SE	Standard error
SI	International System of Units
SPSS	Statistical Package for the Social Science
V	Roman numerals 5
VA	Visual acuity
VI	Roman numerals 6
VII	Roman numerals 7
vs	Versus
VWFA	Visual word form area
W	Width
x	Multiplication/Times
ε	Sphericity

CHAPTER ONE
INTRODUCTION

١,١ BACKGROUND OF THE STUDY

Crowding refers to the deterioration of ability to identify targets with the detrimental effect in presence of nearby objects (Bex, Dakin, & Simmers, 2003; Berg, Roerdink, & Cornelissen, 2007; Gheri, Morgan, & Solomon, 2007; Kennedy & Whitaker, 2010; Whitney & Levi, 2011; Kalpadakis-Smith, Goffaux, & Greenwood, 2018). Over the last few years, interest in crowding has grown dramatically as researchers seek to understand the mechanism of object detection (Whitney & Levi, 2011). The crowding could affect the identification when the target and distractors have similar properties which includes orientation, size, saturation and hue (Berg et al., 2007). Research had showed that the crowding effects are much stronger on orientation and letter size of the stimulus compared to saturation and hue (Berg et al., 2007).

During reading, the effects of crowding occurred between adjacent characters and words which contribute to slow reading speed in peripheral vision (Chung, 2004). Studies had shown that in a wide variety of ways, reading text from print and digital devices such as smartphone differ significantly (Eden & Eshet-Alkalai, 2012). This includes the variations in font type, font size and spacing (Moret-Tatay & Perea, 2011).

Typography is defined as the selection, arrangement dealing with the shape, spacing and layout of words and sentences in the text to optimize the reader's comprehension (Amar, Droulers, & Legohérel, 2017). This is because typography plays an important role in discrimination (legibility) which makes it easy for readers to identify such features from letters and characters (Myung, 2003). The numerous types

of the size and shapes (font) on a page or display are also important factors that determines the legibility (Legge & Bigelow, 2011) which varied from printed material to smartphones (Marinus et al., 2016). Studies had shown that san serif typeface (a particular design of type for each font) is more readable compared to serif (Mohamad Ali, Wahid, Samsudin, & Idris, 2013). Serif based letter has an 'end stroke' that acts as visual noise while san serif does not have 'end stroke' and thus, help readers to easily identify letters (Mohamad Ali et al., 2013). According to the Pölönen, Järvenpää, & Häkkinen (2012) the different typeface promoted inaccurate an imprecise eye movement and could cause foveal crowding (Bedell, Siderov, Formankiewicz, Waugh, & Aydin, 2015).

During the presentation of letters, researchers found that better legibility was achieved by reducing viewing distance or increasing the letter height, as this increases the size of the retinal images (Bernard, Chaparro, Mills, & Halcomb, 2003; Woods, Davis, Scharff, & Austin, 2005). As such, increasing the spacing between letters in words probably reduces crowding effect (Chung, 2004), whereas decreasing the letter spacing makes it harder to identify (Mcgowan, White, Jordan, & Paterson, 2014). The abutting (no space between target and flanker) has been introduced to demonstrate crowding (Coates, Levi, Touch, & Sabesan, 2018). Accordingly, Perea, Moret-Tatay, & Gómez (2011) mentioned that letter spacing playing a major role in recognizing of the presented text. This is because crowded lead to higher guessing rates and random error (Liu & Arditi, 2001).

In this digitalization era, the use of electronic book (e-books) and tablets showed the dependency on computerized technology as a source of information is growing up (Benedetto, Drai-Zerbib, Pedrotti, Tissier, & Baccino, 2013). Furthermore, smartphone has encouraged the rapid expansion of internet use because of its ability to be used

anywhere or at any time (Park et al., 2014). This enables smartphone users from around the world to easily communicate and obtained any information such as browsing the internet (Székely, Talanow, & Bágyi, 2013). Based on a survey conducted by the Malaysian Communications and Multimedia Commission (MCMC, 2017), internet users in Malaysia were found to increase from 24.1 million in the year 2015 to 24.5 million in the year 2016. However, smartphone and tablet usage differs from computers in term of viewing position, distance, screen size, luminance and pattern of use (Jaiswal et al., 2019).

To date, research had shown that the use of small electronic devices (i.e., smartphone) induces a shift in certain accommodative function (accommodative amplitude, accommodative facility and accommodative lag) with closer environment. The use of smartphone lead to a decrease in amplitude of accommodation and an increase in the lag of accommodation (Jaiswal et al., 2019). This is also associated with an increase in visual discomfort and aesthenopic symptoms such as blur, headache and soreness (Jaiswal et al., 2019). In contrast, Hue, Rosenfield, & Saá (2014) find greater accommodative lag with printed targets lead to increase similar symptoms . However, an increase in tired eyes and eye discomfort were noted while reading on a smartphone.

Several studies had identified that the short working distance during near related tasks contributes to high visual demands in the human accommodation system (Huang, Chang, & Wu, 2015; Long, Cheung, Duong, Paynter, & Asper, 2017). Near visual ability known as accommodation provides important information for maintaining a clear and single images (Win-Hall, Ostrin, & Kasthurirangan, 2007). The smaller typeface, increased length or reduced spacing in the reading passages would result in increased demand on the human accommodation systems (Metsing & Ferreira, 2012).

