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The Effect of Document Holder's Degree of Tilt on Working Speed and Fatigue

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Abstract

The prolonged use of computers, followed by incorrect posture, could cause neck pain and excessive eye refocusing. Document holder was one of office ergonomics' tools that could reduce neck pain and eye refocusing problems. The research aims to find out the optimum document holders' degree of tilt. Twenty female respondents from Faculty of Industrial Technology conducted typing activity using a document holder. There were three document holder's tilt angle levels: 15°, 30°, and 45°. The responses of this study were working speed and fatigue's level that have lower the better characteristics. Indicators of fatigue's level that were being used were reaction time's difference and eyes fatigue level. Working speed and reaction time difference were analyzed by using Pearson Correlation test and Multivariate Analysis of Variance. Eye fatigue level was analyzed by using Kruskal-Wallis. The results show that the optimal document holder's degree of tilt is 45°.

Keywords: document holder, tilt angle, working speed, reaction time, eyes fatigue

INTRODUCTION

Office Ergonomics was one of the Ergonomics' applications in adjusting office workstations to support employee performance and increase worker comfort and safety. Office Ergonomics was used for jobs that mainly use computers for a long period. For example, the average computer or laptop usage by students of the Faculty of Medicine at Sam Ratulangi University was between 4 to 5 hours (Kurmasela, et al., 2013). Another study conducted by the American Optometric Association (n.d.) showed that the average computer usage by workers in the United States was 7 hours per day. The objective of office ergonomics' application was to reduce the risk of health problems caused by repetitive awkward postures and prolonged static postures. Health problems that often occur are musculoskeletal disorder (MSD), stress, and visual fatigue. Musculoskeletal disorders could happen when workers do their work by using a computer repeatedly and for a long period, but not ergonomically (Waersted, et al., 2010). One of the important components that need to be considered in office ergonomics is the document holder (OHCOW, 2008).

Most workers place documents flat on the desk when entering data or information from the papers, and this requires excessive forward neck bending. The Department of Environment, Health and Safety at the University of North Carolina recommended the use of document holders for workers who copied documents for more than 1 hour per day. This tool also suggests if during the document copying process, the neck or back was bent. Reading and typing documents indeed took a long time, so the document holder's assistance was needed to prevent various health problems.

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Document holder is a document buffer positioned vertically or with a certain degree of tilt (OHCOW, 2008). The position of the document holder needed to be considered so that it could be used effectively. There are several alternatives for placing the document holder against the worker's position, namely in the middle, left, and right. Based on previous studies, the document holder should be placed at the same distance from the eyes as the monitor. Therefore, it was positioned directly in front of the worker between keyboard and monitor (WorkSaveBC, 2009). Thus, the best position was in the middle between keyboard and monitor.

The document holder helps to minimize head-turning, neck pain, and eye strain. Ambusam, et al. (2015) investigated the effect of document holders on postural neck muscles activity. The neck muscle activities were studied using surface electromyography. The result showed that the least amount of neck muscle activity happened when using a document holder than placing documents flat on the desk (without a document holder). Not only for reducing neck pain, but the document holder also could reduce eye refocusing. Eye refocusing was a condition in which a person's eye must focus alternately for long periods on documents and monitor. This activity could cause eye fatigue. The study conducted by Sya'ban and Riski (2014) showed that 28 out of 33 respondents experienced eye fatigue when they worked at a computer for more than 4 hours. The use of document holders aims to reduce neck pain and the time required for eye refocusing when eye movement transitions from the documents to monitor or vice versa (McKeown, 2008).

Previous studies only discussed the effect of a document holder to reduce neck pain and eye fatigue and clarified the best position of the document holder was in the middle between keyboard and monitor. However, there is still no further investigation regarding the effect of the document holder's degree of tilt against the worker's productivity and at the same time reducing fatigue. The worker's productivity and fatigue are the common measurements to determine the effect of an ergonomic intervention. Therefore, these two indicators are used in this present study. The worker's productivity was measured by working speed. The working speed would be measured by the duration of time needed by a worker to finish the typing activity. The level of fatigue was measured by two indicators, namely reaction time and eye fatigue scores.

