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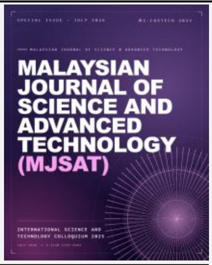

Sustained Accommodative Control in Young Adults: Minimal Change After Brief Digital Reading Across Small Font Sizes Under Photopic Room Illumination

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ABSTRACT

The action of ocular ciliary muscle contributes to the accommodation system, especially when the eye focuses on near objects. Sustaining clear near vision during reading requires precise accommodative control. Each change in viewing distance or target detail initially presents a blur stimulus, prompting the accommodation system to adjust lens power to restore retinal image clarity. This dynamic process is continually challenged by variable task demands, including changes in print size. This study compared the accommodation response with different font sizes before and after near task with digital device under photopic bright room illumination. Thirty young adults with a mean age of 22.13 ± 1.31 years old completed 10 minutes of uninterrupted reading on an iPhone 11 at a fixed near viewing distance. The reading material consisted of black text on a white background with different font sizes of Arial letter equivalent to N5, N8, N10, and N12 under normal photopic room lighting. The dioptric value of accommodation response was measured objectively using an open field Grand Seiko WAM-5500 autorefractor, before and after reading task. The accommodation response in baseline measurement before reading was 4.20 ± 0.63 D, after reading with N5 size was 4.13 ± 0.63 D, after reading with N8 size was 4.32 ± 0.34 D, after reading with N10 size was 4.39 ± 0.75 D, and after reading with N12 size was 4.55 ± 0.60 D. There was a statistically significant difference in accommodation response before and after reading task only for N12 font size (Wilcoxon signed-rank test: $Z = -2.40$, $p = 0.02$). It could be concluded that the action of ocular ciliary muscle is well controlled for intense small size of near target. These findings indicated that the young adult eye responds similarly to small letter sizes after a short duration of reading under photopic room illumination.

1. INTRODUCTION

Ocular ciliary muscle is formed by a ring of smooth muscle within the eye's ciliary body and attached to the crystalline lens via zonular fibres. This ciliary muscle is innervated by the third cranial nerve, known as oculomotor nerve, through parasympathetic innervation from short ciliary nerves. The action of the ciliary muscle affects the zonular fibres when the eye focuses on near objects by changing the lens thickness and curvature [1]. This muscle plays a fundamental role in the accommodative system by facilitating the change in lens shape required to shift focus from distant to near targets, thereby maintaining retinal image clarity.

Accommodation system is a biological process involving natural adaptive optics mechanism that improves the retinal image quality of visual stimuli at different distances [2]. The accommodation of the eye should be accurate to optimize visual performance and provide maximal comfort to the human eye when shifting from distant to near or vice versa. The accommodation accuracy is measured in terms of lag and lead of accommodation. Lag occurs when the visual stimulus is near and the eye appears to focus farther than the stimulus, meanwhile, lead occurs when the visual stimulus is far, and the eye appears to focus nearer than the stimulus [3]. A 2.5D accommodation response for a 40 cm demand of near work indicates a perfect accommodation accuracy [4]. Thus, lag of accommodation is a lesser than 2.5D accommodation response

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while lead of accommodation is a greater than 2.5D accommodation response for the same 40 cm near work.

Lag of accommodation is also related to the transient myopia shift during near work. Prolonged effort in near work activities can result in errors or inaccuracies in accommodation response which affects the visual performance [5]. Liang and colleagues discover that reading with printed text causes twice near work-induced transient myopia (mean: 0.23D) as compared to reading with mobile phone (mean: 0.12D), in addition to longer decay time for printed text [6]. Their findings reveal greater effects of printed text reading on accommodation than the digital display reading. However, as the differences between the two reading tasks are not statistically significant, the printed text and digital display are both susceptible to myopia progression.

This susceptibility is further identified with the reduction in the accuracy of accommodation response for both printed paper-based material and digital screen using iPad, emphasizing the lag of accommodation occurrence regardless of the near work tasks [7]. As there is an inaccuracy in the accommodation system, there can also be a visual discomfort after near work activity. The increase in the lag and variability of accommodation is also associated with closer reading demands that may have important clinical implications as the individuals who is preferring closer reading distances may be more susceptible to myopia due to the greater lag of accommodation. This is associated with the increase in hyperopic blur that can signal increased eye growth [8], thus increasing the risk of eyes to be more myopic.

The level of blur is imposed to be more apparent for smaller as compared to bigger font sizes. Smaller font induces a greater lag of accommodation than larger font by up to 0.07 D difference even between N12 and N24 fonts [9]. This difference is attributed to the different accommodation processing latency across different font sizes. The smaller fonts produce more latencies than bigger fonts, increasing the delay for the eye to physiologically process the visual stimulus. On the other hand, larger fonts involve faster blur-driven accommodation feedback processing as the ciliary muscle produces faster response time to generate accurate accommodation.

