Comparison between physical format text and digital format text regarding the rate of eye blinks

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ABSTRACT
We have conducted an experiment for this report in order to observe such relations between rate of eye blinks and visual fatigue. Although we could not find much significant evidence regarding to that relation in this study, there was a multitude of indication during the experiment that imply the likelihood of existence of such relation. What we found is people blink less frequently while reading text regardless of the format. And there were significant changes witnessed in the period of first 0 to 5 minutes when people started to read.

INTRODUCTION
In recent years, proportion of the use of digital formed materials have been taking over the place of physical formed materials at school, work place, home and even at library. Nowadays it does not feel weird anymore to witness digital book stores everywhere around us. On the other hand, by given tendency, we have been facing a number of issues that haven't been witnessed in the past time. One of well-known side effects of digital book is a visual fatigue, which is we are going to study about and find out the relation with the rate of eye blink as well as comparison between hard copy text and digital format text regarding to the rate of eye blink through this research. Why do we get tired on our eyes? Apparently reading is a very stressful task for our eyes. When people read, their eyes need to make roughly four movements every second – that is 15,000 eyes' movements for every hour they spend time reading. At the same time as the muscles controlling eye movement are working so rapidly, other muscles are busy keeping the lens inside the eye constantly focused at the distance of what they are reading with [2]. General studies on correlation between rate of eye blink and reading book were conducted a great number of times over decades [1,4,5,6]. And also studies on preference between digital books and physical paper books in multitude of perspectives, such as performance, eye fatigue, comprehension and etc, have conducted [7,8]. Talking about eye blink, that is an activity of lubricating and cleansing on eyes which controlled by the central nervous system rather than peripheral processes and it's closely related to 'mental tension' of the subject. Also the mechanism of blinking is well established at birth already [10]. Different from commonly known concept that there would be higher frequency of blinking in the arid environment than humid environment, it is documented by Ponder et al., [10] that people do blink more frequently when exposed to an environment high in air particulates, such as those associated with cigarette smoking. Then how does it relate to reading book or visual fatigue? Fatigue is one variable that's less concerned with physical and environmental factors that may affect blink rate. Although it is difficult to define, one way to operationally does so is to express it in terms of time-on-task (TOT) effects [9]. This is well represented in Hoffman's [4] experiment participated 30 college students read text steadily for 4 hours with 5-minute period of data recording. In the report, blinks increased significantly after the first hour of reading and increased in a steady, though irregular, pattern across the 4-hour period. On the other hand, Carmichael et al., [6] failed to observe a significant increase in eye blink under similar experimental settings with Hoffman's work. He ran 6-hour period of reading for college or high school students both easy and difficult text in hard copy or microfilm format that ended up no significant increase found in blink rate from both type of subjects. Why did Carmichael et al., fail to obtain the expected data? Later on, it is noticed that the major difference was found which Carmichael et al., had used was comprehension test at approximately 20-25 page intervals of reading. And therefore students were interrupted regularly by the test. This experimental mistake has warned by Luckiesh [5] in most of his published papers. And Ponder et al., [10] had demonstrated that any interruption or change in task performance could lead to an alteration in blink rate. Stern ., [9] has addressed regarding to this that motivating instruction and greater rewards have less impact on the results than interruption of reading process does. Tinker's [11] reliability study reminds us to consider 5-minute period as adequate for obtaining reliable data during the course of reading. Correlation between successive 5-minute periods seem to be adequate for every purpose. However, when time sample is extended to 10-minute period the correlation decreases. In the similar vein,

when one does not compare to adjacent 5-minute period correlation dramatically decreases [11]. Reading digital format text and its effect on our eyes has been studied by a number authors and the experiments in that have concluded the result is negative [7,12,13,14]. Macedo-Rouet et al., [13] have noted that students have felt much more tiredness on their eyes when reading on screen. The same, Cushman [12] claimed there has significantly higher visual fatigue when you read a text on screen than on paper. Similarly, Kang et al., [7] have found in his experiment of which measures eye fatigue by CFF(Critical Flicker Fusion) that reading a E-book caused significantly higher eye fatigue than reading a paper book and concluded it's mainly due to the low contrast and resolution of the display for an E-book. Relevant previous work conducted by Jeong [8] referred many of studies mentioned before, then pointed out that the eye fatigue was found in his study. In further Jeong [8] also encouraged E-book designers to take his findings into their deep consideration.