There were three levels of document holder's tilt angle chosen, and they were 15°, 30°, and 45°. All levels were determined through a pre-experiment stage. If the tilt angle were below 15°, the worker's neck would bend forward more than 20°. When the neck bends forward more than 20°, it will increase the risk of neck pain (Hignett and McAtamney, 2000). If the tilt angle exceeds 45˚, it would be too upright and cover the monitor screen, and it also interfered with the respondent's vision.

The optimal tilt angle of the document holder could reduce the time required for eye refocusing. Hence, the optimal tilt angle of the document holder reduced neck pain and increased working speed and reduced fatigue at the same time. Therefore, this study aims to find out the optimal document holder's degree of tilt and how it would affect the working speed and fatigue.

METHOD

The experiment aimed to know the optimal document holder's degree of tilt and how it would affect the working speed and fatigue. But before the experiment is done, a pre-experiment stage was needed to fix some of the experiment's conditions that may affect the experiment. These conditions would be made uniform, adjusted according to the respondent, and following the ergonomic principles. The first condition was about the respondent's workplaces. Respondent's eye height would be adjusted to the height of the monitor screen.

The table that was being used in the experiment had a built-in document holder. The keyboard was placed under the table, with the backspace keys covered. The backspace key was hidden because the typing error was not counted; it only focused on the completion time of typing the whole text. The chair occupied by the respondent could also be adjusted in height and already had lumbar support. The angle formed by the respondent's thighs and legs should be 90˚. The footrest was also provided and could be adjusted in height for respondent's needs.

The second condition was the physical environment condition. The physical conditions of the work environment must be the same. They were temperature, noise, and humidity. The standards for temperature, noise and humidity levels were based on the Indonesian National Standard, which contained the Threshold Value (TLV). TLV was a hazard factor in the workplace as a control guide so that workers did not experience health problems while working. NAV working environment climate was determined based on the allocation of work and rest time in one work cycle (8 hours per day). Typing activities were included in the light category because they only use the hands and arms. The recommended temperature, noise, and humidity levels under the standard were 31ºC, 85 dB, and 40% -60%, respectively. Respondents were asked to wear a headset during the typing process to block outside sounds from disturbing their concentration.

The third condition was about the document and its holder that would be used in this experiment. The chosen text was a short story arranged in A4, landscape, using 12 Times New Roman font and 1.5 spacing. Document's holder degree of tilt used in this experiment were 15˚, 30˚, and 45˚. If the degree of tilt were beyond 45˚, it would be too upright, cover the monitor screen and interfere with the respondent's vision. Pre-experiment by using a document holder was carried out on two random respondents. The goal was to determine how many documents would be given to respondents when the actual experiment was conducted. Both respondents were asked to complete two pages of short stories. The observer would look when the respondent began to show signs of fatigue in his eye and began to feel restless. The limit of the text to be tested was determined after seeing the analysis of the pre-experimental results. The text limitation was determining when the respondent started to look restless and uncomfortable, which could be seen from body gestures and unnatural blinking.

There were some criteria used to select the respondents. Respondents must be female and wearing glasses or soft lenses; the age between 18 to 21 years old; able to experiment 07.30 – 11.30 am; came from the Faculty of Industrial Engineering, Petra Christian University, excluding informatics department. Twenty respondents were chosen to conduct the experiments. They were asked to type document with three levels of the document holder's tilt angle.

Responses that would be investigated further from the research were working speed and fatigue. The data of working speed was obtained from the time required to finish the typing activity. At the same time, the respondent's fatigue was determined in two ways: the eye fatigue questionnaire (qualitative) and the respondent's reaction time (quantitative). Eye fatigue questionnaire (Table 1) was created based on visual fatigue questionnaire, developed by Ames et al. (2005). The eye fatigue questionnaire being used in this experiment can be seen in Figure 1.