It is expected that small font size translates to high visual stress. Small font size with less legible font type significantly decreases visual comfort when conducting a computer work even for a duration of less than 10 minutes [10]. As people can be working in short interrupted near task, by comparing the same brief duration of reading task between Verdana and Times New Roman fonts on computer display, Arya et al. discover that the reading error, which is indicative of visual stress, increases with the complexity in font legibility of Times New Roman. In the real-world application, their study emphasizes the use of proper font for readability and comfort even for short period of near visual task.

Poor surrounding illuminance levels can also lead to visual discomfort, fatigue, eyestrain, migraines, and mood disturbances. Additionally, inadequate illuminance has been found to disrupt alertness [11]. Proper surrounding photopic illuminance can enhance visual performance and comfort, positively influencing productivity and overall well-being. It is greatly suggested by the International Illuminating Society that the illuminance should be within bright photopic illumination between 500 to 1000 lux for office work and tasks that require a large demand [12].

As digital devices are normally used at arm-length distance, accommodation response is crucial for carrying out the near tasks. There are also arising concerns in the precision and accuracy of the accommodation response over the course of a brief sustained near reading digital work. Therefore, the objective of this study is to compare the accommodation response between different font sizes before and after brief duration of near task with digital device under surrounding photopic room illumination.

2. MATERIALS AND METHODS

2.1 Near Reading Digital Task and Instrumentations

A total of 45 pages of English paragraph text with a total of 4 questions on each page for the participant to answer with black text on a white background, letter type of Arial with N5, N8, N10, and N12 font sizes were displayed on an Apple iPhone 11 smartphone, with a 6.1-inch screen. Arial font is chosen as it is a general-purpose font type for reading legibility. Before starting the near-reading task, there was a five-minute wash-up interval looking at far in between changing the font size. It was necessary to relax the accommodation and any remaining accommodation response from preceding near digital reading task to obtain precise data. The iPhone 11 was used under bright 500 lux photopic normal room ambient lighting. The room setting and reading material were kept constants for all participants. Participants were required to conduct a sustained near digital task consisting of reading texts at 20 cm near viewing for 10 minutes, monitored by a clock timer. The 20 cm viewing distance was chosen to ensure sufficient visual stress on accommodation system, with previous work showed a great lag of accommodation on near task [13]. To ensure that the participant's eyes were always focused on reading the text, the participant was required to read out loud but with minimal voice out, and the reading distance was regularly monitored using a measuring tape. The font sizes of the reading materials were randomly assigned to participants to minimize their mental expectation and cognitive response of the reading task difference.

Accommodation response was measured objectively using a binocular open field autorefractor, Grand Seiko WAM-5500. The instrument was connected to a Dell laptop simultaneously running the WCS-1 software via with the WAM-5500 autorefractor was in Hi-Speed mode. This ensured a continuous recording mode that allows refractive and accommodation data collection at a temporal resolution of 5 Hz. The software records dynamic results, including the time (in milliseconds) of accommodative response, which was compiled in a Microsoft Excel spreadsheet. The artefact from the participant's head movement was reduced by using the headrest and chin rest throughout the experiment, as the artefact can contribute to the noise of the accommodation records.

2.2 Research Participants and Data Collection Procedures

Thirty participants were involved in this study consisting of young adults with a mean age of 22.13 ± 1.31 years old. All participants had best corrected distant visual acuity of at least 6/6 and near visual acuity of N5 at 40 cm. None of them had any history of systemic problem and ocular history problem including binocular vision problem or currently under medication. Ethical consideration was approved by the UiTM Research Ethics Committee (FERC/FSK/MR/2023/00125) and participant consents were obtained prior to the data collection.

Prior measurement, all participants were instructed to be rested in a dark room for 5 minutes and do not use their own digital devices. With their refractive correction in placed during the task, baseline measurement of accommodation response before near reading task with digital display was recorded at 20 cm near viewing for 1 minute using the autorefractor. This baseline measurement was taken as the pre-task measurement of accommodation response.

Then the participants conducted their near digital task reading activity while wearing their refractive correction. Immediately after completion of the 10-minute near digital reading task, the accommodation response was recorded again at the same 20 cm near viewing for 1 minute using the autorefractor as post-task measurements. These measurements were ensured to be taken instantly, as the accommodation would change due to exposure to a different stimulus after 3 minutes [14].

3. Results and Discussion

From thirty participants, eight of them were male (26.67%), and twenty-two were female (73.33%). Normality test using Shapiro-Wilk showed that the data of accommodation response (AR) of all different font sizes were not normally distributed. Thus, the descriptive analysis was done using median and interquartile range (IQR), while inferential statistic was conducted using non-parametric test.

At 20 cm near distance, the accommodation responding ability should evoke an exact 5.00 D of accurate accommodation response. Nonetheless, the median and IQR of accommodation response in baseline measurement before reading was 4.20 ± 0.63 D, after reading with N5 size was 4.13 ± 0.63 D, after reading with N8 size was 4.32 ± 0.34 D, after reading with N10 size was 4.39 ± 0.75 D, and after reading with N12 size was 4.55 ± 0.60 D, as illustrated in the Figure 1. Thus, all findings showed lag of accommodation.