However, the accommodative dysfunction might be presented when changing focus from far to near or vice versa (Metsing & Ferreira, 2012).

This study will further investigate the effect of crowding with smartphone and printed targets on changes in accommodation lag and accommodative response. Results from this study will demonstrate how the eyes function at closer viewing distances when reading on various media (printed reading material and smartphone) in the presence of crowding (crowded and uncrowded target).

١,٢ PROBLEM STATEMENT AND SIGNIFICANT OF STUDY

With the advent of technology, the trend of reading had shifted from the traditional printed materials into the digital text (Scaltritti et al., 2019). Stronger crowding effect was reported when the spacing of letter (distance separation) decreased (Levi, 2008). The effect of crowding was worsen as peripheral and amblyopic eye limited letter identification (Levi, 2008). Martelli, Filippo, Spinelli, & Zoccolotti (2017) reported the crowding effect was responsible for the slow reading speed. When a letter is flanked by other letters, it will impact on the object recognition and identification (Martelli et al., 2009). In this present study, we hypothesized that abutting at closed viewing distance may contributed to a greater crowding effect as the ability to recognize the letter becomes more difficult due to closer letter separation.

It is well known that the standard reading distance for adults with printed text is 40 cm (16 inches) (Lan, Rosenfield, & Liu, 2018). However, smartphone was reported to have been widely used and usually held closer viewing distances compared to printed reading materials. The closer distances places increased demand on both ocular accommodation and vergence, thus could exacerbate symptoms for an extended period of time (Lan et al., 2018). The ocular symptoms such as eyestrain and tired eyes

increased significantly with prolonged used of smartphone and computer (Shen, Spors, Mcnaughton, & Liu, 2016) at close viewing distance (Zetterberg, Forsman, & Richter, 2013).

A comparison of symptoms after viewing text on a computer screen and printed reading material had been investigated by Chu, Rosenfield, Portello, Benzoni, & Collier (2011). Hepsen, Evereklioglu, & Bayramlar (2001) reported that the near reading or work can cause accommodative inaccuracies in terms of response error, known as lag and lead of accommodation. In other studies, the increment in trapezius muscle activity showed that near work may contribute to an increased visual discomfort such as neck and shoulder discomfort due to poor visual ergonomic (inadequate lighting) (Zetterberg et al., 2013).

In the previous study, several characters including English, Korean and Chinese were compared in order to evaluate the impact of character on accommodative response (Lan et al., 2018). The findings reported that no significant differences between the accommodative response with different characters when viewed at the same viewing distances (Lan et al., 2018). Although this study compared the differences on accommodation response, there was lack certain information provided such as crowding effect (crowded and uncrowded target) with closer distance. Hence, the main purpose of this study is to investigate the effect of crowded and uncrowded on the accommodation response and changes of accommodative lag when reading at different viewing distance on printed targets and smartphone.

To the best of our knowledge, no studies have yet investigated the accommodative response and changes of accommodative lag when individuals without accommodative dysfunction are presented with crowded and uncrowded target.

Specifically, the variability of letter spacing (crowding) will be investigated at different viewing distance on printed and smartphone reading materials.

١,٣ RESEARCH OBJECTIVES

١,٣,١ General objective

To investigate the crowding effect of smartphone and printed reading materials on accommodative response and lag of accommodation at different viewing distances.

١,٣,٢ Specific Objective

The objective of this study was to investigate the crowding letter (crowded and uncrowded reading material target) in different viewing distances at 33 cm, 40 cm, and 50 cm, to elicit the effect on accommodative response and changes of lag of accommodation. For specific objective was listed in each experiment: printed (Experiment 1, page 65), smartphone reading materials (Experiment 2, page 83) and the comparison of both different reading materials were explained in Experiment 3, page 98.

١,٤ RESEARCH QUESTIONS

١. Does crowded reading target lead to greater crowding effect due to closer separation of letter at closed viewing distance?

٢. Does crowded reading target cause greater accommodative response at closer distance?

٣. Does uncrowded reading target lead to the smallest changes of accommodative lag?

٤. Which type of printed or smartphone targets (crowded or uncrowded reading materials) made the largest change of accommodative lag and accommodative response?

١,٥ RESEARCH HYPOTHESIS

١. Crowded reading materials produces greater crowding effects with closer viewing distances.

٢. Abutting (crowded reading target) cause greater accommodative response at closer working distances.

٣. A crowded target caused the largest change of accommodative lag after reading at viewing distance of 33 cm compared to 40 cm and 50 cm.

٤. Crowded target at closer viewing distance of smartphone reading materials have smaller effect on accommodation response and largest changes of accommodative lag compared to printed reading materials.

١,٦ CHAPTER SUMMARY

This chapter has presented and discussed the background of the research. It explained the possible effect of crowding (crowded and uncrowded target) on accommodative response and changes accommodation lag in different viewing distances between printed materials and smartphone. This was followed by literature review of previous study. Additionally, the problem statement was discussed as this research intended to close the gap of previous studies in crowding effect among the young adult with normal accommodative function. This chapter also presented the research objective which is to understand the effect of crowded and uncrowded target at closer viewing distances when presented via smartphone and printed reading materials. The research questions and hypothesis developed in this chapter could fill the gap in the current knowledge.