Fatigue could be measured by the respondent's reaction time to respond to a stimulus. Respondent's reaction time was measured by using a reaction-time measuring instrument before and after typing documents. The increase in after typing response time compared to before typing response time indicated work fatigue. The stimulus comes from the lights and sounds of the instrument. A trigger that was commonly used to measure reaction time was the flicker of light. Reaction-time measuring instrument consisted of several parts: an on/off button, a central button for giving the stimulation, a reset, and a part of the response button provided to the measured respondent. Respondents only needed to press the appropriate button

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as soon as possible after they saw or heard the stimulus. The response speed would be recorded for the time.

Table 1
Eye Fatigue Indicators

Symptom	None	Slight	Moderate	Severe
Tired eye	0	1, 2	3, 4	5, 6
Sore/aching eye	0	1, 2	3, 4	5, 6
Irritated eye	0	1, 2	3, 4	5, 6
Watery eye	0	1, 2	3, 4	5, 6
Dry eye	0	1, 2	3, 4	5, 6
Eye strain	0	1, 2	3, 4	5, 6
Hot/burning eye	0	1, 2	3, 4	5, 6
Blurred vision	0	1, 2	3, 4	5, 6
Difficulty infocusing	0	1, 2	3, 4	5, 6
Visual discomfort	0	1, 2	3, 4	5, 6

Source: Ames et al., 2005

Eye Fatigue Questionnaire

Name :
Date :
Before/After Work

Please fill out the form with give check mark to one of the following assessment criteria

1 = Strongly disagree
2 = Disagree
3 = Agree
4 = Strongly agree

No	Respondent Condition	Rating			
		Strongly disagree	Disagree	Agree	Strongly agree
1	Headache				
2	Heavy eye (feeling that you cannot keep your eye open)				
3	Watery eye				
4	Burning eye				
5	Itching or dry eye				
6	Eye strain				
7	Blurred vision				
8	Double vision				
9	Difficulty infocusing				

Figure 1. Eye Fatigue Questionnaire

The experiments were conducted at Ergonomic Laboratory Petra Christian University, with some steps as follows:

- Respondents were asked to fill out the first eye fatigue questionnaire to determine whether the respondent was in prime condition when the data was collected.
- Observers assessed the results of the completed eye fatigue questionnaire. If the respondent agreed minimal one condition, the data collection was postponed to another day.
- Respondents who are deemed eligible to conduct experiments would be taught about using the reaction-time measuring instrument, so they understood what to do.
- The data from the first reaction time test were recorded.
- The observer adjusted the document holder's degree of tilt and placed the document to be typed.
- Respondents adjusted their seating position against tables, chairs, and the monitor screen to suit an ergonomic standard.
- Respondents typed the provided text as quickly and accurately as possible without pressing the backspace or delete key.
- Observers recorded the time for the respondent to type the text.
- Respondents immediately did reaction time test after she finished typing.
- Observers recorded the time of the respondent's second reaction speed test.
- Respondents filled out the second eye fatigue questionnaire.
- This experimental data was analyzed by using Multivariate Analysis of Variance with 20 replications.

RESULTS AND DISCUSSION

Responses that would be analyzed in this study were working speed and fatigue's level. Speed was the ability of everyone to do the same movement repeatedly in the shortest possible time. Some factors affect a person's speed, including muscle power, muscle viscosity, reaction speed, contraction rate, coordination between the central nerve and muscles, and speed endurance. Working speed was a physical condition's ability to complete the job in the shortest possible time. Everyone had a different speed even though they did the same job. Fatigue is obtained when the burden given to work is greater than what the worker could bear. Fatigue’s level indicators used in this study were the difference in respondent’s reaction time and eye fatigue level. Reaction time was the period from giving a stimulus to a moment of awareness or activity (Santoso, 2013). Someone who experienced fatigue will respond to stimuli given more slowly than people who did not experience work fatigue. The shortest reaction time a person could give was 150 to 200 milliseconds. This time also depended on several factors, such as age and differences between individuals, the intensity of stimulation, and the type of stimulation given. A slower response could indicate that the person was experiencing a slowdown in the physiological processes of the nerves and muscles, and this indicated that the person was experiencing work fatigue (Santoso, 2013). The use of document holders prevented or at least slowed down work fatigue, especially in administrative jobs. Document holders helped and made it easier for workers to see documents so that the neck muscles effort became smaller.