METHOD DESCRIPTION

1. Participants

   In this study, a total of 5 Master students from engineering department and 2 bachelor students one each from electronic department and agriculture department have participated. However 1 Master student has left during the experiment so, we will consider only 6 students who have completed entire procedure of the experiment as participants in this report.

   A total of 4 students were male and the rest two students were female. Then we assigned 6 participants into each subject numbered 1 to 6. Subject 1 and 5 are female group and subject 2, 3 and 4 wear a glasses. Subject 2, 4 and 6 are from department of computer science which assumes there might have relatively higher tiredness on eyes. Also, according to the information collected from questionnaire, subject 1 and 5 are comparatively younger aged group (21-22 year old) and the rest 2, 3, 4, 6 are older aged group (25-32). Regardless of average hours of reading for weekly, most of subjects preferred paper format material than digital format except one subject. There was a wide range of average sleep hours within the group (Min 5h to Max 9h). Referring to Morris's [16] experiment that claims an assumption that sleep deprived persons should show TOT effects more rapidly than non-sleep deprived persons. Given that, we have contributed our experiment preferably during the night (8 pm – 3 am) and exposed three of male students to the condition of sleep-deprivation (average of 4 hours of sleep) and two of them were in condition of a constant lack of sleep (5h, 6h).

2. Materials

   A novel named "The hundred year old man who climbed out of the window and disappeared" was used for reading material in both form of digital and hard copy. The language was chosen English due to avoid variation on the result induced by using various languages. Kang et al., [7] have noted that language used in experiment could be variable because of alphabetic system. A laptop has been utilized for reading digital form of text and a physical book for reading hard copy form of text. Whole process of the experiment has been recorded either by an external webcam or an embedded webcam in the laptop for the purpose of better precise count on eye blinks. Participants were asked to fill up a sheet of questionnaire when each of experiments is done.

3. Procedure

   The experiment was conducted after explanation of how the participants should act. The experiment consists of six sessions. Of two sessions are main recordings of reading text in each digital format and hard copy format. Each reading session lasts for 30 minutes and participant was asked not to be distracted by any chance. This introduction has been issued from a number of previous studies [5,9,10]. The rest four sessions which 'before' and 'after' 5 minute of recordings were carried out under spontaneous atmosphere. Participants were allowed a talk and making small movements while sitting. These short recording sessions were designed to measure eye blink in ordinary condition of the participant. Previous study conducted by McFarland et al., (1942) presented that no reliable effects of manipulating light intensity was obtained. In this study, hence, illumination intensity of the room and screen brightness were modified at the level of participant's preference.

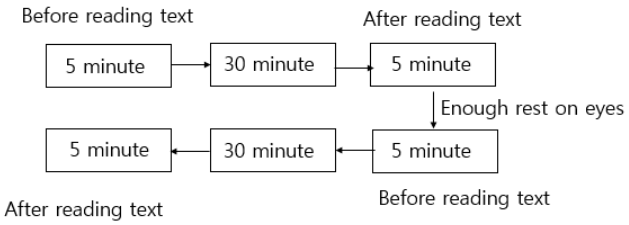

Figure 1. Simple structure of the experiment

Figure 1 explains the entire structure of an experiment. Order of the formats of reading text is randomized in order to avoid biased result.

Therefore, in total, six video records, 80 minutes have been collected per participant. Eye blink was manually counted by going through the videos later on.

RESULTS

Figure 2 shows correlation between successive 5-minutes periods of all subjects in reading P-book (hard copy). It features although, statistically significant ($t < 0.05$) overall, period1 indicates unlike value that's comparatively low Significance to most of other period. **Figure 3** on the other hand, shows only a few of statistically significant results in

reading E-book. **Chart 1 to 6** display variance of rate of eye blink of each subject and compare it between P-book and E-book in reading. **Chart 7 and 8** compare the rate of eye blinks in 'before reading' and 'after reading' conditions.