There was a statistically significant difference in accommodation response before and after reading task only for N12 font size (Wilcoxon signed rank test: $Z = -2.40$, $p = 0.02$). On the other hand, the accommodation response after reading with other smaller font sizes were not significantly different than the baseline before reading for N5 font size ($Z = 0.000$, $p = 1.000$), N8 font size ($Z = -0.442$, $p = 0.658$), and N10 font size ($Z = -1.759$, $p = 0.079$). These results showed that there was a significant difference in accommodation response between before and after near reading task with digital display for N12 font size as found in the previous study [1]. Previously, Narawi et al. discovered that there were significant changes in accommodation status before and after 20 minutes of continuous smartphone usage, with the lag of accommodation increased after the near smartphone task. As the standard font size in smartphones used in their study was 16 pixels, it was nearly equivalent to 12-point size. Thus, the findings from Narawi et al. corroborated this current study as only the N12 font size reading showed a statistically significant difference.

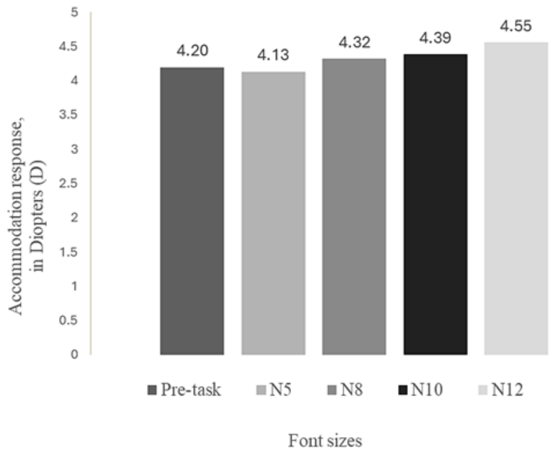

Fig. 1. The Median of Accommodation Response in Pre- and Post Reading Task with Different Font Sizes

Zamani Shahri and colleagues also showed a significant difference in the lag of accommodation of the eye before and after longer continuous duration of one hour smartphone usage under habitual condition [15]. However, the participants in their study were not required to do any specific near work tasks on smartphones and there was no standardized near viewing distance. As their study was conducted for an hour of near digital task, there was a difference with the current study in the duration for the eyes being exposed to near visual stimulus. The 10 minutes of reading on smartphone in this current study still manage to illicit visual stress at near task. Although the duration seems short, the ciliary muscle was required and able to respond accordingly from the initial reading task in the focusing of ocular accommodation.

In contrast, the results on smaller fonts in the current study revealed that there were no statistically significant differences of accommodation response for all other small font sizes of N5, N8 and N10 between before and after near-digital task. Although the visual processing delay is higher for small font [9], the smaller font sizes in this study might produce nearly similar latencies in the accommodation response, which can be small to differentiate. These findings were supported by Schmid et al. which discovered that the differences in accommodation response magnitude were too small and considered to be clinically irrelevant [16]. Their study reported that N4 which was the smallest font showed the most accurate accommodation response while N8, the largest font used in the study showed the least accurate accommodation response indicating largest lags of accommodation by 0.94 D using monocular estimated method (MEM) retinoscopy technique. Thus, they implicated that the reductions in font sizes did not cause greater error in accommodation response.

As the current study discovered that there were no statistical differences in the lag of accommodation for smaller font sizes in the pre- and post-near reading task with digital display, the results were supported by Collier and Rosenfield [17] that throughout the 30-minute task in the study, there was no statistically significant change in the accommodation response during an extended fixation time on visual display terminal. They also used autorefractor WAM-5500 to quantify the accommodation response before and after their participants work for 30 minutes at a continuous near-digital assignment of 8.5-point size Times New Roman black text reading on white background displayed on the screen on a laptop at a viewing distance of 50 cm. Although there was a 30 cm in the near distance as compared the current study, the accommodation response for the small font sizes seems to be within the range of accommodation response baseline state before the near reading task.

Study by Landrum found the otherwise [18], in which the small font sizes had significant effect on the accommodation response. In the previous study, the smallest letter used was 1.9 minutes of arc and the largest letter was 37.8 minutes of arc of Bailey-Lovie acuity chart. Landrum reported that the larger letters exhibited a larger lag of accommodation (2.97 ± 0.36 D) compared to smaller letters exhibited smaller lag of accommodation (3.44 ± 0.24 D) at a 4 D stimulus demand of accommodation response. Eventually he inferred that smaller letters had more accurate accommodative response at near viewing. The opposite findings between this study and Landrum's study could be that the previous study used printed material via laser printer that produced better text clarity. In addition, the Bailey-Lovie chart and letter sizes with more defined characters visual task used in the previous study could be the contributing factor to the different findings as compared to the current findings that highlighted the commonly used font sizes in digital display task.

4. Conclusion

This study indicates that the young adult eye shows minimal change to small letter sizes after a short duration of reading under photopic room illumination. However, there was a difference in the accommodation response pre-post near reading task with digital display for a bigger N12 font size. These findings suggest that the action of ocular ciliary muscle is well regulated for intense small size, demonstrating precise control for high-acuity small targets.

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