The fatigue’s level was measured by reaction time dan eye fatigue level. The reaction time and working speed are categorized as ratio data, while eye fatigue level is categorized as ordinal data. Therefore, the processing of ratio data and ordinal data must be done separately. Working speed and reaction time were analyzed using parametric statistics. First, these responses were tested whether they correlated or not. If they did not correlate with each other, they would be analyzed separately using the ANOVA test. But if they correlated with each other, they would be analyzed together using the MANOVA test. Meanwhile, eye fatigue level was analyzed using non-parametric statistics.

Two quantitative responses in this study, working speed and reaction time difference were analyzed using the Pearson Correlation test to find any correlation between these responses. This data analysis was carried out using the Minitab software. The result of Pearson Correlation Test can be seen in Figure 2, which showed *p*-value for Pearson Correlation Test was 0.667. This meant that there was a correlation between working speed and reaction time. Therefore, working speed and reaction time cannot be analyzed separately, so the Multivariate Analysis of Variance (MANOVA) test would be used instead of the Analysis of Variance (ANOVA) test. From the diagnostic checking, both working speed and reaction time data were assumed to be normally and independently distributed (NID).

Correlations

Pearson correlation	0.667
P-value	0.000

Figure 2**.** Pearson Correlation Test

The result of MANOVA test for the document holder's degree of tilt can be seen in Figure 3. The null hypothesis for this experiment was document holder's degree of tilt did not significantly affect working speed and reaction time, while the alternative hypothesis was document holder's degree of tilt significantly affected working speed and reaction time. From the MANOVA test, it could be seen that *P*-value is equal to 0.000 for all of the tests (Wilk's test, Lawley-Hotelling test, and Pillai's test). If 5% alpha was used, this *P*-value was less than alpha, which meant that the document holder's degree of tilt affected working speed and reaction time. The *R*-squared for the working speed model was 85.45%, which means 85.45% of the data fitted the model, while the *R*-squared for the reaction time model was 93.34% (Figure 4a and 4b).

	Test		DF		
Criterion	Statistic	F	Num	Denom	P
Wilks'	0.08815	43.809	4	74	0.000
Lawley-Hotelling	9.21766	82.959	4	72	0.000
Pillai's	1.01111	19.427	4	76	0.000
Roy's	9.09384				

Figure 3. Manova Test

Model Summary

S	R-sq	R-sq(adj)
0.0179473	85.45%	77.40%

Figure 4a**.** Model Summary of Working Speed

Model Summary

S	R-sq	R-sq(adj)
27.4300	93.34%	89.66%

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Figure 4b. Model Summary of Reaction Time

MANOVA test was also done to test the effect of respondents toward working speed and reaction time. The result could be seen in Figure 5. The null hypothesis was respondents did not significantly affect working speed and reaction time, while the alternative hypothesis was respondents significantly affected working speed and reaction time. Furthermore, it could be seen that *p*-value was also less than alpha, which meant that different respondents also affected the working speed and reaction time. In this study, the respondent was being blocked because it was not the aim of this study, but it needed to be blocked to avoid experiment inaccuracy.