Correlations

			period1	period2	period3	period5	period4	period6
Spearman's rho	period1	Correlation Coefficient	1.000	.829*	.829*	.886*	.943**	.841*
		Sig. (2-tailed)	.	.042	.042	.019	.005	.036
		N	6	6	6	6	6	6
	period2	Correlation Coefficient	.829*	1.000	1.000**	.886*	.943**	.928**
		Sig. (2-tailed)	.042	.	.	.019	.005	.008
		N	6	6	6	6	6	6
	period3	Correlation Coefficient	.829*	1.000**	1.000	.886*	.943**	.928**
		Sig. (2-tailed)	.042	.	.	.019	.005	.008
		N	6	6	6	6	6	6
	period5	Correlation Coefficient	.886*	.886*	.886*	1.000	.943**	.986**
		Sig. (2-tailed)	.019	.019	.019	.	.005	.000
		N	6	6	6	6	6	6
	period4	Correlation Coefficient	.943**	.943**	.943**	.943**	1.000	.928**
		Sig. (2-tailed)	.005	.005	.005	.005	.	.008
		N	6	6	6	6	6	6
	period6	Correlation Coefficient	.841*	.928**	.928**	.986**	.928**	1.000
		Sig. (2-tailed)	.036	.008	.008	.000	.008	.
		N	6	6	6	6	6	6

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 2. Correlations within successive 5-minutes periods while reading P-book

Correlations

			period1	period2	period3	period4	period5	period6
Spearman's rho	period1	Correlation Coefficient	1.000	.886*	.771	.943**	.771	.943**
		Sig. (2-tailed)	.	.019	.072	.005	.072	.005
		N	6	6	6	6	6	6
	period2	Correlation Coefficient	.886*	1.000	.657	.943**	.657	.771
		Sig. (2-tailed)	.019	.	.156	.005	.156	.072
		N	6	6	6	6	6	6
	period3	Correlation Coefficient	.771	.657	1.000	.829*	.543	.714
		Sig. (2-tailed)	.072	.156	.	.042	.266	.111
		N	6	6	6	6	6	6
	period4	Correlation Coefficient	.943**	.943**	.829*	1.000	.600	.886*
		Sig. (2-tailed)	.005	.005	.042	.	.208	.019
		N	6	6	6	6	6	6
	period5	Correlation Coefficient	.771	.657	.543	.600	1.000	.600
		Sig. (2-tailed)	.072	.156	.266	.208	.	.208
		N	6	6	6	6	6	6
	period6	Correlation Coefficient	.943**	.771	.714	.886*	.600	1.000
		Sig. (2-tailed)	.005	.072	.111	.019	.208	.
		N	6	6	6	6	6	6

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 3. Correlations within successive 5-minutes periods while reading E-book