Criterion	Test Statistic	F	DF Num	DF Denom	P
Wilks'	0.04655	7.078	38	74	0.000
Lawley-Hotelling	8.46392	8.018	38	72	0.000
Pillai's	1.51286	6.211	38	76	0.000
Roy's	6.65949				

Figure 5. MANOVA Test for Respondent

Main effect analysis was done to determine the best document holder's degree of tilt. Main effect plot can be seen in Figure 6 and Figure 7. Both of the responses characteristics was lower the better. However, it was better when the difference in reaction time before and after the experiment was smaller. The slight difference in reaction time also indicated that the respondent did not have excessive fatigue. The plot showed that the best working speed and reaction time was obtained when the document holder's degree of tilt was 45°. Document holder's degree of tilt affected a person's reaction time because if the degree of tilt were too low, the person would feel tired compared to if the degree of tilt was higher. When the respondent was tired, then the reaction time was longer. Document holder's degree of tilt also affected working speed. When the slope was higher, the person would be easier and more comfortable in viewing the document, then the respondent could finish the typing process more quickly. Therefore, the optimal document holder's degree of tilt was 45°. This finding complements a previous study carried out by Ambusam, et al. (2015); that stated that the most precise and comfortable position of the document holder that gave the smallest neck's muscle movement was in the middle position.

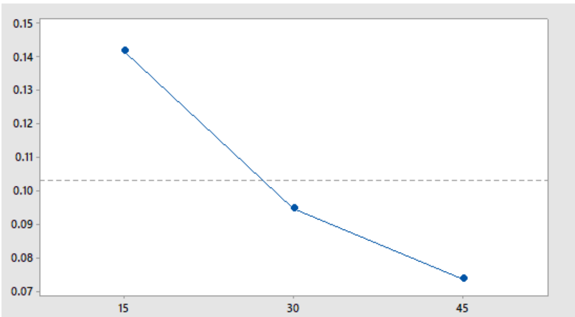

Figure 6. Main Effect Plot for Reaction Time

The second indicator of fatigue's level was eye fatigue level. Document holder was a tool designed for activities requiring workers to view documents and computer screens over a long period repeatedly. Document holders could reduce eye refocusing because the location of the

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paper and computer screen was close, so it was faster to look for words. Refocusing was a condition in which a person's eye had to focus alternately for long periods on documents and monitors. If done continuously for a long time, this refocusing could cause fatigue and strain on one's eye (Yu and Kim, 2015). Reducing eye refocusing could reduce the overuse of eye muscles. Typing process without a document holder made excessive eye refocusing because it was used to search words in the documents (OHCOW, 2008).

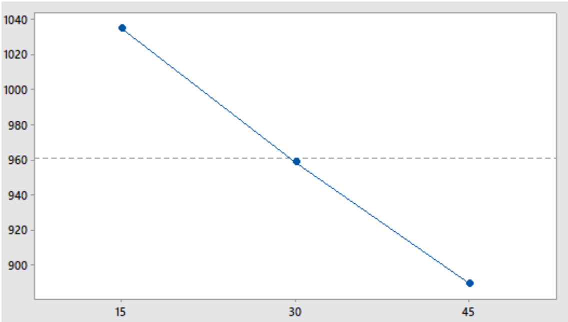

Figure 7. Main Effect Plot for Working Speed

Apart from refocusing, eye fatigue and strain could occur due to activities that required a high level of focus from the eye, such as reading, working for long periods at a computer/gadget, and working on projects that required perfect eye accuracy; without using tools such as document holders (Mekhora, et al., 2000). Everyone could have eye strain and fatigue experience, especially those who often did something related to small letters or objects. There were several muscles in the eye; one of them was the ciliary muscle which helped the eye focused on an object. The function of the ciliary muscle moved the pupil, shrank the pupil to get clear vision, and made an object look bigger for things that were quite far away. The eye muscles, including the ciliary muscle, could experience tension that causes eye fatigue (Mekhora et al., 2000). Some indicators of eye fatigue were eye irritation, double vision, pain around the eye area, and decreasing accommodation power, visual acuity, sensitivity to contrast and speed of perception. Lighting that was not well designed could cause visual disturbances or fatigue during work (Kroemer, 2017). Inadequate lighting would result in eye fatigue, mental fatigue, stiffness in the eye area and headaches around the eye, sense of sight damage, etc. Furthermore, the effect of eye fatigue would decrease work performance.

In this study, eye fatigue level was observed by using an eye fatigue questionnaire. A result from the eye fatigue questionnaire was needed to determine the effect respondents felt before and after the experiment. The higher the difference indicated that there were many changes in the respondent's condition after the experiment. The questionnaire was also used to see whether there was a difference in the influence of document holder's degree of tilt. The results obtained from the Kruskal-Wallis test (Figure 8) showed that there was a significant effect. The initial hypothesis was that all median values were the same. The critical limit was set with a value of 0.05. The results of the questionnaire data processing on treatment using Kruskal-Wallis were 0.007 (less than 5% alpha). Therefore, the treatment given had a significant difference.

The lower the document holder's degree of tilt, the higher the difference in the value of the questionnaire. Eye fatigue questionnaire data were obtained subjectively based on the feelings of the respondents after experimenting. Figure 8 shows the mean rank value that was obtained from the Kruskal-Wallis test. 45° degree of tilt had the smallest mean rank value, while the mean rank value at the 15° document holder's degree of tilt was the highest. The

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smaller the mean rank value, the lower the eye fatigue experienced. Therefore, it meant the 45° degree of tilt was the best one.

Descriptive Statistics

Sudut	N	Median	Mean Rank	Z-Value
15	20	5.0	38.1	2.38
30	20	3.5	32.1	0.51
45	20	2.0	21.3	-2.89
Overall	60		30.5	

Test

Null hypothesis H_0: All medians are equal
Alternative hypothesis H_1: At least one median is different

Method	DF	H-Value	P-Value
Not adjusted for ties	2	9.54	0.008
Adjusted for ties	2	9.88	0.007

Figure 8**.** Kruskal-Wallis Test

The results of this study showed the document holder's degree of tilt affected working speed reaction time, and eye fatigue level, which the best document holder's degree of tilt was 45°. This finding complemented the previous study about the impact of document holders on neck pain. The best document holder position is in the middle of the computer screen and keyboard. This finding also showed qualitatively, based on respondents' feelings, that the best document holder's degree of tilt that could reduce eye fatigue is 45°. This result might be useful for those who work with many documents in front of a computer, such as data entry staff, administrative staff, the one who work in the law firm, etc. Some ergonomics standards were not explicitly stated about the optimal document holder's degree of tilt from the table surface, such as MIL-STD 1472G (2019) and ANSI/HFES 100-2007 (2007). MIL-STD 1472G, clause 5.10.3.1.2 about work surface, only gave standard about support document (such as job instruction manuals or worksheets) height from standing surface shall be 35.4 to 36.6 inches above the standing surface. Clause 5.10.3.6.4 about design principles only stated that the display should be closer to the user's line of sight and perpendicular to the line of sight. Therefore, the angular deviation from the line of sight up to 45 degrees may be acceptable. Clause 5.2.3.12.7 about viewing angle also only stated that the optimum viewing angle was perpendicular to the display. ANSI/HFES 100-2007 stated adjustable document holders allowed users to read and/or transcribe hard-copy materials without assuming awkward postures. Therefore, the finding of this study complemented the existing ergonomic standards.

CONCLUSION

This study concluded that the document holder’s degree of tilt affected working speed and fatigue; the optimal document holder’s degree of tilt for both working speed and fatigue was 45°. Faster typing times indicated that a better document holder’s degree of tilt was applied. In addition, the smaller difference in reaction time indicated the respondent’s fatigue was smaller. The results also showed the eye fatigue level was decreased when the document holder’s degree of tilt was 45°. Hence, the correct placement of document holder was in the middle of computer screen and keyboard, with a degree of tilt of 45°, and this finding also complemented the existing ergonomic standards.

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