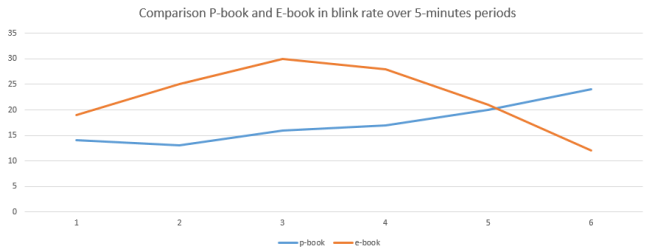

Chart 1. Blink rate of Subject 1, P-book and E-book

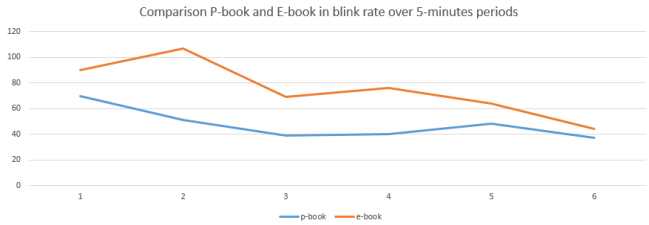

Chart 2. Blink rate of Subject 2, P-book and E-book

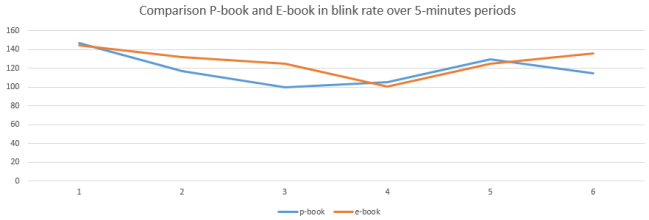

Chart 3. Blink rate of Subject 3, P-book and E-book

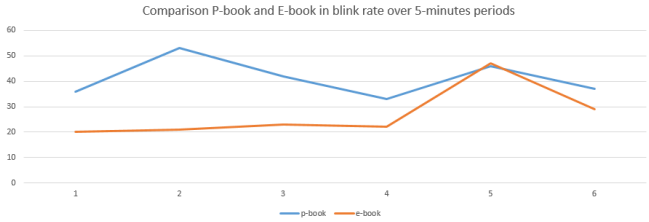

Chart 4. Blink rate of Subject 4, P-book and E-book

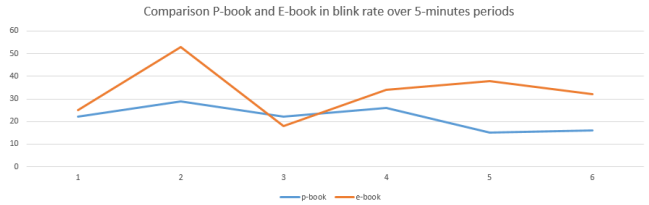

Chart 5. Blink rate of Subject 5, P-book and E-book

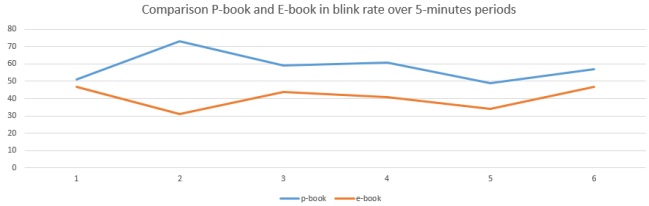

Chart 6. Blink rate of Subject 6, P-book and E-book

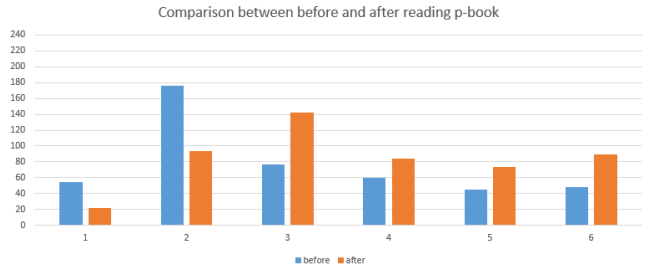

Chart 7. Eye blinks before and after reading P-book

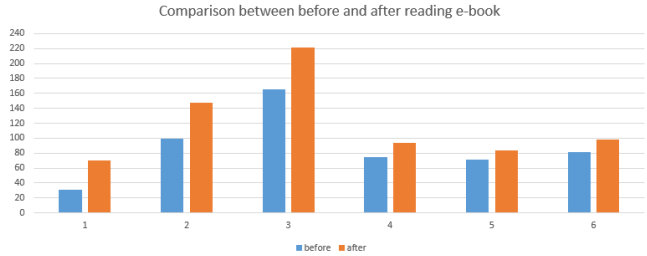

Chart 8. Eye blinks before and after reading E-book

DISCUSSION

This report with an experiment was proposed to find relation between rate of eye blink and visual fatigue based on previous studies. We have expected to see an increment to rate of eye blink while reading, as well as higher rate of eye blinks when reading E-book than reading P-book. And then relate the results to another topic of previous studies that claims reading on screen or E-book increases visual fatigue. For that, we have gathered 6 participants and conducted the experiment of observing subjects reading P-book and E-book in turn. The results shown **Chart 7 and 8** seem to satisfy our goal though, it does not have a significant difference or a pattern. For instance, while in **Chart 8** indicates an increased eye blinks after reading E-book, in **Chart 7**, subject 1 and 2 indicate the result the other way around. We then try to find variables that might have affected on the result. Gender, glasses, frequency of exposure to visual fatigue in general, age, average hours of sleep and so forth. However, we could have had neither none of the list of variables observed in our experiment nor significantly visible patterns from **Chart 1 to 6**. Moreover, in Figure 2, although we could achieve enough value of significance, there was no such result of drop-down in significance in correlation during comparing two periods that are not adjacent one another (ex., comparison of period 1 and period 6) which does not correspond to the demonstration conducted by Tinker [11]. In addition, there was no statistically significance in correlation between periods in **Chart 8**. We would assume a number of reasons of why getting unexpected results is first because of too small scale of dataset. Second, because of low accuracy on counting eye blinks. It was really hard to set an environment for the experiment without any other influences around. Furthermore, counting eye blinks needs a trained counter or well prepared settings that gives participants less restriction and more freedom on their movement while reading. It was a real tiring and time consuming work to count eye blinks after all. To talk about what we still have found that corresponds to previous works from our experiment is that there was a tendency of clearly lower frequency of eye blinks while reading regardless of type of the material. And more frequent eye blinks after reading on screen. There one interesting phenomena that we found was even though all of participants answered in questionnaire that they feel much more visual fatigue after reading on screen, they still answered at the end that they would prefer digital format material than hard copy material. This have come to us somewhat contradictive yet, presumable the reason. The further study might be related to this findings, if there will be one.

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